PHYWE

30 New Experiments

15 for Optical Base Plate — pages 94 ff

1 for Scanning Tunneling Microscopy (STM) — page 254

14 for X-ray Energy Detector — pages 278 ff

TESS expert

PHYWE

LABORATORY EXPERIMENTS PHYSICS

Dear customer,

this catalogue of physics laboratory experiments for universities, colleges, high schools etc. is a valuable and extensive work of scientific literature for experiment-oriented education purposes. It includes numerous successful and classical experiments playing an essential role in every physics laboratory course. The experiments have been field-tested over and over again and countless enthusiastic customers all over the world have been inspired by them.

Our team of experienced scientists has set great store on using both classical equipment, such as oscilloscopes, recorders and modern interface systems for the experiments. This is why you will often find several versions for one experiment. Just choose the experiment version which best meets your specific requirements.

If you need help in selecting the right experiments, our sales representatives in your country would be more than happy to assist you.

We hope you enjoy our manual and look forward to your questions.

Phywe Systeme GmbH & Co. KG

excellence in science

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Founded in Göttingen, Germany in 1913 by Dr. Gotthelf Leimbach, Phywe Systeme GmbH & Co. KG quickly advanced to one of the leading manufacturers of scientific equipment.

Over this period of more than 95 years Phywe has been putting quality and innovation into its products as a fundamental requirement.

As a well known international supplier in the fields of science and engineering we have made a significant impact on the market through high quality equipment.

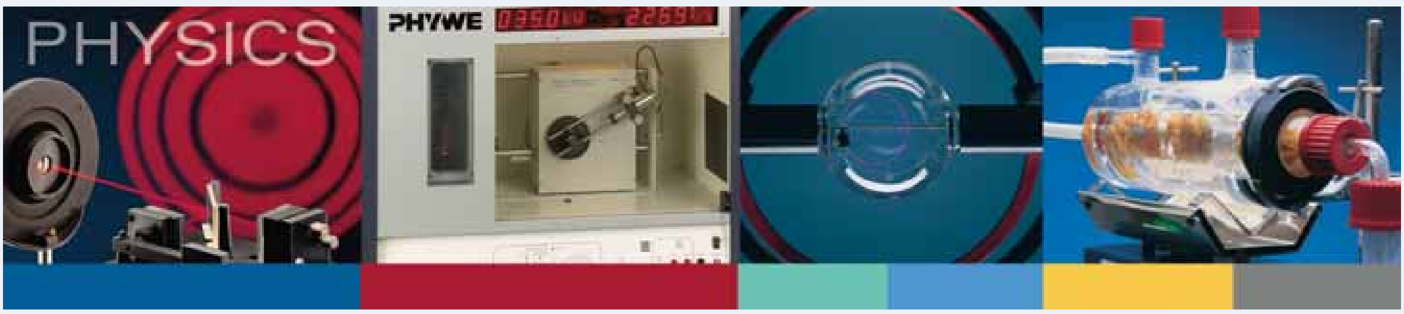
Phywe products are made in Germany and in use throughout the world in the fields of education und research, from primary schools right through to university level.

Up-to-date educational systems, planning and commissioning of scientific and engineering laboratories to meet specific requirements are our daily business.

As a supplier of complete, fully developed and established systems, Phywe provides teaching and learning systems for students as well as teacher demonstration experiments. The system ranges from simple, easy to operate equipment intended for student use up to coverage of highly sophisticated and specialised university equipment demands.

Phywe Systeme GmbH & Co. KG has achieved a very high standard based on research and technology and through exchange of experiences with universities and high schools as well as with professors and teachers.

As experienced and competent manufacturer, we would gladly assist you in the selection of the "right" experiments for your particular curricula.

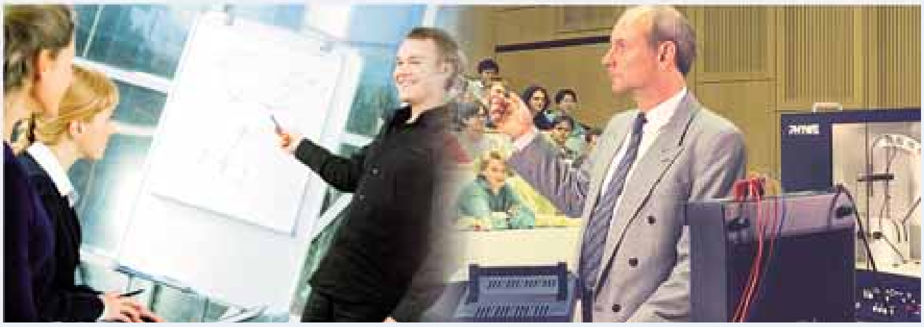


Natural sciences have a longstanding tradition in Göttingen. More than 40 Nobel prizewinners coming from all areas of scientific disciplines and numerous university institutes successfully conduct research in practically all areas of science.

The following research institutions and university institutes are located in Göttingen: Academy of Science, several Max-Planck institutes, the German Primate Centre, the Centre of Molecular Physiology of the Brain, the Centre of Molecular Life Science – to name just a few.

We are in contact with these institutions and exchange our views with them to ensure that the latest trends and scientific innovations are always reflected in the product range of Phywe Systeme GmbH & Co. KG.

Nobel Price winner
Prof. Otto Hahn visiting
PHYWE in 1966



GÖTTINGEN is a city of teaching and research. Scientific equipment, teaching equipment and laboratory installations developed and produced in this city are famous throughout the world.

Göttingen would not be what it is without its university.

“Georgia Augusta” was founded in 1734 and by 1777 it was Germany‘s largest university, with 700 students. It still is one of the leading universities in Germany, with 14 faculties, significant scientific facilities and more than 30,000 students.

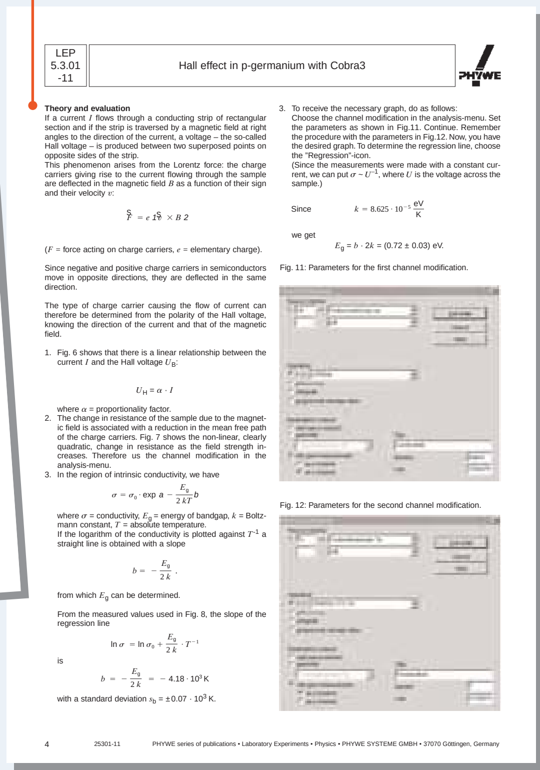
The gracious Goose Girl (“Gänseliesel”) on the market place well is the most kissed girl in Germany. Why? Because every newly graduated doctor must kiss the cold beauty on her bronze mouth. That is Göttingen tradition.

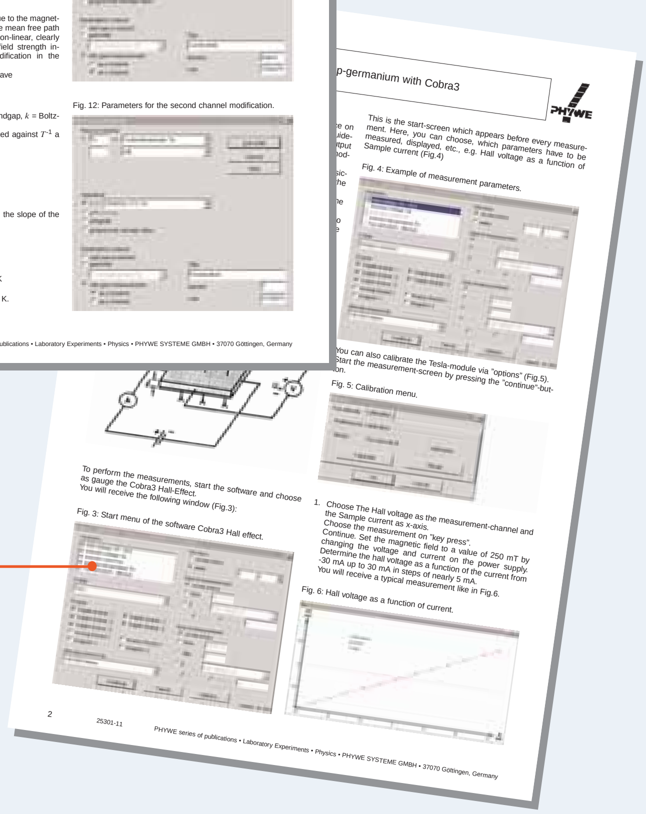
Doctor’s kiss for the “Goose Girl”

The experiments in the PHYWE Publication Series “Laboratory Experiments Physics” are intended for the heads of physics laboratory courses at universities, colleges of advanced technology, technical colleges and similar institutions and also for advanced courses in high schools.

All experiments are uniformly built-up and contain references such as Related topics and Principle and task to introduce the subject.

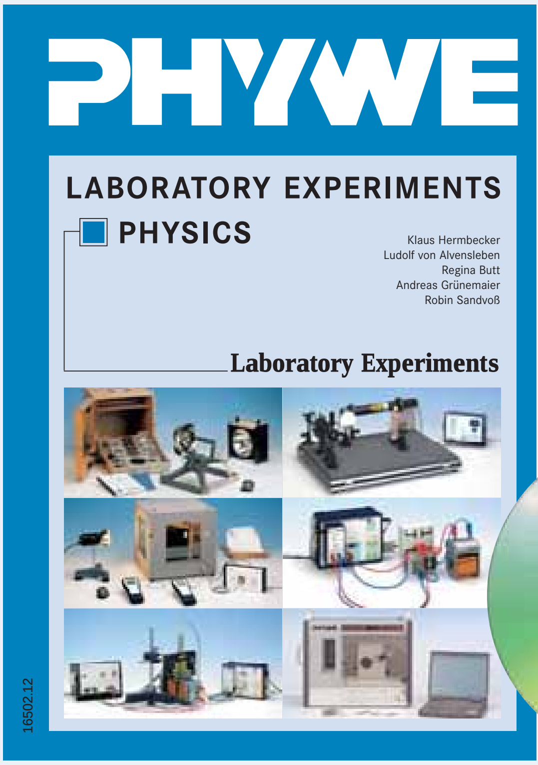
Theory and evaluation states full theory involved and shows graphical and numerical experimental results including error calcules.





Picture and Equipment List guarantee time-saving and easy conducting of the experiment.

Example of measurement parameters



Experimental literature

Laboratory Experiments Physics

Print Version	No. 16502.32
CD	No. 16502.42

The present volume which has been developed by PHYWE, complements the previously existing collection of about 304 experiments in twenty-six chapters as the following comprehensive Table of Contents shows. In this brochure we present the experiments in short form. The experiments can be ordered or offered completely or partially, if desired, in accordance with the Comprehensive Equipment Lists. On request, we will gladly send you detailed experimental descriptions.

You can order the experiments as follows:

What you need:		
Hall effect module,	11801.00	1
Hall effect, p-Ge, carrier board	11805.01	1
Coil, 600 turns	06514.01	2
Iron core, U-shaped, laminated	06501.00	1
Pole pieces, plane	06489.00	1
Hall probe, tangent., prot. cap	13610.02	1
Power supply 0-12 V DC/6 V, 12 V AC	13505.93	1
Tripod base -PASS-	02002.55	1
Support rod -PASS-, square, l = 264 mm	02025.55	1
Right angle clamp -PASS-	02040.55	1
Connecting cord, l = 100 mm, red	07359.01	1
Connecting cord, l = 100 mm, blue	07359.04	1
Connecting cord, l = 500 mm, red	07361.01	2
Connecting cord, l = 500 mm, blue	07361.04	1
Connecting cord, l = 500 mm, black	07361.05	2
Cobra3 BASIC-UNIT, USB	12150.50	1
Power supply, 12 V	12151.99	1
Tesla measuring module	12109.00	1
Cobra3 Software Hall	14521.61	1
RS 246 data cable	14602.00	2
PC, Windows® 95 or higher		
Complete Equipment Set, Manual on CD-ROM included		
Hall effect in p-germanium with Cobra3	P2670111	

Quantity

Order No.

Please specify this Order No. if you would like to order the complete experiment.

- Didactically adapted descriptions of experiments – easy, direct preparation by the students is possible

- Comprehensive experiments – cover the entire range of classical and modern physics

- Complete equipment offering modular experimental set-up – multiple use of individual devices, cost effective and flexible

- Excellent measurement accuracy – results agree with theory

- Developed and proven by practicians – unproblematical and reliable performance

- Computer-assisted experiments – simple, rapid assessement of the results

1 Mechanics

1.1 Measurement Techniques

1.1.01-00	Measurement of basic constants: length, weight and time	

1.2 Statics

1.2.01-00	Moments	
1.2.02-00	Modulus of elasticity	
1.2.03-00	Mechanical hysteresis	

1.3 Dynamics

1.3.01-01	Hooke's law	
1.3.01-11	Hooke's law with Cobra3	Cobra3
1.3.03-01/05	Newton's second law / Air track or Demonstration track	
1.3.03-11/15	Newton's second law with Cobra3 / Air track or Demonstration track	Cobra3
1.3.05-01/05	Laws of collision / Air track or Demonstration track	
1.3.05-11/15	Laws of collision with Cobra3 / Air track or Demonstration track	Cobra3
1.3.07-01	Free fall	
1.3.07-11	Free fall with Cobra3	Cobra3
1.3.09-01	Determination of the gravitational constant with a Cavendish balance	
1.3.11-00	Projectile motion	
1.3.12-00	Ballistic Pendulum	
1.3.13-01	Moment of inertia and angular acceleration	
1.3.13-11	Moment of inertia and angular acceleration with Cobra3	Cobra3
1.3.15-00	Moment and angular momentum	
1.3.16-01	Centrifugal force	
1.3.16-11	Centrifugal force with Cobra3	Cobra3
1.3.18-00	Mechanical conservation of energy / Maxwell's wheel	
1.3.19-00	Laws of gyroscopes / 3-axis gyroscope	
1.3.20-00	Laws of gyroscopes / cardanic gyroscope	
1.3.21-00	Mathematical pendulum	
1.3.22-00	Reversible pendulum	
1.3.23-01	Pendulum oscillations / variable g pendulum	
1.3.23-11	Pendulum oscillations with Cobra3	Cobra3
1.3.25-01	Coupled Pendula	
1.3.25-11	Coupled Pendula with Cobra3	Cobra3
1.3.26-11	Harmonic oscillations of spiral springs – Springs linked in parallel and series	Cobra3
1.3.27-01	Forced Oscillations – Pohl's pendulum	
1.3.27-11	Forced Oscillations – Pohl's pendulum; Determination of resonance frequencies by Fourier analysis	Cobra3
1.3.28-01	Moments of inertia / Steiner's theorem	
1.3.28-11	Moments of inertia of different bodies / Steiner's theorem with Cobra3	Cobra3
1.3.30-00	Torsional vibrations and torsion modulus	
1.3.31-00	Moment of inertia and torsional vibrations	
1.3.32-00	The propagation of a periodically excited continuous transverse wave	
1.3.33-00	Phase velocity of rope waves	
1.3.34-00	Wave phenomena in a ripple tank	
1.3.35-00	Interference and diffraction of water waves with the ripple tank	

1.4 Mechanics of Liquids and Gaseous Bodies

1.4.01-00	Density of liquids	
1.4.02-00	Surface of rotating liquids	
1.4.03-00	Viscosity of Newtonian and non-Newtonian liquids (rotary viscometer)	
1.4.04-00	Viscosity measurements with the falling ball viscometer	
1.4.05-00	Surface tension by the ring method (Du Nouy method)	
1.4-06-11	Surface tension by the pull-out method with Cobra3	Cobra3
1.4.07-00	Barometric height formula	
1.4.08-00	Lift and drag (resistance to flow)	

1.5 Mechanical Vibration, Acoustics

1.5.01-00	Vibration of strings	
1.5.03-11	Velocity of sound in air with Cobra3	Cobra3
1.5.04-11	Acoustic Doppler effect	Cobra3
1.5.05-15	Chladni figures with FG-Module	
1.5.06-01/15	Velocity of sound using Kundt's tube	Cobra3
1.5.07-01/15	Wavelengths and frequencies with a Quincke tube	Cobra3
1.5.08-11	Resonance frequencies of Helmholtz resonators with Cobra3	Cobra3
1.5.09-11	Interference of acoustic waves, stationary waves and diffraction at a slot with Cobra3	Cobra3
1.5.10-00	Optical determination of velocity of sound in liquids	
1.5.11-00	Phase and group velocity of ultrasonics in liquids	
1.5.12-00	Temperature dependence of the Velocity of sound in liquids	
1.5.13-00	Stationary ultrasonic waves, determination of wavelength	
1.5.14-00	Absorption of ultrasonic in air	
1.5.15-15	Ultrasonic diffraction at different single and double slit systems	
1.5.16-15	Ultrasonic diffraction at different multiple slit systems	
1.5.17-15	Diffraction of ultrasonic waves at a pin hole and a circular obstacle	
1.5.18-00	Diffraction of ultrasound at a Fresnel zone plate / Fresnel's zone construction	
1.5.19-15	Interference of two identical ultrasonic transmitters	
1.5.20-00	Interference of ultrasonic waves by a Lloyd mirror	
1.5.21-15	Determination of the velocity of sound (sonar principle)	Cobra3
1.5.22-00	Ultrasonic Michelson-Interferometer	
1.5.23-00	Ultrasonic diffraction by a straight edge	
1.5.24-15	Ultrasonic Doppler effect	

1.6 Handbooks

- Physics Experiments – Linear Motion
- Physics Demonstration Experiments – Magnet Board Mechanics 1
- Physics Demonstration Experiments – Magnet Board Mechanics 2

2 Optics

2.1 Geometrical Optics

2.1.01-01	Measuring speed of light	
2.1.02-00	Laws of lenses and optical instruments	
2.1.03-00	Dispersion and resolving power of the prism and grating spectroscope	

4 Electricity

4.1 Stationary Currents

4.1.01-01	Measurement of small resistance	
4.1.01-15	Ohm's Law with FG-Module	Cobra3
4.1.02-00	Wheatstone Bridge	
4.1.03-00	Internal resistance and matching in voltage source	
4.1.04-01/15	Temperature dependence of different resistors and diodes	Cobra3
4.1.06-01/15	Current balance/ Force acting on a current-carrying conductor	Cobra3
4.1.07-00	Semiconductor thermogenerator	
4.1.08-00	Peltier heat pump	
4.1.09-01	Characteristic curves of a solar cell	
4.1.09-15	Characteristic curves of semiconductors with FG-Module	Cobra3
4.1.11-00	Characteristic and efficiency of PEM fuel cell and PEM electrolyser	
4.1.12-00	Faraday's law	
4.1.13-15	Second order conductors. Electrolysis with FG-Module	Cobra3

4.2 Electric Field

4.2.01-00	Electrical fields and potentials in the plate capacitor	
4.2.02-01	Charging curve of a capacitor	
4.2.02-15	Switch-on behaviour of a capacitor and an inductivity with FG-Module	Cobra3
4.2.03-00	Capacitance of metal spheres and of a spherical capacitor	
4.2.04-01	Coulomb's law / Image charge	
4.2.04-15	Coulomb's law with Cobra3	Cobra3
4.2.05-00	Coulomb potential and Coulomb field of metal spheres	
4.2.06-00	Dielectric constant of different materials	

4.3 Magnetic Field

4.3.01-00	Earth's magnetic field	
4.3.02-01/15	Magnetic field of single coils / Biot-Savart's law	Cobra3
4.3.03-01/15	Magnetic field of paired coils in Helmholtz arrangement	Cobra3
4.3.04-00	Magnetic moment in the magnetic field	
4.3.05-00	Magnetic field outside a straight conductor	
4.3.06-00	Magnetic field inside a conductor	
4.3.07-11	Ferromagnetic hysteresis	Cobra3
4.3.08-00	Magnetostriction with the Michelson interferometer	

4.4 Electrodynamics

4.4.01-00	Transformer	
4.4.02-01/15	Magnetic induction	Cobra3
4.4.03-01/11	Inductance of solenoids	Cobra3
4.4.04-01/11	Coil in the AC circuit with Cobra3	Cobra3
4.4.05-01/15	Capacitor in the AC circuit	Cobra3
4.4.06-01/11	RLC Circuit with Cobra3	Cobra3
4.4.07-00	Rectifier circuits	
4.4.08-00	RC Filters	
4.4.09-01/15	High-pass and low-pass filters	Cobra3
4.4.10-00	RLC measuring bridge	
4.4.11-00	Resistance, phase shift and power in AC circuits	
4.4.12-11	Induction impulse	Cobra3

4.5 Electromagnetic Oscillations and Waves

4.5.02-00	Coupled oscillating circuits
4.5.04-00	Interference of microwaves
4.5.05-00	Diffraction of microwaves
4.5.06-00	Diffraction and polarization of microwaves
4.5.08-00	Radiation field of a horn antenna / Microwaves
4.5.09-00	Frustrated total reflection / Microwaves

4.6 Handbooks

Demonstration Experiments Physics – Electricity/Electronics on the Magnetic Board 1 + 2

5 Physical Structure of Matter

5.1 Physics of the Electron

5.1.01-00	Elementary charge and Millikan experiment
5.1.02-00	Specific charge of the electron – e/m
5.1.03-11	Franck-Hertz experiment with Hg-tube
5.1.03-15	Franck-Hertz experiment with Ne-tube
5.1.04-01/05	Planck's "quantum of action" from photoelectric effect (line separation by interference filters)
5.1.05-01/05	Planck's "quantum of action" from the photoelectric effect (line separation by defraction grating)
5.1.06-00	Fine structure, one-electron and two-electron spectra
5.1.07-00	Balmer series / Determination of Rydberg's constant
5.1.08-00	Atomic spectra of two-electron systems: He, Hg
5.1.10-05/07	Zeeman effect
5.1.11-01/11	Stern-Gerlach experiment
5.1.12-00	Electron spin resonance
5.1.13-00	Electron diffraction

5.2 Radioactivity

5.2.01-01	Half-life and radioactive equilibrium	
5.2.01-11	Half-life and radioactive equilibrium with Cobra3	Cobra3
5.2.03-11	Poisson's distribution and Gaussian distribution of radioactive decay with Cobra3 – Influence of the dead time of the counter tube	Cobra3
5.2.04-00	Visualisation of radioactive particles / Diffusion cloud chamber	
5.2.20-15	Alpha-Energies of different sources with MCA	
5.2.21-01/11/15	Rutherford experiment	Cobra3
5.2.22-11/15	Fine structure of the α-spectrum of ^{255}Am	Cobra3
5.2.23-11/15	Study of the α-energies of ^{240}Ra	Cobra3
5.2.24-11/15	Energy loss of α-particles in gases	Cobra3
5.2.31-00	Electron absorption	
5.2.32-00	β-spectroscopy	
5.2.41-01/11	Law of distance and absorption of gamma or beta rays	Cobra3
5.2.42-11/15	Energy dependence of the γ-absorption coefficient	Cobra3
5.2.44-11/15	Compton effect	Cobra3
5.4.45-11/15	Internal conversion in ^{137m}Ba	Cobra3
5.2.46-11/15	Photonuclear cross-section / Compton scattering cross-section	Cobra3
5.2.47-11/15	X-ray fluorescence and Moseley's law	Cobra3

To help you in selecting your experiments, we have added pictograms to several of our experiments. These pictograms give you a quick overview of the most important features of the experiments and provide you with all the essential information at a glance.

New Products

New products which have been launched in the last few months. Here you will also find particularly successful experiments with new additional features to offer you even more measurement and experiment possibilities.

Student Worksheet

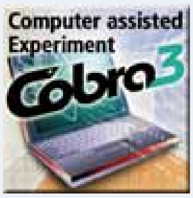
For this experiment, there is a student worksheet with detailed information.

Our Best-Sellers

Particularly successful and reliable products which have been field-tested over and over again in numerous countries - some for many years. We would be more than happy to provide you with references upon request.

Training recommended

For some experiments we recommend a training performed by our specialists to get an easier access to the complete experiment.



Computer-Assisted Experiments with our Cobra3 PC Interface

A large number of experiments can be performed in a particularly comfortable and elegant way with the help of our Cobra3 measurement interface. All you need is a PC. The advantage is that you can process the data particularly well using a PC.

PC interfaced instruments

Some Phywe devices already have an interface included.

These instruments can be connected directly to a PC where you can use the Phywe measure Software to work with the data.

Experiments with medical relevance

Several experiments cover medical and biological topics and can be used both for demonstration during lectures and as student lab experiments.

Mechanics

1

1

Mechanics

Contents

Measurement of basic constants: length, weight and time 1.1.01-00

What you can learn about …

- → Length
- → Diameter
- → Inside diameter thickness
- → Curvature
- → Vernier
- → Weight resolution
- → Time measurement

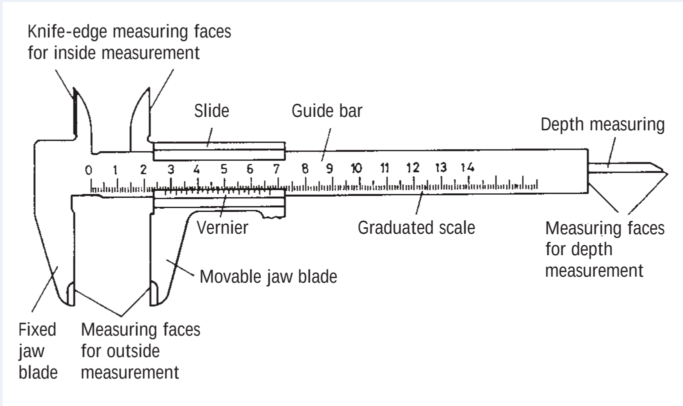
Principle:

Caliper gauges, micrometers and spherometers are used for the accurate measurement of lengths, thicknesses, diameters and curvatures. A mechanical balance is used for weight determinations, a decade counter is used for accurate time measurements. Measuring procedures, accuracy of measurement and reading accuracy are demonstrated.

What you need:

Vernier calipers, stainless steel	03010.00	1
Micrometer	03012.00	1
Spherometer	03017.00	1
Light barrier, compact	11207.20	1
Universal counter	13601.99	1
Alternatively to 13601.99:		
Timer 2-1	13607.99	1
Precision balance, double pan type, 500 g	44011.50	1
Set of precision weights, 1 mg...200 g, in case	44070.20	1
Iron column	03913.00	1
Iron wire, d = 1.0 mm, l = 10 m	06104.01	1
Aluminium foil, 4 sheets	06270.00	1
Glass plate, 100 mm x 85 mm x 1 mm	08203.00	1
Watch glass, d = 80 mm	34572.00	1
Watch glass, d = 100 mm	34574.00	1
Watch glass, d = 125 mm	34575.00	1
Glass tube, AR-glass, straight, d = 8 mm, l = 80 mm, 10 pcs.	36701.65	1
Glass tubes, AR-glass, d = 24 mm, l = 120 mm	45158.00	1
Cubes, set of 8	02214.00	1
Fishing line on spool, d = 0.5 mm, l = 100 mm	02090.00	1
Steel balls with eyelet, d = 32 mm	02466.01	1
Rod with hook	02051.00	1
Support rod -PASS-, square, l = 630 mm	02027.55	1
Tripod base -PASS-	02002.55	1
Right angle clamp -PASS-	02040.55	2
Measuring tape, l = 2 m	09936.00	1
Connecting cable, 4 mm plug, 32 A, red, l = 50 cm	07361.01	1
Connecting cable, 4 mm plug, 32 A, blue, l = 50 cm	07361.04	1
Connecting cable, 4 mm plug, 32 A, yellow, l = 50 cm	07361.02	1

Complete Equipment Set, Manual on CD-ROM included
Measurement of basic constants: length, weight and time P2110100



Vernier caliper

Tasks:

1. Determination of the volume of tubes with the caliper gauge.
2. Determination of the thickness of wires, cubes and plates with the micrometer.
3. Determination of the thickness of plates and the radius of curvature of watch glasses with the spherometer.

1.2.01-00 Moments

What you can learn about ...

- → Moments
- → Couple
- → Equilibrium
- → Statics
- → Lever
- → Coplanar forces

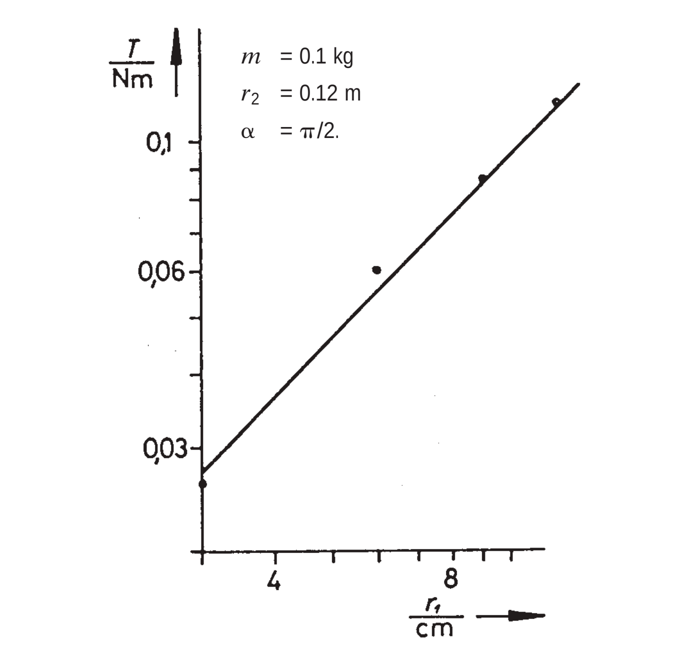
Principle:

Coplanar forces (weight, spring balance) act on the moments disc on either side of the pivot. In equilibrium, the moments are determined as a function of the magnitude and direction of the forces and of the reference point.

What you need:

Moments disk	02270.00	1
Precision spring balance 1 N	03060.01	2
Tripod base -PASS-	02002.55	2
Barrel base -PASS-	02006.55	1
Support rod -PASS-, square, l = 400 mm	02026.55	2
Right angle clamp -PASS-	02040.55	1
Swivel clamp -PASS-	02041.55	1
Bolt with pin	02052.00	1
Weight holder for slotted weights	02204.00	1
Slotted weights, 10 g, coated black	02205.01	4
Slotted weight, 50 g, coated black	02206.01	1
Fishing line on spool, d = 0,5 mm, l = 100 mm	02090.00	1
Rule, plastic, 200 mm	09937.01	1

Complete Equipment Set, Manual on CD-ROM included
Moments P2120100



Moment as a function of the distance between the origin of the coordinates and the point of action of the force.

Tasks:

1. Moment as a function of the distance between the origin of the coordinates and the point of action of the force,
2. moment as a function of the angle between the force and the position vector to the point of action of the force,
3. moment as a function of the force.

Modulus of elasticity 1.2.02-00

What you can learn about …

- ➔ Young's modulus
- ➔ Modulus of elasticity
- ➔ Stress
- ➔ Deformation
- ➔ Poisson's ratio
- ➔ Hooke's law

Principle:

A flat bar is supported at two points. It is bent by the action of a force acting at its centre. The modulus of elasticity is determined from the bending and the geometric data of the bar.

What you need:

Dial gauge, 10/0.01 mm	03013.00	1
Holder for dial gauge	03013.01	1
Flat rods, set	17570.00	1
Knife-edge with stirrup	03015.00	1
Bolt with knife edge	02049.00	2
Weight holder for slotted weights	02204.00	1
Precision spring balance 1 N	03060.01	1
Tripod base -PASS-	02002.55	2
Support rod -PASS-, square, l = 250 mm	02025.55	2
Support rod -PASS-, square, l = 630 mm	02027.55	1
Right angle clamp -PASS-	02040.55	5
Slotted weights, 10 g, coated black	02205.01	10
Slotted weight, 50 g, coated black	02206.01	6
Measuring tape, l = 2 m	09936.00	1
Vernier calipers, stainless steel	03010.00	1
Fishing line on spool, d = 0.5 mm, l = 100 mm	02090.00	1

Complete Equipment Set, Manual on CD-ROM included
Modulus of elasticity P2120200

Material	Dimensions [mm]	E $[N \cdot m^{-2}]$
Steel	10 × 1.5	$2.059 \cdot 10^{11}$
Steel	10 × 2	$2.063 \cdot 10^{11}$
Steel	10 × 3	$2.171 \cdot 10^{11}$
Steel	15 × 1.5	$2.204 \cdot 10^{11}$
Steel	20 × 1.5	$2.111 \cdot 10^{11}$
Aluminium	10 × 2	$6.702 \cdot 10^{10}$
Brass	10 × 2	$9.222 \cdot 10^{10}$

Table 1: The modulus of elasticity for different materials.

Tasks:

1. Determination of the characteristic curve of the dial gauge
2. Determination the bending of flat bars as a function
   - of the force
   - of the thickness, at constant force
   - of the width, at constant force
   - of the distance between the support points at constant force
3. Determination the modulus of elasticity of steel, aluminium and brass.

1.2.03-00 Mechanical hysteresis

What you can learn about ...

- ➔ Mechanical hysteresis
- ➔ Elasticity
- ➔ Plasticity
- ➔ Relaxation
- ➔ Torsion molulus
- ➔ Plastic flow
- ➔ Torque
- ➔ Hooke's law

Principle:

The relationship between torque and angle of rotation is determined when metal bars are twisted. The hysteresis curve is recorded.

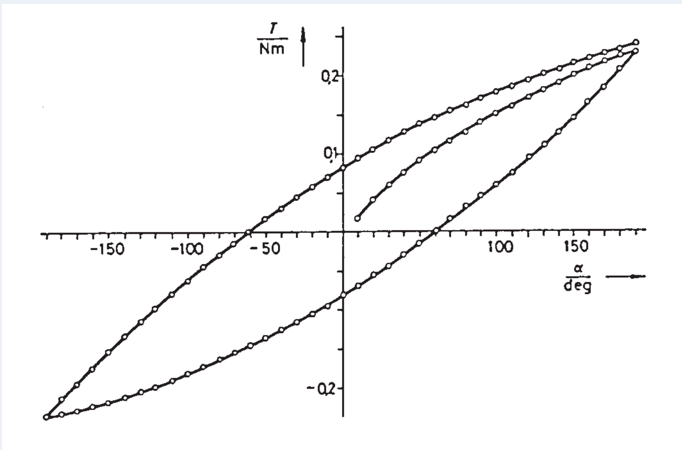
Tasks:

1. Record the hysteresis curve of steel and copper rods.
2. Record the stress-relaxation curve with various relaxation times of different materials.

What you need:

Torsion apparatus	02421.00	1
Torsion rod, steel, d = 2 mm, l = 500 mm	02421.01	1
Torsion rod, Al, d = 2 mm, l = 500 mm	02421.02	1
Torsion rod, Al, d = 2 mm, l = 400 mm	02421.03	1
Torsion rod, Al, d = 2 mm, l = 300 mm	02421.04	1
Torsion rod, Al, d = 3 mm, l = 500 mm	02421.05	1
Torsion rod, Al, d = 4 mm, l = 500 mm	02421.06	1
Torsion rod, brass, d = 2 mm, l = 500 mm	02421.07	1
Torsion rod, copper, d = 2 mm, l = 500 mm	02421.08	1
Precision spring balance 1 N	03060.01	1
Precision spring balances, 2.5 N	03060.02	1
Stopwatch, digital, 1/100 s	03071.01	1
Support base -PASS-	02005.55	1
Support rod -PASS-, square, l = 250 mm	02025.55	1
Support rod -PASS-, square, l = 630 mm	02027.55	1
Right angle clamp -PASS-	02040.55	2

Complete Equipment Set, Manual on CD-ROM included
Mechanical hysteresis P2120300



Mechanical hysteresis curve for the torsion of a copper rod of 2 mm diameter and 0.5 m long.

Hooke's law 1.3.01-01

What you can learn about …

- ➔ Hooke's law
- ➔ Spring constant
- ➔ Limit of elasticity
- ➔ Elastic hysteresis
- ➔ Elastic after-effect

Principle:

The validity of Hooke's law is determined for two helical springs with different spring constants. The elongation of the helical spring, which depends on the deforming force, is studied by means of the weights of masses. For comparison, a rubber band, for which no proportionality exists between the exerted force and the resulting elongation, is submitted to the same forces.

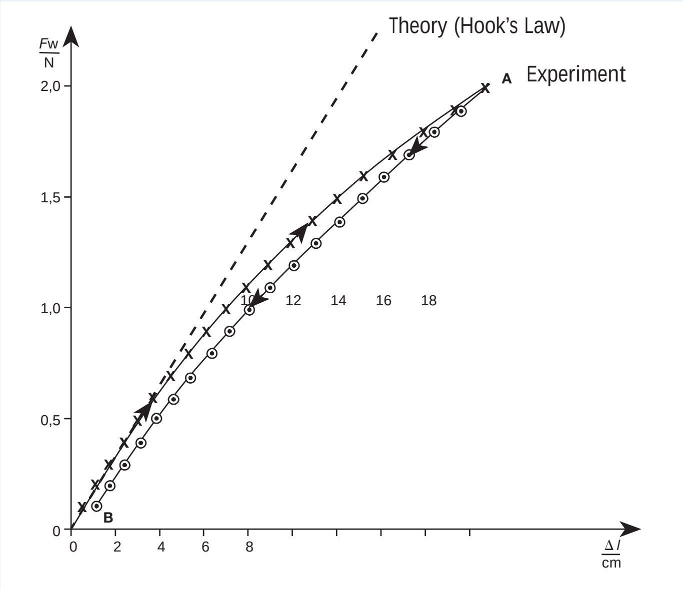
Tasks:

1. Determining the spring constants of helical springs
2. Study of the elongation of a rubber band

What you need:

Tripod base -PASS-	02002.55	1
Barrel base -PASS-	02006.55	1
Support rod -PASS-, square, l = 1000 mm	02028.55	1
Right angle clamp -PASS-	02040.55	1
Cursor for scale, 2 pieces, plastic, red	02201.00	1
Weight holder for slotted weights	02204.00	1
Slotted weights, 10 g, coated black	02205.01	2
Slotted weights, 10 g, silver colour	02205.02	2
Slotted weight, 50 g, coated black	02206.01	1
Slotted weights, 50 g, silver bronzing	02206.02	2
Helical springs, 3 N/m	02220.00	1
Helical springs, 20 N/m	02222.00	1
Silk thread on spool, l = 200 mm	02412.00	1
Meter Scale, l = 1000 x 27 mm	03001.00	1
Holding pin	03949.00	1
Square section rubber strip, l = 10 m	03989.00	1

Complete Equipment Set, Manual on CD-ROM included
Hooke's law P2130101



Acting weight F_W as a function of the extension Δl for a rubber band (elastic hysteresis).

1.3.01-11 Hooke's law with Cobra3

What you can learn about …

- → Spring constant
- → Limit of elasticity
- → Extension and compression

Principle:

The validity of Hooke's Law is proven using various helical springs with different spring constants. In comparison, the behaviour of a stretched rubber band is examined, for which there is no proportionality between acting force and resulting extension.

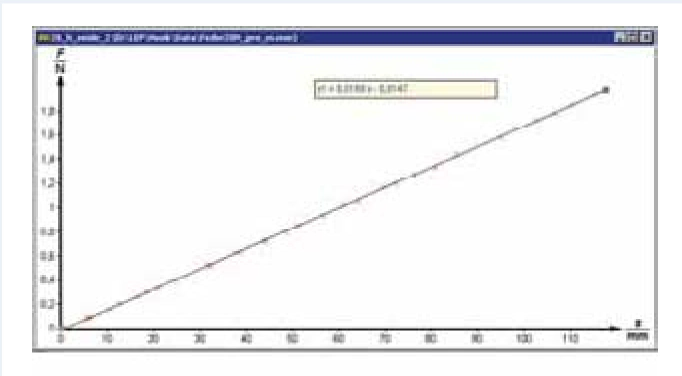
Tasks:

1. Calibration of the system (movement sensor and force sensor).
2. Measurement of the tensile force as a function of the path for three different helical springs and a rubber band.
3. Determination of the spring constant and evaluation of a hysteresis curve.
4. Verification of Hooke's law.

What you need:

Cobra3 Basic-Unit, USB	12150.50	1
Power supply 12V/2A	12151.99	1
Software Cobra3 Force/Tesla	14515.61	1
Square section rubber strip, l = 10 m	03989.00	1
Newton measuring module	12110.00	1
Newton Sensor	12110.01	1
Movement sensor with cable	12004.10	1
Adapter BNC socket/4 mm plug pair	07542.27	1
Adapter, BNC socket - 4 mm plug	07542.20	1
Helical springs, 3 N/m	02220.00	1
Helical springs, 20 N/m	02222.00	1
Helical springs, 30 N/m	02224.00	1
Right angle clamp -PASS-	02040.55	2
Support rod -PASS-, square, l = 1000 mm	02028.55	1
Stand tube	02060.00	1
Barrel base -PASS-	02006.55	1
Bench clamp -PASS-	02010.00	1
Plate holder, opening width 0...10 mm	02062.00	1
Meter Scale, l = 1000 x 27 mm	03001.00	1
Nylon thread on spool, d = 0,4 mm, l = 50 mm	02095.00	1
PC, Windows® XP or higher		

Complete Equipment Set, Manual on CD-ROM included
Hooke's law with Cobra3 P2130111



Characteristic elongation curve for a helical spring with D = 20 N/m.

Newton’s second law / Air track or Demonstration track 1.3.03-01/05

Set-up of experiment P2130301 with air track

What you can learn about …

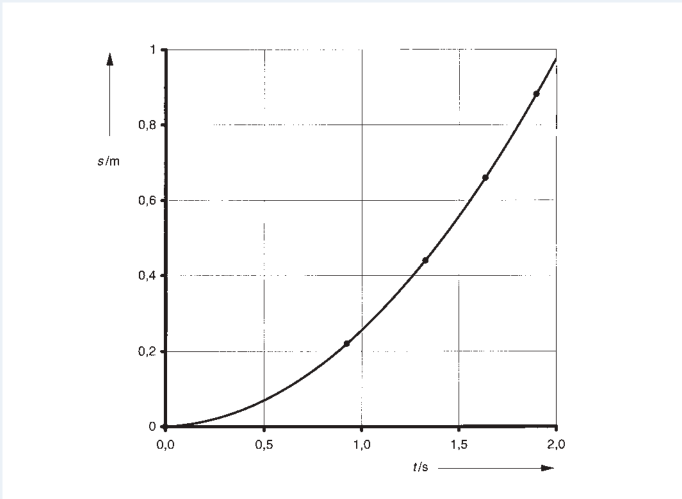
- → Velocity
- → Acceleration
- → Force
- → Acceleration of gravity

Principle:

The distance-time law, the velocity-time law, and the relationship between mass, acceleration and force are determined with the aid of the air track rail for uniformly accelerated motion in a straight line.

What you need:

	Order No.	Experiment P2130301 with air track	Experiment P2130305 with demo track
Timer 4-4 with USB-interface	13604.99	1	1
Light barrier, compact	11207.20	4	4
Precision pulley	11201.02	1	
Air track rail	11202.17	1	
Blower 230V/50Hz	13770.97	1	
Pressure tube, l = 1.5 m	11205.01	1	
Glider for air track	11202.02	1	
Diaphragm, l = 100 mm	11202.03	1	
Slotted weights, 1 g, polished	03916.00	20	20
Slotted weights, 10 g, coated black	02205.01	8	8
Slotted weight, 50 g, coated black	02206.01	4	4
Stop, adjustable	11202.19	1	
Endholder for air track rail	11202.15	1	
Starter system, mechanical with release	11202.13	1	
Starter system for motion track	11309.00		1
Magnet with plug for starter system	11202.14	1	1
Fork with plug	11202.08	1	1
Tube with plug	11202.05		1
Plasticine, 10 sticks	03935.03		1
Hook with plug	11202.07	1	1
Silk thread on spool, l = 200 mm	02412.00	1	1
Weight holder, 1g, silver bronzing	02407.00	1	1
Barrel base -PASS-	02006.55	4	
Support rod -PASS-, square, l = 400 mm	02026.55	4	
Right angle clamp -PASS-	02040.55	4	
Shutter plate for low friction cart, w = 100 mm	11308.00		1
Needle with plug	11202.06	1	1
Demonstration Track, Aluminium, l = 1.5 m	11305.00		1
Cart, low friction sapphire bearings	11306.00		1
Pulley for demonstration track	11305.10		1
Holder for pulley	11305.11		1
Pulley, movable, d = 40 mm, with hook	03970.00		1
Weight for low friction cart, 400 g	11306.10		1
End holder for demonstration track	11305.12		1
Holder for light barrier	11307.00		4
Portable balance, OHAUS CS2000	48917.93	1	1
Connecting cable, 4 mm plug, 32 A, red, l = 100 cm	07363.01	4	4
Connecting cable, 4 mm plug, 32 A, yellow, l = 100 cm	07363.02	4	4
Connecting cable, 4 mm plug, 32 A, blue, l = 100 cm	07363.04	4	4
Connecting cable, 4 mm plug, 32 A, yellow, l = 200 cm	07365.02	4	1
Connecting cable, 4 mm plug, 32 A, black, l = 200 cm	07365.05	4	1



The distance travelled s plotted as a function of the time t; m_1 = 10 g, m_2 = 201 g.

You can find more experiments in experimental literature “Linear Motion” Order No. 16001.02 (see page 84)

Tasks:

Determination of:

1. Distance travelled as a function of time
2. Velocity as a function of time
3. Acceleration as a function of the accelerated mass
4. Acceleration as a function of force.

Complete Equipment Set, Manual on CD-ROM included
Newton’s second law / Air track or Demonstration track P21303 01/05

1.3.03-11/15 Newton's second law with Cobra3 / Air track or Demonstration track

Set-up of experiment P2130315 with demo track

What you can learn about ...

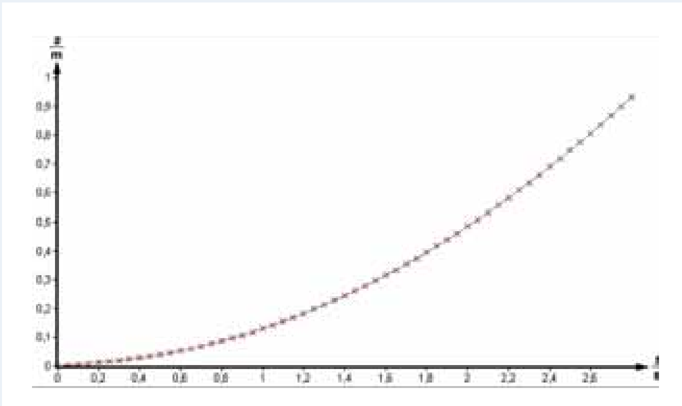
- ➔ Linear motion
- ➔ Velocity
- ➔ Acceleration
- ➔ Conservation of energy

Principle:

According to Newton's 2nd law of motion for a mass point, the relationship between mass, acceleration and force are investigated.

What you need:

		Experiment P2130315 with demo track	Experiment P2130311 with air track
Cobra3 Basic-Unit, USB	12150.50	1	1
Power supply 12V/2A	12151.99	1	1
Software Cobra3, Translation/ Rotation	14512.61	1	1
Light barrier, compact	11207.20	1	1
Air track rail	11202.17		1
Blower 230V/50Hz	13770.97		1
Pressure tube, l = 1.5 m	11205.01		1
Glider for air track	11202.02		1
Slotted weights, 1 g, polished	03916.00	20	9
Slotted weights, 10 g, coated black	02205.01	4	4
Slotted weights, 50 g, silver bronzing	02206.02	4	4
Stop, adjustable	11202.19		1
Starter system, mechanical with release	11202.13		1
Magnet with plug for starter system	11202.14		1
Tube with plug	11202.05	1	1
Plasticine, 10 sticks	03935.03	1	1
Hook with plug	11202.07		1
Pulley, movable, d = 40 mm, with hook	03970.00	1	
Silk thread on spool, l = 200 mm	02412.00	1	1
Weight holder, 1 g, silver bronzing	02407.00	1	1
Bench clamp -PASS-	02010.00		1
Bosshead	02043.00		2
Support rod, stainless steel 18/8, l = 250 mm, d = 10 mm	02031.00		1
Support rod, stainless steel 18/8, l = 100 mm	02030.00		1
Measuring tape, l = 2 m	09936.00	1	1
Needle with plug	11202.06	2	1
Demonstration Track, Aluminium, l = 1.5 m	11305.00	1	
Cart, low friction sapphire bearings	11306.00	1	
Holder for pulley	11305.11	1	
Weight for low friction cart, 400 g	11306.10	1	
End holder for demonstration track	11305.12	2	
Portable balance, OHAUS CS2000	48917.93	1	1
Connecting cable, 4 mm plug, 32 A, red, l = 100 cm	07363.01	1	1
Connecting cable, 4 mm plug, 32 A, blue, l = 100 cm	07363.04	1	1
Connecting cable, 4 mm plug, 32 A, yellow, l = 100 cm	07363.02		1
Connecting cable, 4 mm plug, 32 A, black, l = 100 cm	07363.05	1	
Connecting plug, pack of 2	07278.05	1	1
Crocodile clips, black, plastic insulation, pack of 10	07276.15	1	1
PC, Windows® XP or higher			



Path-time law.

Tasks:

The distance-time law, the velocity-time law and the relationship between mass, acceleration and force are determined. The conservation of energy can be investigated.

Complete Equipment Set, Manual on CD-ROM included
Newton's second law with Cobra3 / Air track or Demonstration track P21303 11/15

Laws of collision / Air track or Demonstration track 1.3.05-01/05

Set-up of experiment P2130505 with demo track

What you can learn about …

- ➔ Conservation of momentum
- ➔ Conservation of energy
- ➔ Linear motion
- ➔ Velocity
- ➔ Elastic loss
- ➔ Elastic collision

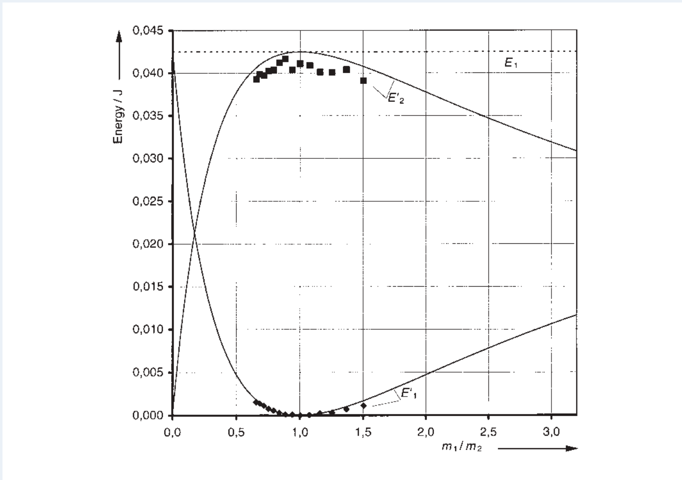
Principle:

The volocities of two gliders, moving without friction on an air-cushion track, are measured before and after collision, for both elastic and inelastic collision.

What you need:

		Experiment P2130501 with air track	Experiment P2130505 with demo track
Air track rail	11202.17	1	
Blower 230V/50Hz	13770.97	1	
Pressure tube, l = 1.5 m	11205.01	1	
Glider for air track	11202.02	2	
Diaphragm, l = 100 mm	11202.03	2	
Tube with plug	11202.05	2	2
Needle with plug	11202.06	1	2
Fork with plug	11202.08	1	1
Rubber bands for fork with plug, 10 pcs.	11202.09	1	1
Plate with plug	11202.10	1	1
Starter system, mechanical with release	11202.13	1	
Magnet with plug for starter system	11202.14	1	1
Endholder for air track rail	11202.15	1	
Slotted weights, 10 g, coated black	02205.01	10	10
Slotted weight, 50 g, coated black	02206.01	6	6
Light barrier, compact	11207.20	2	2
Timer 4-4 with USB-interface	13604.99	1	1
Portable balance, OHAUS CS2000	48917.93	1	1
Barrel base -PASS-	02006.55	2	
Support rod -PASS-, square, l = 400 mm	02026.55	2	
Right angle clamp -PASS-	02040.55	2	
Demonstration Track, Aluminium, l = 1.5 m	11305.00		1
Cart, low friction sapphire bearings	11306.00		2
Starter system for motion track	11309.00		1
Weight for low friction cart, 400 g	11306.10		2
Shutter plate for low friction cart, w = 100 mm	11308.00		2
Holder for light barrier	11307.00		2
End holder for demonstration track	11305.12		1
Connecting cable, 4 mm plug, 32 A, red, l = 100 cm	07363.01	2	2
Connecting cable, 4 mm plug, 32 A, yellow, l = 100 cm	07363.02	2	2
Connecting cable, 4 mm plug, 32 A, blue, l = 100 cm	07363.04	2	2

Complete Equipment Set, Manual on CD-ROM included
Laws of collision / Air track or Demonstration track P21305 01/05



Elastic collision: calculated energies after the collision as functions of the mass ratio of the gliders.

Tasks:

1. Elastic collision

1.1 The impulses of the two gliders as well as their sum after the collision. For comparison the mean value of the impulses of the first glider is entered as a horizontal line in the graph.

1.2 Their energies, in a manner analogous to Task 1.1

1.3 In accordance with the mean value of the measured impulse of the first glider before the collision, the theoretical values of the impulses for the two gliders are entered for a range of mass ratios from 0 to 3. For purposes of comparison the measuring points (see 1.1) are plotted in the graph.

1.4 In accordance with the mean value of the measured energy of the first glider before the collision, the theoretical values of the energy after the collision are plotted analogously to Task 1.3. In the process, the measured values are compared with the theoretical curves.

2. Inelastic collision

2.1 The impulse values are plotted as in Task 1.1.

2.2 The energy values are plotted as in Task 1.2.

2.3 The theoretical and measured impulse values are compared as in Task 1.3.

2.4 As in Task 1.4, the theoretical an measured energy values are compared. In order to clearly illustrate the energy loss and its dependence on the mass ratios, the theoretical functions of the total energy of both gliders and the energy loss after the collision are plotted.

1.3.05-11/15 Laws of collision with Cobra3 / Air track or Demonstration track

Set-up of experiment P2130511 with air track

What you can learn about ...

- → Conservation of momentum
- → Conservation of energy
- → Linear motion
- → Velocity
- → Elastic loss

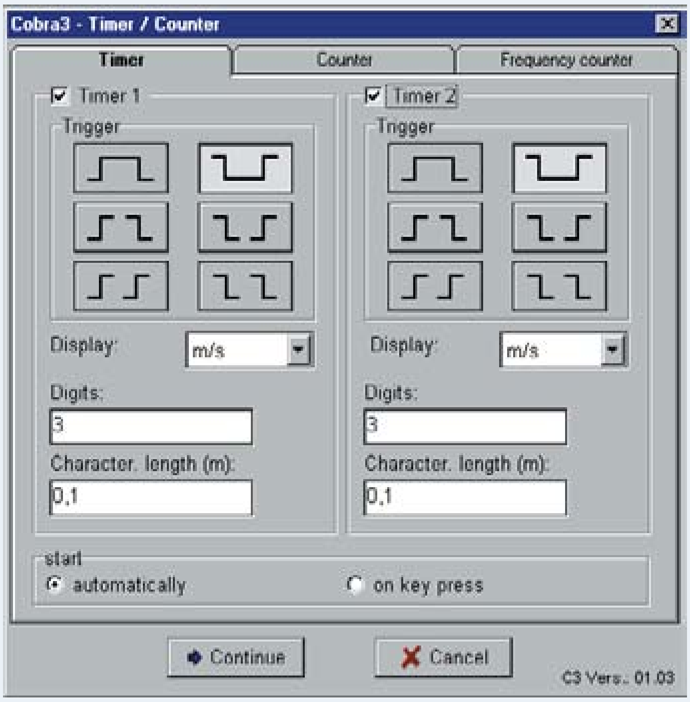
Principle:

The velocity of two gliders, moving without friction on an air-cushion track, are measured before and after collision, for both elastic and inelastic collision.

What you need:

		Experiment P2130511 with air track	Experiment P2130515 with demo track
Air track rail	11202.17	1	
Blower 230V/50Hz	13770.97	1	
Pressure tube, l = 1.5 m	11205.01	1	
Glider for air track	11202.02	1	
Diaphragm, l = 100 mm	11202.03	2	
Tube with plug	11202.05	2	2
Needle with plug	11202.06	2	2
Fork with plug	11202.08	1	1
Rubber bands for fork with plug, 10 pcs.	11202.09	1	1
Plate with plug	11202.10	1	1
Starter system, mechanical with release	11202.13	1	
Magnet with plug for starter system	11202.14	1	1
Endholder for air track rail	11202.15	2	
Slotted weights, 10 g, coated black	02205.01	4	10
Slotted weight, 50 g, coated black	02206.01	4	6
Light barrier, compact	11207.20	2	2
Portable balance, OHAUS CS2000	48917.93	1	1
Demonstration Track, Aluminium, l = 1.5 m	11305.00		1
Cart, low friction sapphire bearings	11306.00		2
Starter system for motion track	11309.00		1
Weight for low friction cart, 400 g	11306.10		2
Shutter plate for low friction cart, w = 100 mm	11308.00		2
Holder for light barrier	11307.00		2
End holder for demonstration track	11305.12		1
Connecting cable, 4 mm plug, 32 A, red, l = 100 cm	07363.01	2	2
Connecting cable, 4 mm plug, 32 A, yellow, l = 100 cm	07363.02	2	2
Connecting cable, 4 mm plug, 32 A, blue, l = 100 cm	07363.04	2	2
Cobra3 Basic-Unit, USB	12150.50	1	1
Power supply 12V/2A	12151.99	1	1
Software Cobra3, Timer/Counter	14511.61	1	1
Plasticine, 10 sticks	03935.03	1	1
Support rod, stainless steel 18/8, l = 500 mm	02032.00	2	
Barrel base -PASS-	02006.55	2	
Bosshead	02043.00	2	
Stop, adjustable	11202.19	1	
Connecting cable, 4 mm plug, 32 A, red, l = 10 cm	07359.01	2	2
Diaphragm, l = 25 mm	11202.04	2	
PC, Windows® XP or higher			

Complete Equipment Set, Manual on CD-ROM included
Laws of collision with Cobra3 / Air track or Demonstration track P21305 11/15



Measuring parameters for velocity measurement

Tasks:

1. Elastic collision
   A glider whose mass always remains unchanged collides with a second resting glider at a constant velocity. A measurement series, in which the velocities of the first glider before the collision and the velocities of both gliders after it are to be measured, is conducted by varying mass of the resting glider.
2. Inelastic collision
   A glider, whose mass always remains unchanged, collides with a constant velocitiy with a second resting glider. A measurement series with different masses of the resting glider is performed: the velocities of the first glider before the collision and those of both gliders, which have equal velocities, after it are to be measured.

Free fall 1.3.07-01

What you can learn about ...

- → Linear motion due to constant acceleration
- → Laws of falling bodies
- → Gravitational acceleration

Principle:

A sphere falling freely covers certain distances. The falling time is measured and evaluated from diagrams. The acceleration due to gravity can be determined.

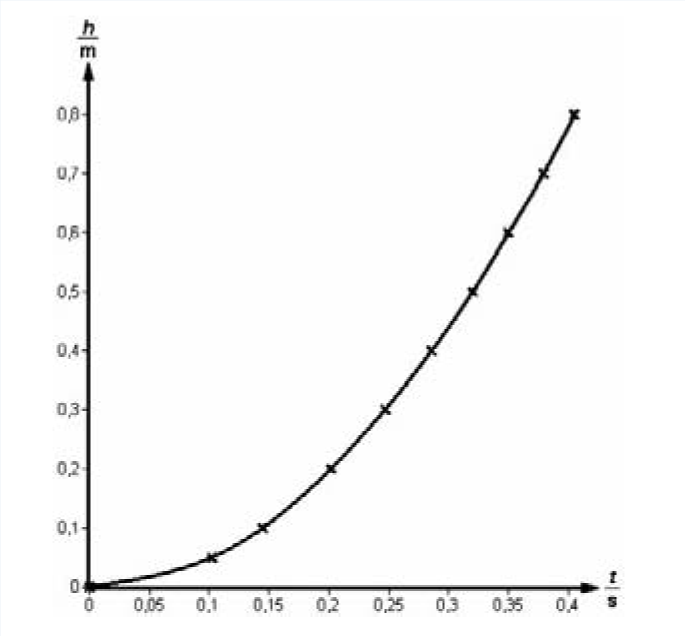
Tasks:

1. To determine the functional relationship between height of fall and falling time ($h = h(t) = 1/2\ gt^2$).
2. To determine the acceleration due to gravity.

What you need:

Falling sphere apparatus	02502.88	1
Universal counter	13601.99	1
Alternatively to 13601.99:		
Timer 2-1	13607.99	1
Support base -PASS-	02005.55	1
Right angle clamp -PASS-	02040.55	2
Plate holder, opening width 0...10 mm	02062.00	1
Cursor for scale, 2 pieces, plastic, red	02201.00	1
Meter Scale, l = 1000 x 27 mm	03001.00	1
Support rod -PASS-, square, l = 1000 mm	02028.55	1
Connecting cable, 4 mm plug, 32 A, red, l = 100 cm	07363.01	2
Connecting cable, 4 mm plug, 32 A, blue, l = 100 cm	07363.04	2

Complete Equipment Set, Manual on CD-ROM included
Free fall P2130701



Height of fall as a function of falling time.

1.3.07-11 Free fall with Cobra3

What you can learn about …

- → Linear motion due to constant acceleration
- → Laws governing falling bodies
- → Acceleration due to gravity

Principle:

The fall times t are measured for different heights of fall h. h is represented as the function of t or t^2, so the distance-time law of the free fall results as

$$h = \frac{1}{2} \cdot g \cdot t^2$$

Then the measured values are taken to determine the acceleration due to gravity g.

Tasks:

Determination of:

– Distance time law for the free fall.

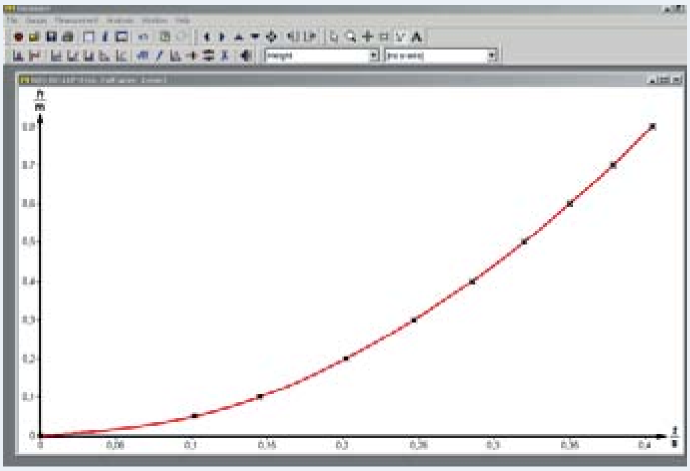
– Velocity-time law for the free fall.

– Precise measurement of the acceleration due to gravity for the free fall.

What you need:

Falling sphere apparatus	02502.88	1
Cobra3 Basic-Unit, USB	12150.50	1
Power supply 12V/2A	12151.99	1
Software Cobra3, Timer/Counter	14511.61	1
Tripod base -PASS-	02002.55	1
Support rod -PASS-, square, l = 1000 mm	02028.55	1
Right angle clamp -PASS-	02040.55	2
Measuring tape, l = 2 m	09936.00	1
Connecting cable, 4 mm plug, 32 A, yellow, l = 75 cm	07362.02	1
Connecting cable, 4 mm plug, 32 A, blue, l = 75 cm	07362.04	1
Connecting cable, 4 mm plug, 32 A, yellow, l = 150 cm	07364.02	1
Connecting cable, 4 mm plug, 32 A, blue, l = 150 cm	07364.04	1
PC, Windows® XP or higher		

Complete Equipment Set, Manual on CD-ROM included
Free fall with Cobra3 P2130711



Height of fall as a function of falling time.

Determination of the gravitational constant with a Cavendish balance 1.3.09-01

What you can learn about …

- ➔ Law of gravitation
- ➔ Torsional vibrations
- ➔ Free and damped oscillations
- ➔ Forced oscillations
- ➔ Angular restoring moment
- ➔ Moment of inertia of spheres and rods
- ➔ Steiner`s theorem
- ➔ Shear modulus

Principle:

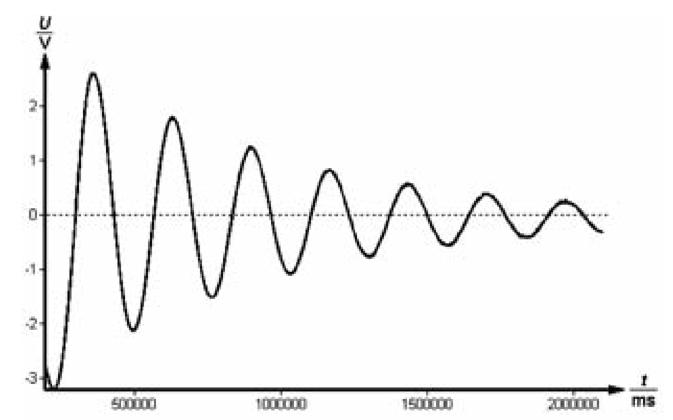
Two small lead balls of equal mass are positioned one at each end of a beam which is held suspended by a thin tungsten thread, so that it can swing freely across its equilibrium position. When two further, but larger, lead balls held on a swivel arm are now brought near to the small lead balls, forces of attraction resulting from gravitation effect acceleration of the small balls in the direction of the larger balls. At the same time, the twisted metal thread generates a restoring moment of rotation, so that the beam is subjected to damped oscillation across a new equilibrium position. The gravitational constant can be determined both from the difference in the angle of rotation of the different equilibrium positions and from the dynamic behaviour of the swinging system during attraction.

An integrated capacitive sensor produces a direct voltage that is proportional to the angle of deflection. This can be recorded over time by an interface system, and the value of the angle of rotation that is required be so determined.

What you need:

Cavendish-balance, computerized	02540.00	1
Circular level with mounting, d = 35 mm	02122.00	1
PC, Windows® XP or higher		

Complete Equipment Set, Manual on CD-ROM included
Determination of the gravitational constant with a Cavendish balance P2130901



Output voltage of the free and damped oscillating Cavendish balance.

Tasks:

1. Calibrate the voltage of the capacitive angle sensor.
2. Determine the time of oscillation and the damping of the freely swinging torsion pendulum.
3. Determine the gravitational constant, using either the acceleration method, the final deflection method or the resonance method.

1.3.11-00 Projectile motion

What you can learn about ...

- ➔ Trajectory parabola
- ➔ Motion involving uniform acceleration
- ➔ Ballistics

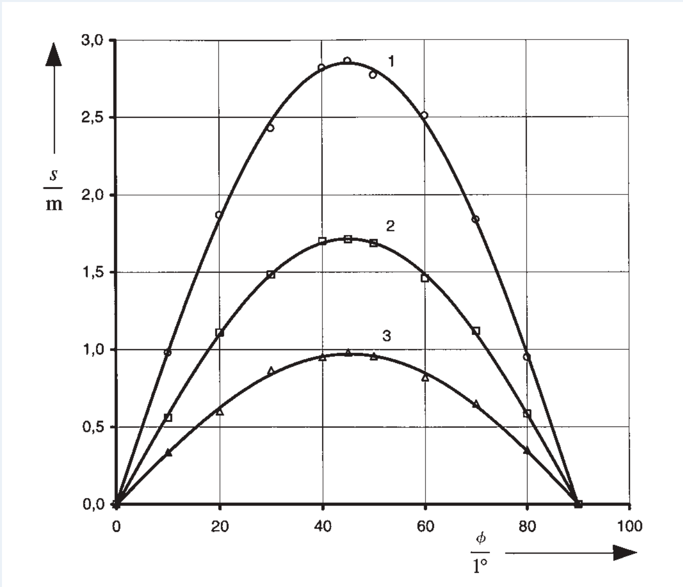
Principle:

A steel ball is fired by a spring at different velocities and at different angles to the horizontal. The relationships between the range, the height of projection, the angle of inclination, and the firing velocity are determined.

What you need:

Ballistic unit	11229.10	1
Recording paper, 1 roll, 25 m	11221.01	1
Steel ball, hardened and polished, d = 19 mm	02502.01	2
Two tier platform support	02076.03	1
Meter Scale, l = 1000 x 27 mm	03001.00	1
Barrel base -PASS-	02006.55	1
Speed measuring attachment	11229.30	1
Power supply 5 VDC/2.4 A with DC-socket 2.1 mm	13900.99	1

Complete Equipment Set, Manual on CD-ROM included
Projectile motion P2131100



Maximum range as a function of the angle of inclination ϕ for different initial velocity v_0: Curve 1 v_0 = 5.3 m/s
Curve 2 v_0 = 4.1 m/s
Curve 3 v_0 = 3.1 m/s

Tasks:

1. To determine the range as a function of the angle of inclination.
2. To determine the maximum height of projection as a function of the angle of inclination.
3. To determine the (maximum) range as a function of the initial velocity.

Ballistic Pendulum 1.3.12-00

What you can learn about ...

- → Potential and kinetic energy
- → Rotational energy
- → Moment of inertia
- → Inelastic collision
- → Principle of conservation of momentum
- → Angular momentum
- → Measurement of projectile velocities

Principle:

A classic method of determining the velocity of a projectile is to shoot the projectile into a resting mass which is large compared to the projectile's mass and hung as a pendulum. In the process, the projectile remains in the pendulum mass and oscillates with it. This is an inelastic collision in which the momentum remains unchanged. If the pendulum's mechanical data are known, one can infer the velocity of the pendulum's mass (including the projectile's mass) at the lowest point of the pendulum's oscillation from the amplitude of the pendulum's oscillation. The momentum of the two masses in this phase of the oscillation must thus be equal to the impulse of the projectile before it struck the pendulum. If one knows the masses of the pendulum and the projectile, one can calculate the projectile's velocity.

In order to be able to use this measuring principle without danger, the following set-up is used here: A steel ball is shot at the mass of a pendulum with the aid of a spring catapult. The pendulum mass has a hollow space in which the steel ball is held.

If, additionally, two light barriers and a time measuring device are available, an independent, direct measurement of the initial velocity of the ball can be made.

What you need:

Ballistic unit	11229.10	1
Ballistic pendulum f. ballistic unit	11229.20	1
Speed measuring attachment	11229.30	1
Steel ball, hardened and polished, d = 19 mm	02502.01	2
Power supply 5 VDC/2.4 A with DC-socket 2.1 mm	13900.99	1

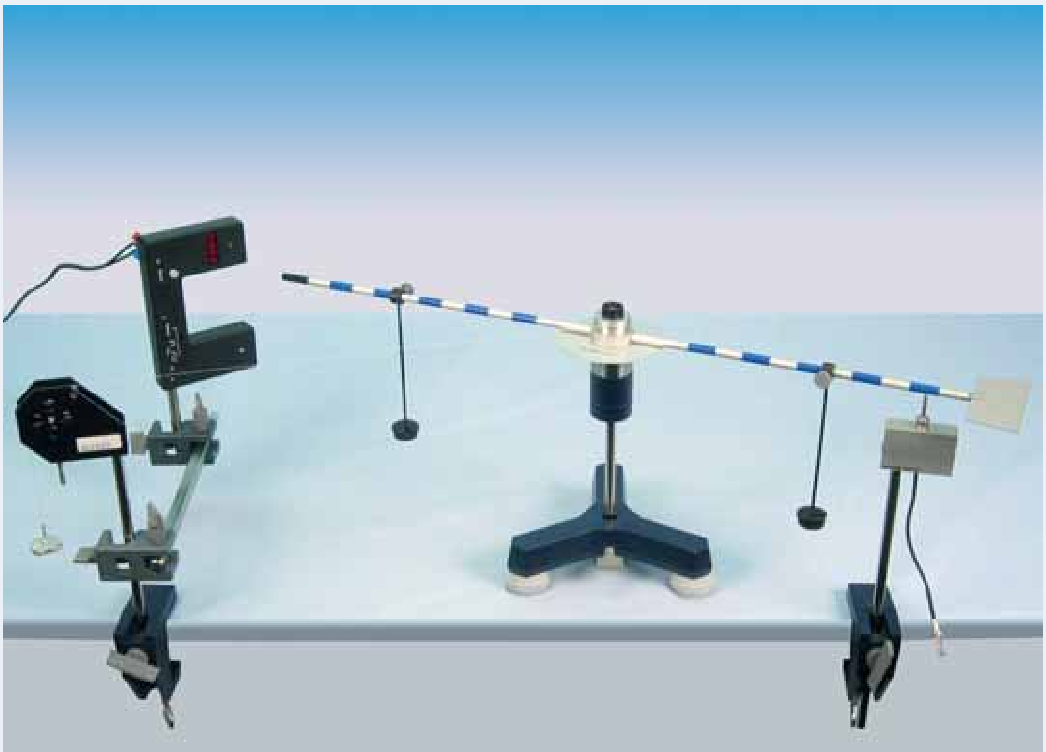
Complete Equipment Set, Manual on CD-ROM included
Ballistic Pendulum P2131200

Tasks:

1. Measurement of the oscillation amplitudes of the ballistic pendulum after capturing the steel ball for the three possible tension energies of the throwing device.
2. Calculation of the initial velocities of the ball from the measured oscillation amplitudes and the mechanical data of the pendulum is performed using the approximation formula (3).
3. Plotting of the velocity v of the steel ball as a function of the maximum deflection φ (0...90°) of the pendulum according to formula (3), taking into consideration the special mechanical data of the experiment.
4. Determination of the correction factor f_{cor} for the utilised pendulum for the conversion of the velocities determined by using the approximation formula into the values obtained from the exact theory. Correction of the velocity values from Tasks 2.
5. If the supplementary devices for the direct measurement of the initial velocity are available, measure the initial velocities corresponding to the three tension steps of the throwing device by performing 10 measurements each with subsequent mean value calculation. Plot the measured points in the diagram from Task 3. Give reasons for contingent systematic deviations from the theoretical curve.

Experimental set-up with supplement for direct measurement of the initial velocity of the ball.

1.3.13-01/05 Moment of inertia and angular acceleration



Set-up of experiment P2131305 with pivot bearing

What you can learn about …

- → Angular velocity
- → Rotary motion
- → Moment
- → Moment of inertia of a disc
- → Moment of inertia of a bar
- → Moment of inertia of a mass point

Principle:

A moment acts on a body which can be rotated about a bearing without friction. The moment of inertia is determined from the angular acceleration.

Tasks:

From the angular acceleration, the moment of inertia is determined as a function of the mass and of the distance from the axis of rotation.

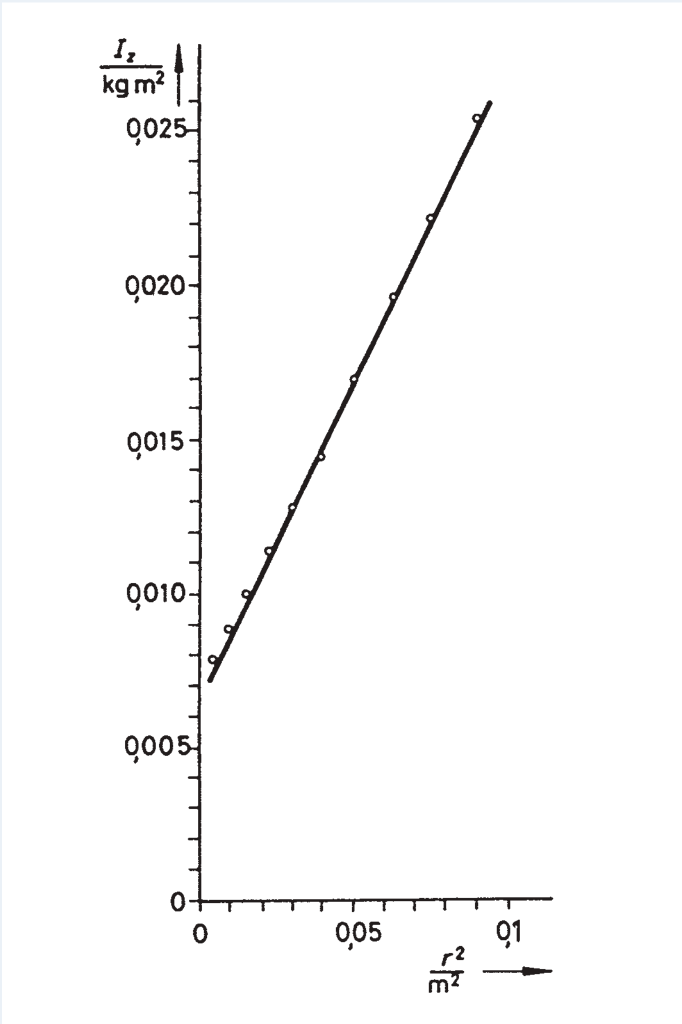
1. of a disc,
2. of a bar,
3. of a mass point.

What you need:

Item	Order No.	Experiment P2131301 with air bearing	Experiment P2131305 with precision pivot bearing
Tripod base -PASS-	02002.55	2	1
Precision pivot bearing	02419.00		1
Inertia rod	02417.03	1	1
Turntable with angular scale	02417.02	1	2
Aperture plate for turntable	02417.05	1	1
Air bearing	02417.01	1	
Holding device with cable release	02417.04	1	1
Precision pulley	11201.02	1	1
Blower 230 V/50Hz	13770.97	1	
Pressure tube, l = 1.5 m	11205.01	1	
Light barrier with counter	11207.30	1	1
Power supply 5 V DC/2.4 A with 4 mm plugs	11076.99	1	1
Supporting blocks, 10, 20, 30, 40 mm	02070.00	1	
Slotted weights, 1 g, polished	03916.00	20	20
Slotted weights, 10 g, coated black	02205.01	10	10
Slotted weight, 50 g, coated black	02206.01	2	2
Weight holder, 1g, silver bronzing	02407.00	1	1
Silk thread on spool, l = 200 mm	02412.00	1	1
Support rod -PASS-, square, l = 1000 mm	02028.55	1	
Support rod -PASS-, square, l = 400 mm	02026.55	1	1
Right angle clamp -PASS-	02040.55	3	2
Bench clamp -PASS-	02010.00	2	2
Connecting cord, 32 A, 1000 mm, red	07363.01		1
Connecting cord, 32 A, 1000 mm, blue	07363.04		1
Adapter, BNC-plug/socket 4 mm.	07542.26		1
Capacitor 100 nF/250V, G1	39105.18		1
Circular level	02122.00		1
Weight holder for slotted weights	02204.00		1
Measuring tape, l = 2 m	09936.00		1

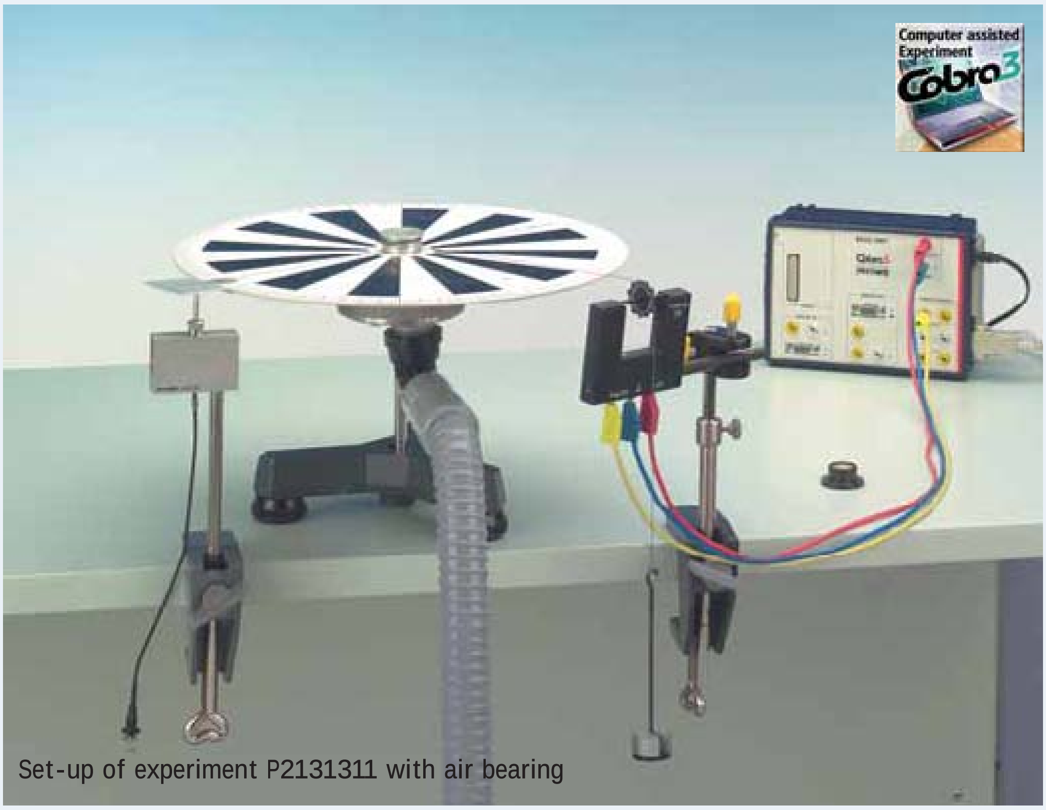
Complete Equipment Set, Manual on CD-ROM included

Moment of inertia and angular acceleration P2131301/05



Moment of inertia of a mass point as a function of the square of its distance from the axis of rotation.

Moment of inertia and angular acceleration with Cobra3 1.3.13-11/15



Set-up of experiment P2131311 with air bearing

What you can learn about ...

- → Angular velocity
- → Rotation
- → Moment
- → Torque
- → Moment of inertia
- → Rotational energy

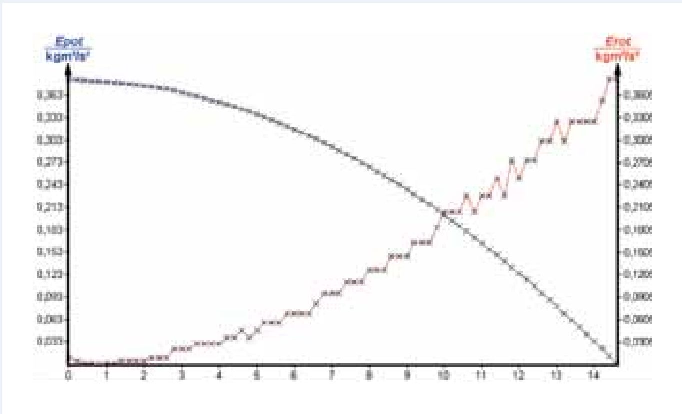
Principle:

If a constant torque is applied to a body that rotates without friction around a fixed axis, the changing angle of rotation increases proportionally to the square of the time and the angular velocity proportional to the time.

What you need:

		Experiment P2131311 with air bearing	Experiment P2131315 with precision pivot bearing
Cobra3 Basic-Unit, USB	12150.50	1	1
Tripod base -PASS-	02002.55	1	1
Precision pivot bearing	02419.00		1
Inertia rod	02417.03		1
Power supply 12V/2A	12151.99	1	1
Software Cobra3, Translation/ Rotation	14512.61	1	1
Light barrier, compact	11207.20	1	1
Blower 230V/50Hz	13770.97	1	
Pressure tube, l = 1.5 m	11205.01	1	
Air bearing	02417.01	1	
Turntable with angular scale	02417.02	1	1
Holding device with cable release	02417.04	1	1
Aperture plate for turntable	02417.05	1	1
Slotted weights, 1 g, polished	03916.00	9	20
Slotted weights, 10 g, coated black	02205.01	3	10
Slotted weight, 50 g, coated black	02206.01	2	2
Silk thread on spool, l = 200 mm	02412.00	1	1
Weight holder for slotted weights	02204.00	1	1
Bench clamp -PASS-	02010.00	2	2
Stand tube	02060.00	1	
Support rod, stainless steel 18/8, l = 250 mm, d = 10 mm	02031.00	1	1
Measuring tape, l = 2 m	09936.00	1	1
Circular level with mounting, d = 35 mm	02122.00	1	1
Right angle clamp -PASS-	02040.55	1	1
Connecting cable, 4 mm plug, 32 A, red, l = 100 cm	07363.01	1	1
Connecting cable, 4 mm plug, 32 A, blue, l = 100 cm	07363.04	1	1
Connecting cable, 4 mm plug, 32 A, yellow, l = 100 cm	07363.02	1	1
Weight holder, 1 g	02407-00		1
PC, Windows® XP or higher			

Complete Equipment Set, Manual on CD-ROM included
Moment of inertia and angular acceleration with Cobra3 P2131311/15

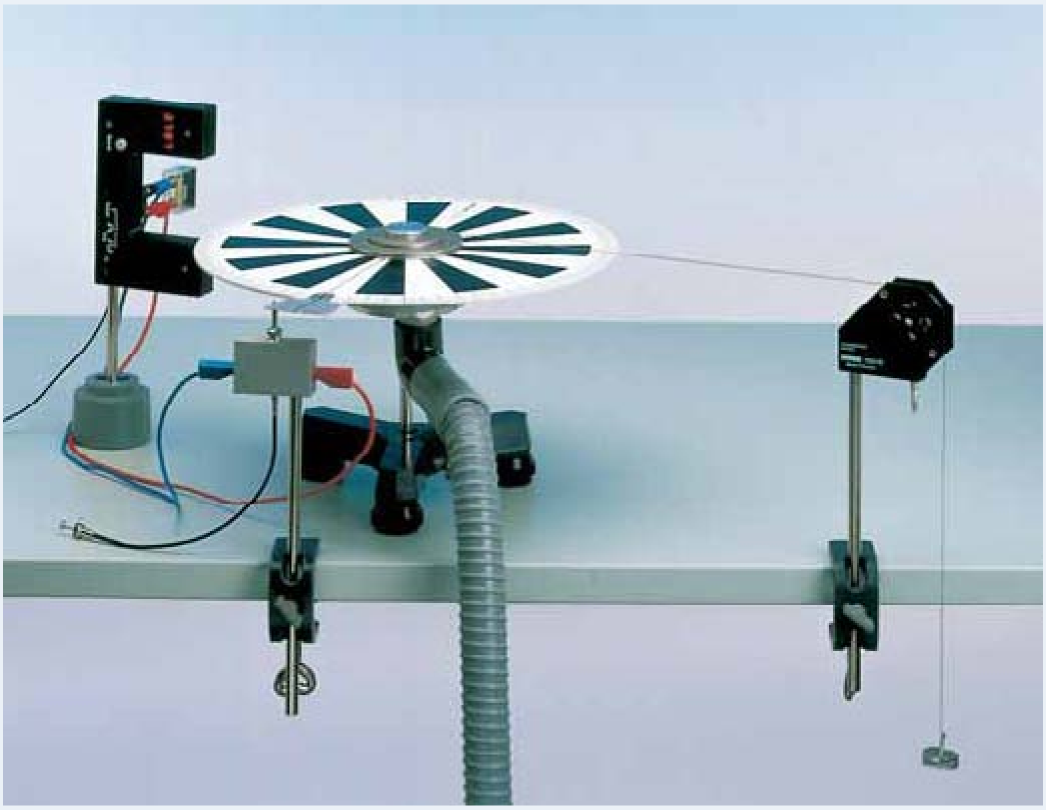


Potential energy and additionally the rotational energy.

Tasks:

1. Measurement of the laws of angle and angular velocity according to time for a uniform rotation movement.
2. Measurement of the laws of angle and angular velocity according to time for a uniformly accelerated rotational movement.
3. Rotation angle φ is proportional to the time t required for the rotation.

1.3.15-00 Moment and angular momentum



What you can learn about ...

- ➔ Circular motion
- ➔ Angular velocity
- ➔ Angular acceleration
- ➔ Moment of inertia
- ➔ Newton's laws
- ➔ Rotation

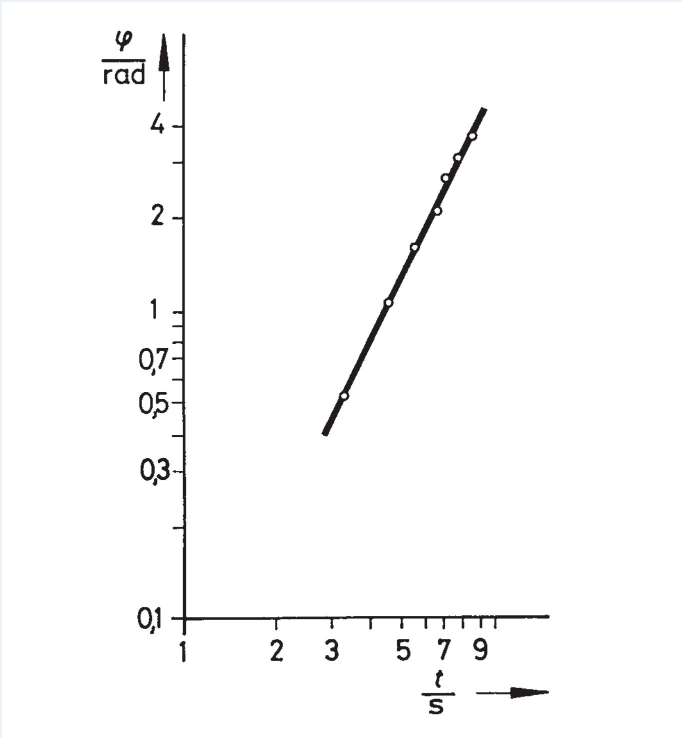
Principle:

The angle of rotation and angular velocity are measured as a function of time on a body which is pivoted so as to rotate without friction and which is acted on by a moment. The angular acceleration is determined as a function of the moment.

What you need:

Turntable with angular scale	02417.02	1
Aperture plate for turntable	02417.05	1
Holding device with cable release	02417.04	1
Air bearing	02417.01	1
Precision pulley	11201.02	1
Pressure tube, l = 1.5 m	11205.01	1
Blower 230V/50Hz	13770.97	1
Light barrier with counter	11207.30	1
Power supply 5 V DC/2.4 A with 4 mm plugs	11076.99	1
Capacitor 100 nF/250 V, G1	39105.18	1
Adapter, BNC plug/4 mm socket	07542.26	1
Weight holder, 1 g, silver bronzing	02407.00	1
Slotted weights, 1 g, polished	03916.00	20
Silk thread on spool, l = 200 mm	02412.00	1
Connecting cable, 4 mm plug, 32 A, blue, l = 100 cm	07363.04	1
Connecting cable, 4 mm plug, 32 A, red, l = 100 cm	07363.01	1
Circular level with mounting, d = 35 mm	02122.00	1
Tripod base -PASS-	02002.55	1
Barrel base -PASS-	02006.55	1
Bench clamp -PASS-	02010.00	2

Complete Equipment Set, Manual on CD-ROM included
Moment and angular momentum P2131500



Angle of rotation as a function of time with uniformly accelerated rotary motion for m = 0.01 kg, r = 0.015 m.

Tasks:

With uniformly accelerated rotary motion, the following will be determined:

1. the angle of rotation as a function of time,
2. the angular velocity as a function of time.
3. the angular acceleration as a function of time,
4. the angular acceleration as a function of the lever arm.

Centrifugal force 1.3.16-01

What you can learn about …

- ➔ Centripetal force
- ➔ Rotary motion
- ➔ Angular velocity
- ➔ Apparent force

Principle:

A body with variable mass moves on a circular path with adjustable radius and variable angular velocity. The centrifugal force of the body will be measured as a function of these parameters.

Tasks:

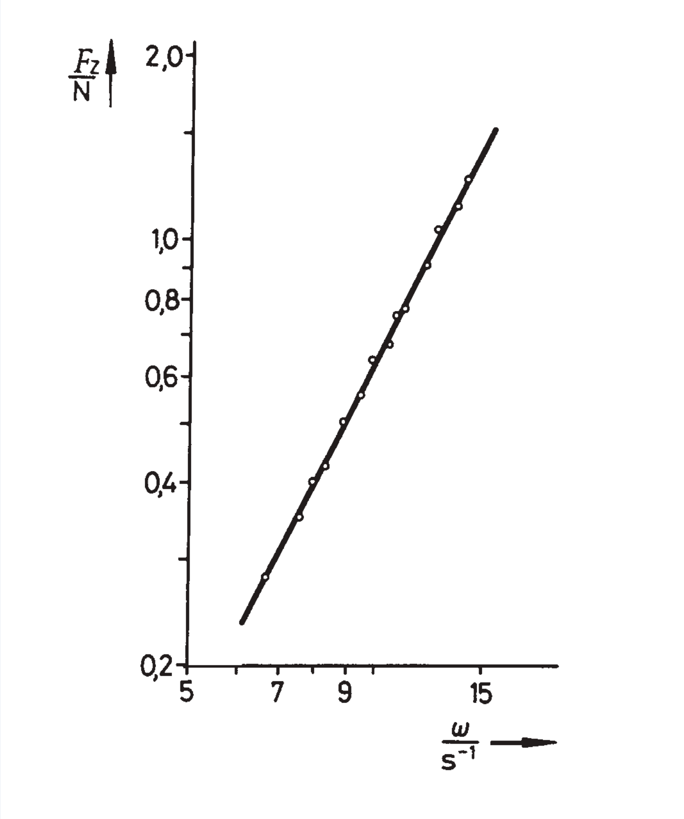
Determination of the centrifugal force as a function

1. of the mass,
2. of the angular velocity,
3. of the distance from the axis of rotation to the centre of gravity of the car.

What you need:

Centrifugal force apparatus	11008.00	1
Car for measurements and experiments	11060.00	1
Holding pin	03949.00	1
Laboratory motor, 220 VAC	11030.93	1
Gearing 30:1	11029.00	1
Bearing unit	02845.00	1
Driving belt	03981.00	1
Support rod with hole, stainless steel, l = 10 cm	02036.01	1
Barrel base -PASS-	02006.55	1
Power supply 5 V DC/2.4 A with 4 mm plugs	11076.99	1
Spring balance holder	03065.20	1
Support rod -PASS-, square, l = 250 mm	02025.55	1
Bosshead	02043.00	2
Bench clamp -PASS-	02010.00	2
Fishing line on spool, d = 0,5 mm, l = 100 mm	02090.00	1
Transparent spring balances, 2 N	03065.03	1
Slotted weights, 10 g, coated black	02205.01	4
Slotted weight, 50 g, coated black	02206.01	2
Light barrier with counter	11207.30	1

Complete Equipment Set, Manual on CD-ROM included
Centrifugal force P2131601



Centrifugal force as a function of the angular velocity ω.

1.3.16-11 Centrifugal force with Cobra3

What you can learn about …

- ➔ Centrifugal force
- ➔ Centripetal force
- ➔ Rotary motion
- ➔ Angular velocity
- ➔ Apparent force

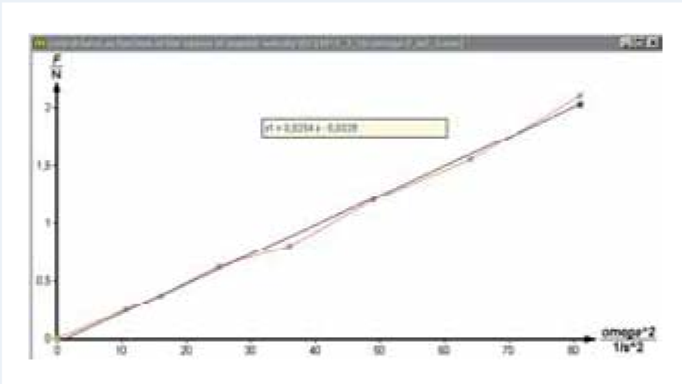
Principle:

A body with variable mass moves on a circular path with adjustable radius and variable angular velocity. The centrifugal force of the body will be measured as a function of these parameters.

What you need:

Cobra3 Basic-Unit, USB	12150.50	1
Power supply 12V/2A	12151.99	1
Newton measuring module	12110.00	1
Newton Sensor	12110.01	1
Software Cobra3 Force/Tesla	14515.61	1
Centrifugal force apparatus	11008.00	1
Car for measurements and experiments	11060.00	1
Holding pin	03949.00	1
Laboratory motor, 220 VAC	11030.93	1
Gearing 30:1	11029.00	1
Bearing unit	02845.00	1
Driving belt	03981.00	1
Support rod with hole, stainless steel, l = 10 cm	02036.01	1
Support rod -PASS-, square, l = 250 mm	02025.55	1
Barrel base -PASS-	02006.55	1
Right angle clamp -PASS-	02040.55	1
Bench clamp -PASS-	02010.00	3
Fishing line on spool, d = 0,5 mm, l = 100 mm	02090.00	1
Slotted weights, 10 g, coated black	02205.01	4
Slotted weight, 50 g, coated black	02206.01	2
PC, Windows® XP or higher		

Complete Equipment Set, Manual on CD-ROM included
Centrifugal force with Cobra3 P2131611



Typical evaluation of central force as a function of the square of angular velocity.

Tasks:

Determination of the centrifugal force as a function

1. of the mass,
2. of the angular velocity,
3. of the distance from the axis of rotation to the centre of gravity of the car.

Mechanical conservation of energy / Maxwell's wheel 1.3.18-00

What you can learn about …

- → Maxwell disk
- → Energy of translation
- → Energy of rotation
- → Potential energy
- → Moment of inertia
- → Angular velocity
- → Angular acceleration
- → Instantaneous velocity
- → Gyroscope

Principle:

A disk, which can unroll with its axis on two cords, moves in the gravitational field. Potential energy, energy of translation and energy of rotation are converted into one another and are determined as a function of time.

What you need:

Support base -PASS-	02005.55	1
Support rod -PASS-, square, l = 1000 mm	02028.55	3
Right angle clamp -PASS-	02040.55	4
Meter Scale, l = 1000 x 27 mm	03001.00	1
Cursor for scale, 2 pieces, plastic, red	02201.00	1
Maxwell wheel	02425.00	1
Connecting cable, 4 mm plug, 32 A, red, l = 100 cm	07363.01	1
Connecting cable, 4 mm plug, 32 A, blue, l = 100 cm	07363.04	1
Light barrier with counter	11207.30	1
Holding device with cable release	02417.04	1
Plate holder, opening width 0...10 mm	02062.00	1
Adapter, BNC plug/4 mm socket	07542.26	1
Capacitor 100 nF/250 V, G1	39105.18	1
Power supply 5 V DC/2.4 A with 4 mm plugs	11076.99	1

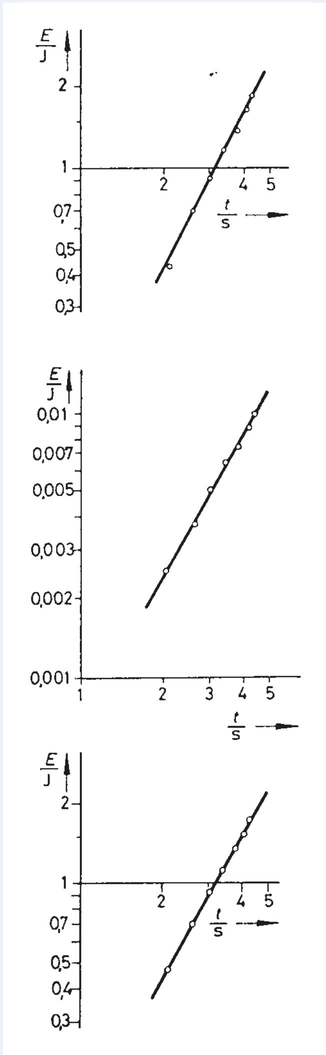
Complete Equipment Set, Manual on CD-ROM included
Mechanical conservation of energy / Maxwell's wheel P2131800

Tasks:

The moment of inertia of the Maxwell disk is determined.

Using the Maxwell disk,
1. the potential energy,
2. the energy of translation,
3. the energy of rotation,

are determined as a function of time.



Energy of the Maxwell disk as a function of time.
1. Negative potential energy
2. Energy of translation
3. Energy of rotation

1.3.19-00 Laws of gyroscopes / 3-axis gyroscope

What you can learn about …

- ➔ Momentum of inertia
- ➔ Torque
- ➔ Angular momentum
- ➔ Precession
- ➔ Nutation

Principle:

The momentum of inertia of the gyroscope is investigated by measuring the angular acceleration caused by torques of different known values. In this experiment, two of the axes of the gyroscope are fixed.

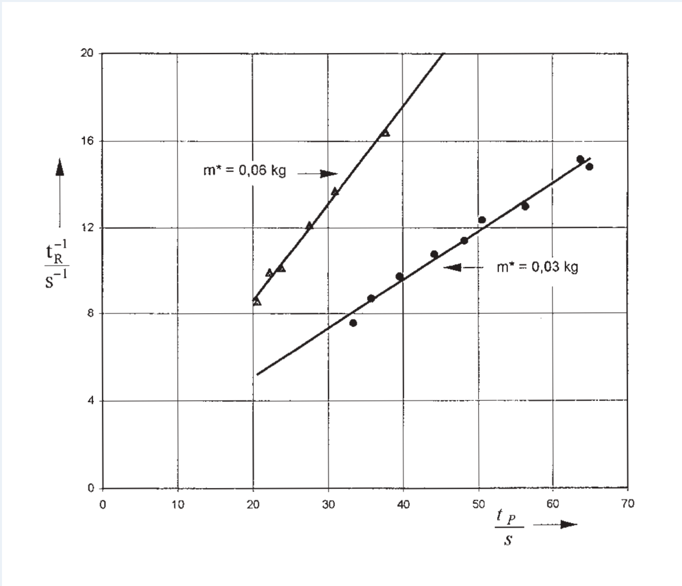
The relationship between the precession frequency and the gyro-frequency of the gyroscope with 3 free axes is examined for torques of different values applied to the axis of rotation.

If the axis of rotation of the force-free gyroscope is slightly displaced, a nutation is induced. The nutation frequency will be investigated as a function of gyro-frequency.

What you need:

Gyroscope with 3 axis	02555.00	1
Light barrier with counter	11207.30	1
Power supply 5 V DC/2.4 A with 4 mm plugs	11076.99	1
Additional gyro disk with counter weight	02556.00	1
Stopwatch, digital, 1/100 s	03071.01	1
Barrel base -PASS-	02006.55	1
Slotted weights, 10 g, coated black	02205.01	4
Slotted weights, 50 g, coated black	02206.01	7
Weight holder for slotted weights	02204.00	1

Complete Equipment Set, Manual on CD-ROM included
Laws of gyroscopes / 3-axis gyroscope P2131900



Determination of the momentum of inertia from the slope of straight line $t_R^{-1} = f(t_P)$.

Tasks:

1. Determination of the momentum of inertia of the gyroscope by measurement of the angular acceleration.
2. Determination of the momentum of inertia by measurement of the gyro-frequency and precession frequency.
3. Investigation of the relationship between precession and gyro-frequency and its dependence from torque.
4. Investigation of the relationship between nutation frequency and gyro-frequency.

Laws of gyroscopes / cardanic gyroscope 1.3.20-00

What you can learn about …

- → Moment of inertia
- → Torque
- → Angular momentum
- → Nutation
- → Precession
- → Chaotic behaviour

Principle:

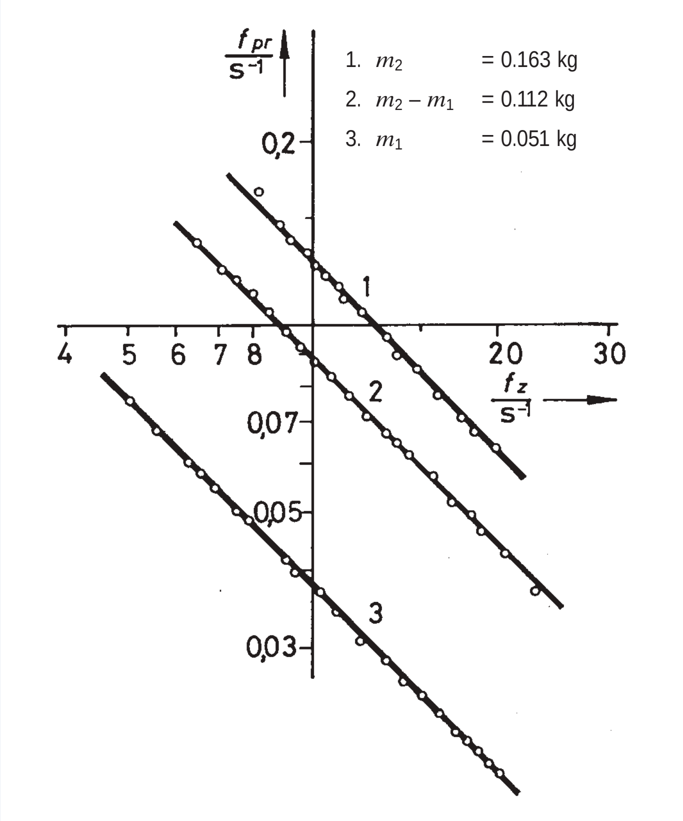
If the axis of rotation of the forcefree gyroscope is displaced slightly, a nutation is produced. The relationship between precession frequency or nutation frequency and gyro-frequency is examined for different moments of inertia.

Additional weights are applied to a gyroscope mounted on gimbals, so causing a precession.

What you need:

Gyroscope, Magnus type, incl. Handbook	02550.00	1
Stopwatch, digital, 1/100 s	03071.01	1
Digital stroboscope	21809.93	1

Complete Equipment Set, Manual on CD-ROM included
Laws of gyroscopes / cardanic gyroscope P2132000



Precession frequency as a function of the gyro frequency for different additional masses.

Tasks:

1. To determine the precession frequency as a function of the torque and the angular velocity of the gyroscope.
2. To determine the nutational frequency as a function of the angular velocity and the moment of inertia.

Note:

A detailed handbook (128 pages) containing additional experiments is included, free of charge, in the equipment.

1.3.21-00 Mathematical pendulum

What you can learn about …
- ➔ Duration of oscillation
- ➔ Period
- ➔ Amplitude
- ➔ Harmonic oscillation

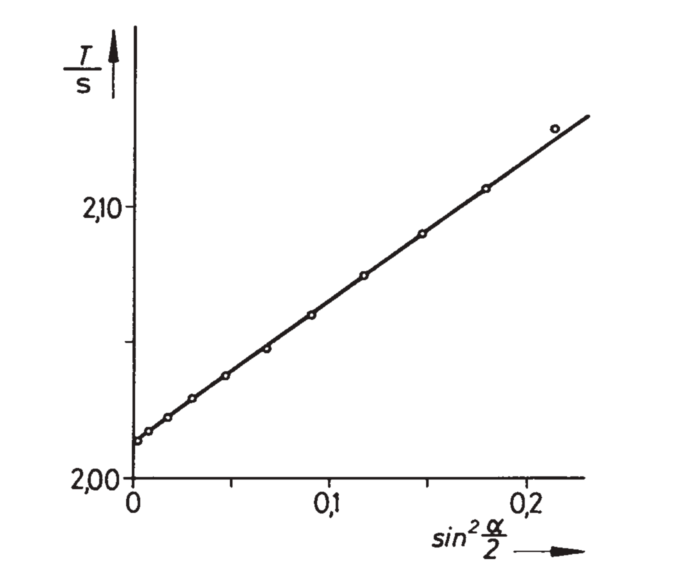
Principle:

A mass, considered as of point form, suspended on a thread and subjected to the force of gravity, is deflected from its position of rest. The period of the oscillation thus produced is measured as a function of the thread length and the angle of deflection.

What you need:

Light barrier with counter	11207.30	1
Power supply 5 V DC/2.4 A with 4 mm plugs	11076.99	1
Steel balls with eyelet, d = 25.4 mm	02465.01	1
Steel balls with eyelet, d = 32 mm	02466.01	1
Meter Scale, l = 1000 x 27 mm	03001.00	1
Cursor for scale, 2 pieces, plastic, red	02201.00	1
Fishing line on spool, d = 0,5 mm, l = 100 mm	02090.00	1
Right angle clamp -PASS-	02040.55	2
Clamping pads on stem	02050.00	1
Support rod -PASS-, square, l = 1250 mm	02029.55	1
Tripod base -PASS-	02002.55	1

Complete Equipment Set, Manual on CD-ROM included
Mathematical pendulum P2132100



Period of the pendulum as a function of the angle of deflection.

Tasks:

1. For small deflections, the oscillation period is determined as a function of the cord length.
2. The acceleration due to gravity is determined.
3. The oscillation period is determined as a function of the deflection.

Reversible pendulum 1.3.22-00

What you can learn about ...

- → Physical pendulum
- → Moment of inertia
- → Steiner's law
- → Reduced length of pendulum
- → Reversible pendulum
- → Terrestrial gravitational acceleration

Principle:

By means of a reversible pendulum, terrestrial gravitational acceleration g may be determined from the period of oscillation of a physical pendulum, knowing neither the mass nor the moment of inertia of the latter.

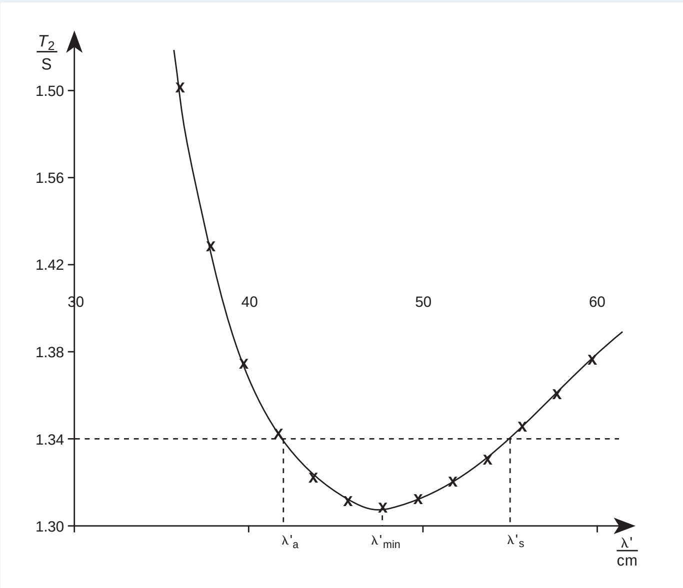
Tasks:

1. Measurement of the period for different axes of rotation.
2. Determination of terrestrial gravitational acceleration g.

What you need:

Bearing bosshead for reversing pendulum	02805.00	2
Support rod, stainless steel, l = 750 mm	02033.00	1
Bolt with knife edge	02049.00	2
Power supply 5 V DC/2.4 A with 4 mm plugs	11076.99	1
Light barrier with counter	11207.30	1
Right angle clamp -PASS-	02040.55	3
Bench clamp -PASS-	02010.00	2
Tripod base -PASS-	02002.55	1
Support rod -PASS-, square, l = 250 mm	02025.55	3
Measuring tape, l = 2 m	09936.00	1

Complete Equipment Set, Manual on CD-ROM included
Reversible pendulum P2132200



Period T_2 as a function of the position of the axis of rotation of the physical pendulum.

1.3.23-01 Pendulum oscillations / variable g pendulum

What you can learn about …

- → Oscillation period
- → Harmonic oscillation
- → Mathematical pendulum
- → Physical pendulum
- → Decomposition of force
- → Moment of inertia

Principle:

Investigate the oscillation behaviour of a pendulum (rod pendulum) by varying the magnitude of the components of the acceleration of gravity which are decisive for the oscillation period. The pendulum that is to be used is constructed in such a manner that its oscillation plane can be progressively rotated from a vertical orientation to a horizontal one. The angle F, by which the oscillation plane deviates from its normal vertical position, can be read from a scale.

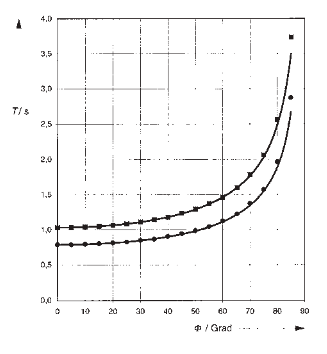
Tasks:

1. Measurement of the oscillation period of the pendulum as a function of the angle of inclination Φ of the oscillation plane for two different pendulum lengths.
2. Graphical analysis of the measured correlations and a comparison with the theoretical curves, which have been standardised with the measured value at $\Phi = 0$.
3. Calculation of the effective pendulum length l for the acceleration of gravity, which is assumed to be known. Comparison of this value with the distance between the pivot point of the pendulum and the centre of gravity of the mobile pendulum weight.
4. On the moon's surface the "lunar acceleration of gravity" g_m is only 16.6% of the earth's acceleration of gravity g. Calculate the angle Φ and set it on the device such that the pendulum in the laboratory oscillates with the same oscillation period with which it would oscillate on the moon in a perpendicular position. Compare the measured oscillation period with the calculated one.

What you need:

Variable g-pendulum	02817.00	1
Holder for light barrier	02817.10	1
Light barrier, compact	11207.20	1
Timer 4-4 with USB-interface	13604.99	1
Alternatively to 13604.99:		
Timer 2-1	13607.99	1
Tripod base -PASS-	02002.55	1
Connecting cable, 4 mm plug, 32 A, red, l = 50 cm	07361.01	1
Connecting cable, 4 mm plug, 32 A, yellow, l = 50 cm	07361.02	1
Connecting cable, 4 mm plug, 32 A, blue, l = 50 cm	07361.04	1

Complete Equipment Set, Manual on CD-ROM included
Pendulum oscillations / variable g pendulum P2132301



Oscillation period of the pendulum as a function of the slope Φ. of the oscillation plane. The measured points are plotted above the corresponding theoretical curve (solid line). Upper curve: L = 270 mm; lower curve: L = 141 mm.

Pendulum oscillations with Cobra3 1.3.23-11

What you can learn about …

- ➔ Oscillation period
- ➔ Harmonic oscillation
- ➔ Mathematical pendulum
- ➔ Physical pendulum
- ➔ Variable g-pendulum
- ➔ Decomposition of force
- ➔ Gravitational force

Principle:

Earth's gravitational acceleration g is determined for different lengths of the pendulum by means of the oscillating period. If the oscillating plane of the pendulum is not parallel to the gravitational field of the earth, only one component of the gravitational force acts on the pendulum movement.

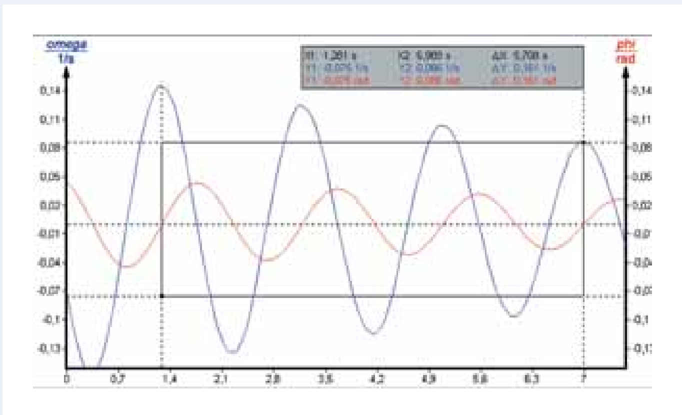
Tasks:

1. Determination of the oscillation period of a thread pendulum as a function of the pendulum length.
2. Determination of g.
3. Determination of the gravitational acceleration as a function of the inclination of the pendulum force.

What you need:

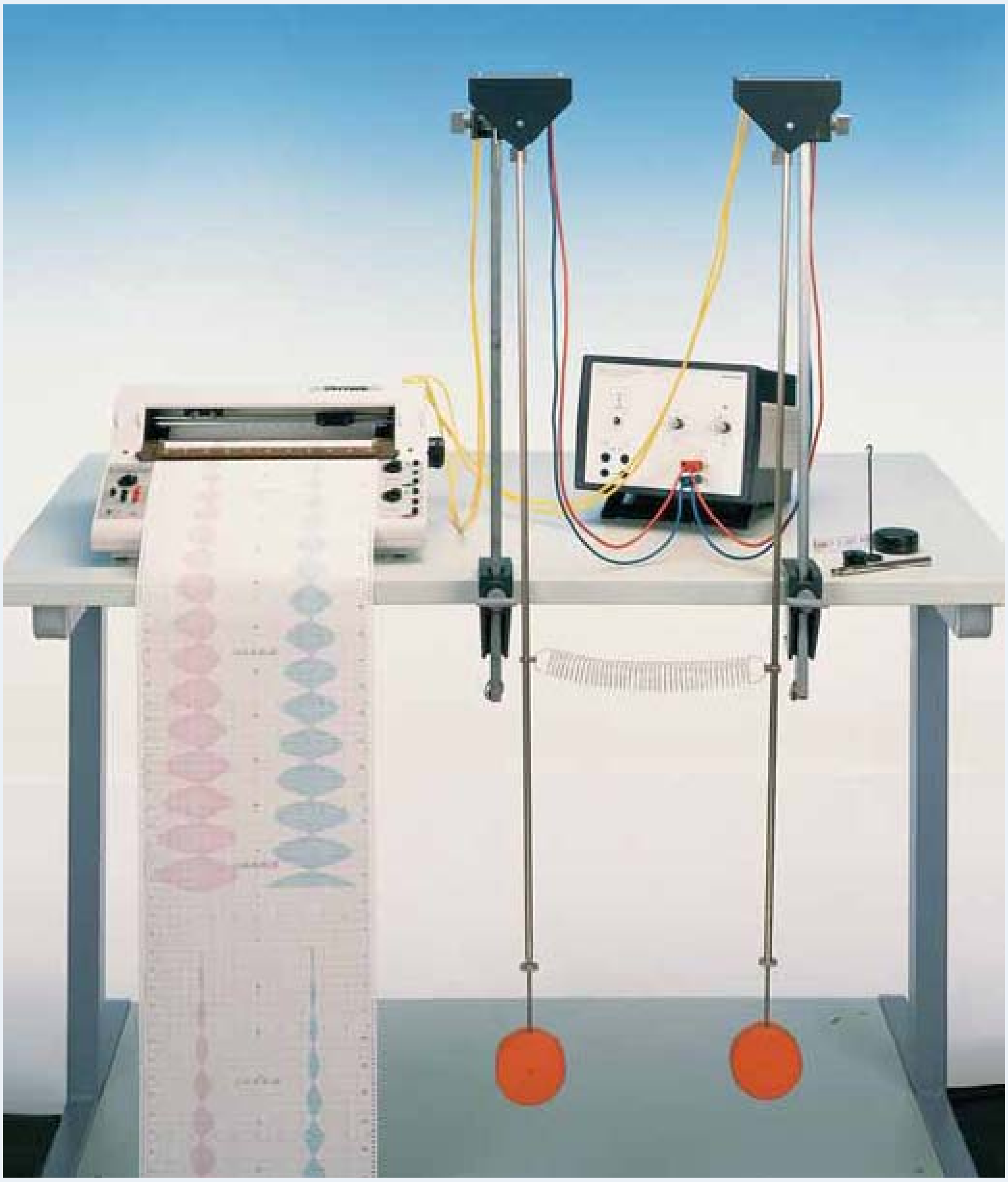
Cobra3 Basic-Unit, USB	12150.50	1
Power supply 12V/2A	12151.99	1
Software Cobra3, Translation/ Rotation	14512.61	1
Movement sensor with cable	12004.10	1
Adapter BNC socket/4 mm plug pair	07542.27	1
Adapter, BNC socket - 4 mm plug	07542.20	1
Silk thread on spool, l = 200 mm	02412.00	1
Fishing line on spool, d = 0,7 mm, l = 20 mm	02089.00	1
Weight holder, 1g, silver bronzing	02407.00	1
Steel balls with eyelet, d = 32 mm	02466.01	2
Tripod base -PASS-	02002.55	1
Support rod -PASS-, square, l = 1000 mm	02028.55	1
Stand tube	02060.00	1
Plate holder, opening width 0...10 mm	02062.00	1
Right angle clamp -PASS-	02040.55	2
Bench clamp -PASS-	02010.00	1
Protractor scale with pointer	08218.00	1
Circular level with mounting, d = 35 mm	02122.00	1
Measuring tape, l = 2 m	09936.00	1
Pendulum	12004.11	1
PC, Windows® XP or higher		

Complete Equipment Set, Manual on CD-ROM included
Pendulum oscillations with Cobra3 P2132311



Typical measurement result

1.3.25-01 Coupled Pendula



What you can learn about …

- ➔ Spiral spring
- ➔ Gravity pendulum
- ➔ Spring constant
- ➔ Torsional vibration
- ➔ Torque
- ➔ Beat
- ➔ Angular velocity
- ➔ Angular acceleration
- ➔ Characteristic frequency

Principle:

Two equal gravity pendula with a particular characteristic frequency are coupled by a "soft" spiral spring. The amplitudes of both pendula are recorded as a function of time for various vibrational modes and different coupling factors using a y/t recorder. The coupling factors are determined by different methods.

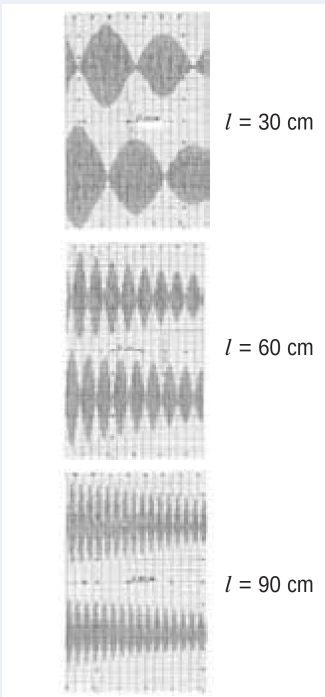
Tasks:

1. To determine the spring constant of the coupling spring.
2. To determine and to adjust the characteristic frequencies of the uncoupled pendula.
3. To determine the coupling factors for various coupling-lengths using
   a) the apparatus constants
   b) the angular frequencies for "inphase" and "in opposite phase" vibration
   c) the angular frequencies of the beat mode.
4. To check the linear relation between the square of the coupling-lengths and
   a) the particular frequencies of the beat mode
   b) the square of the frequency for "in opposite phase" vibration.
5. To determine the pendulum's characteristic frequency from the vibrational modes with coupling and to compare this with the characteristic frequency of the uncoupled pendula.

What you need:

Pendulum with recorder connection	02816.00	2
Helical springs, 3 N/m	02220.00	1
Rod with hook	02051.00	1
Weight holder for slotted weights	02204.00	1
Slotted weights, 10 g, coated black	02205.01	5
Yt recorder, 2 channels	11415.95	1
Power supply 0-12 V DC/ 6 V, 12 V AC	13505.93	1
Bench clamp -PASS-	02010.00	2
Support rod -PASS-, square, l = 630 mm	02027.55	2
Right angle clamp -PASS-	02040.55	2
Measuring tape, l = 2 m	09936.00	1
Connecting cable, 4 mm plug, 32 A, yellow, l = 100 cm	07363.02	4
Connecting cable, 4 mm plug, 32 A, red, l = 100 cm	07363.01	2
Connecting cable, 4 mm plug, 32 A, blue, l = 100 cm	07363.04	2

Complete Equipment Set, Manual on CD-ROM included
Coupled Pendula P2132501



Amplitude curves of the vibrations of coupled pendula in the beat case for three different coupling lengths l as a function of time.
Speed of recorder: t = 10 s/Div.

Coupled Pendula with Cobra3 1.3.25-11

What you can learn about ...

- ➔ Spiral spring
- ➔ Gravity pendulum
- ➔ Spring constant
- ➔ Torsional vibration
- ➔ Torque
- ➔ Beat
- ➔ Angular velocity
- ➔ Angular acceleration
- ➔ Characteristic frequency

Principle:

Two equal gravity pendula with a particular characteristic frequency are coupled by a "soft" spiral spring. The amplitudes of both pendula are recorded as a function of time for various vibrational modes and different coupling factors using a y/t recorder. The coupling factors are determined by different methods.

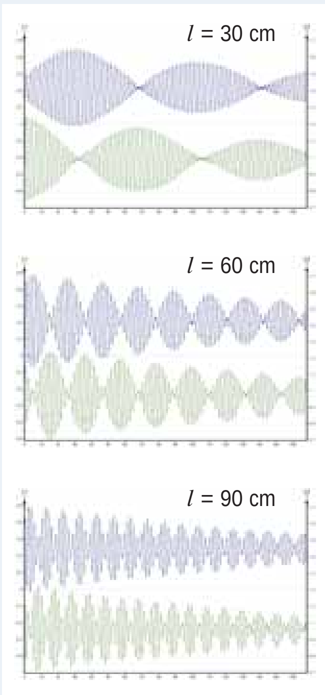
Tasks:

1. To determine the spring constant of the coupling spring.
2. To determine and to adjust the characteristic frequencies of the uncoupled pendula.
3. To determine the coupling factors for various coupling-lengths using
   a) the apparatus constants
   b) the angular frequencies for "inphase" and "in opposite phase" vibration
   c) the angular frequencies of the beat mode.
4. To check the linear relation between the square of the coupling-lengths and
   a) the particular frequencies of the beat mode
   b) the square of the frequency for "in opposite phase" vibration.
5. To determine the pendulum's characteristic frequency from the vibrational modes with coupling and to compare this with the characteristic frequency of the uncoupled pendula.

What you need:

Pendulum with recorder connection	02816.00	2
Helical springs, 3 N/m	02220.00	1
Rod with hook	02051.00	1
Weight holder for slotted weights	02204.00	1
Slotted weights, 10 g, coated black	02205.01	5
Electrolyte capacitors G1, 10 µF	39105.28	2
Cobra3 Basic-Unit, USB	12150.50	1
Power supply 12V/2A	12151.99	1
Software Cobra3 Universal recorder	14504.61	1
Power supply 0-12 V DC/ 6 V, 12 V AC	13505.93	1
Bench clamp -PASS-	02010.00	2
Support rod -PASS-, square, l = 630 mm	02027.55	2
Right angle clamp -PASS-	02040.55	2
Measuring tape, l = 2 m	09936.00	1
Connecting cable, 4 mm plug, 32 A, red, l = 100 cm	07363.01	4
Connecting cable, 4 mm plug, 32 A, blue, l = 100 cm	07363.04	4
PC, Windows® XP or higher		

Complete Equipment Set, Manual on CD-ROM included
Coupled Pendula with Cobra3 P2132511



Amplitude curves of the vibrations of coupled pendula in the beat case for three different coupling lengths l (30 cm, 60 cm and 90 cm) as a function of time.

1.3.26-11 Harmonic oscillations of spiral springs – Springs linked in parallel and series

What you can learn about …

- ➔ Spring constant
- ➔ Hooke's law oscillations
- ➔ Limit of elasticity
- ➔ Parallel springs
- ➔ Serial springs
- ➔ Use of an interface

Principle:

The spring constant D is determined for different experimental set-ups from the oscillation period and the suspended mass.

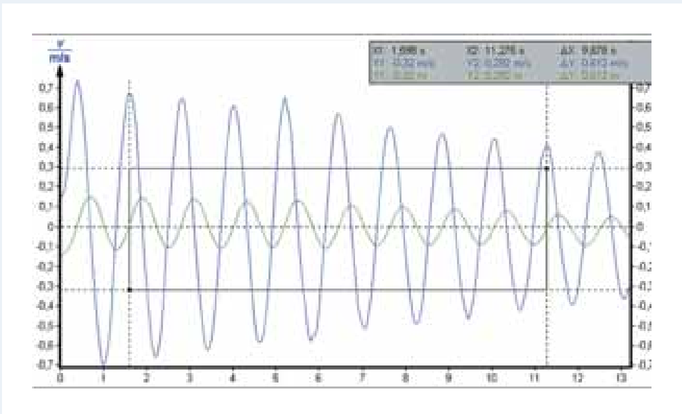
Tasks:

1. Determination of the spring constant D for different springs.
2. Determination of the spring constant for springs linked in parallel.
3. Determination of the spring constant for springs linked in series.

What you need:

Cobra3 Basic-Unit, USB	12150.50	1
Power supply 12V/2A	12151.99	1
Software Cobra3, Translation/ Rotation	14512.61	1
Light barrier, compact	11207.20	1
Silk thread on spool, l = 200 mm	02412.00	1
Weight holder for slotted weights	02204.00	1
Slotted weights, 10 g, coated black	02205.01	4
Slotted weights, 50 g, coated black	02206.01	7
Tripod base -PASS-	02002.55	1
Support rod -PASS-, square, l = 1000 mm	02028.55	1
Stand tube	02060.00	1
Rod with hook	02051.00	1
Right angle clamp -PASS-	02040.55	2
Helical springs, 3 N/m	02220.00	2
Helical springs, 20 N/m	02222.00	1
Connecting cable, 4 mm plug, 32 A, red, l = 100 cm	07363.01	1
Connecting cable, 4 mm plug, 32 A, blue, l = 100 cm	07363.04	1
Connecting cable, 4 mm plug, 32 A, yellow, l = 100 cm	07363.02	1
PC, Windows® XP or higher		

Complete Equipment Set, Manual on CD-ROM included
Harmonic oscillations of spiral springs – Springs linked in parallel and series P2132611



Typical measurement result

Forced Oscillations – Pohl's pendulum 1.3.27-01

What you can learn about ...

- → Angular frequency
- → Characteristic frequency
- → Resonance frequency
- → Torsion pendulum
- → Torsional vibration
- → Torque and Restoring torque
- → Damped/undamped free oscillation
- → Forced oscillation
- → Ratio of attenuation/ decrement
- → Damping constant
- → Logarithmic decrement
- → Aperiodic case
- → Creeping

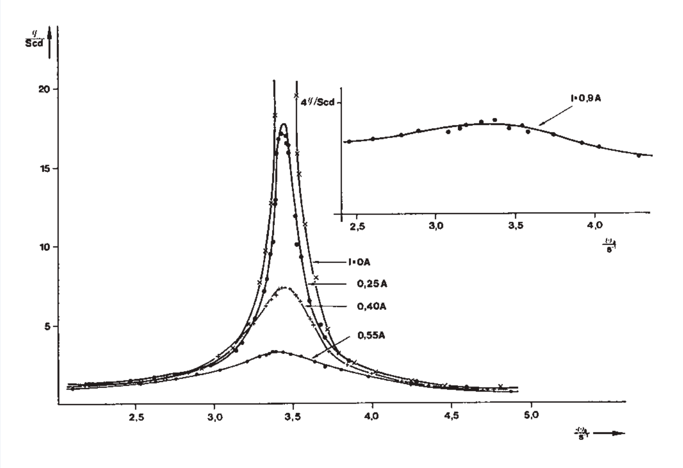
Principle:

If an oscillating system is allowed to swing freely it is observed that the decrease of successive maximum amplitudes is highly dependent on the damping. If the oscillating system is stimulated to swing by an external periodic torque, we observe that in the steady state the amplitude is a function of the frequency and the amplitude of the external periodic torque and of the damping. The characteristic frequencies of the free oscillation as well as the resonance curves of the forced oscillation for different damping values are to be determined.

What you need:

Torsion pendulum after Pohl	11214.00	1
Power supply, universal	13500.93	1
Bridge rectifier, 30 VAC/1 ADC	06031.10	1
Stopwatch, digital, 1/100 s	03071.01	1
Digital multimeter 2010	07128.00	1
Connecting cable, 4 mm plug, 32 A, yellow, l = 25 cm	07360.02	2
Connecting cable, 4 mm plug, 32 A, red, l = 75 cm	07362.01	2
Connecting cable, 4 mm plug, 32 A, blue, l = 75 cm	07362.04	3

Complete Equipment Set, Manual on CD-ROM included
Forced Oscillations – Pohl's pendulum P2132701



Resonance curves for different dampings.

Tasks:

A. <u>Free oscillation</u>

1. To determine the oscillating period and the characteristic frequency of the undamped case.
2. To determine the oscillating periods and the corresponding characteristic frequencies for different damping values. Successive, unidirectional maximum amplitudes are to be plotted as a function of time. The corresponding ratios of attenuation, the damping constants and the logarithmic decrements are to be calculated.
3. To realize the aperiodic case and the creeping.

B. <u>Forced oscillation</u>

1. The resonance curves are to be determined and to be represented graphically using the damping values of A.
2. The resonance frequencies are to be determined and are to be compared with the resonance frequency values found beforehand.
3. The phase shifting between the torsion pendulum and the stimulating external torque is to be observed for a small damping value assuming that in one case the stimulating frequency is far below the resonance frequency and in the other case it is far above it.

1.3.27-11 Forced Oscillations – Pohl's pendulum

Determination of resonance frequencies by Fourier analysis

What you can learn about ...

- ➔ Angular frequency
- ➔ Characteristic frequency
- ➔ Resonance frequency
- ➔ Torsion pendulum
- ➔ Torsional vibration
- ➔ Torque
- ➔ Testoring torque
- ➔ Damped/undamped free oscillation
- ➔ Forced oscillation
- ➔ Ratio of attenuation/decrement
- ➔ Damping constant
- ➔ Logarithmic decrement
- ➔ Aperiodic case
- ➔ Creeping
- ➔ Chaotic behaviour

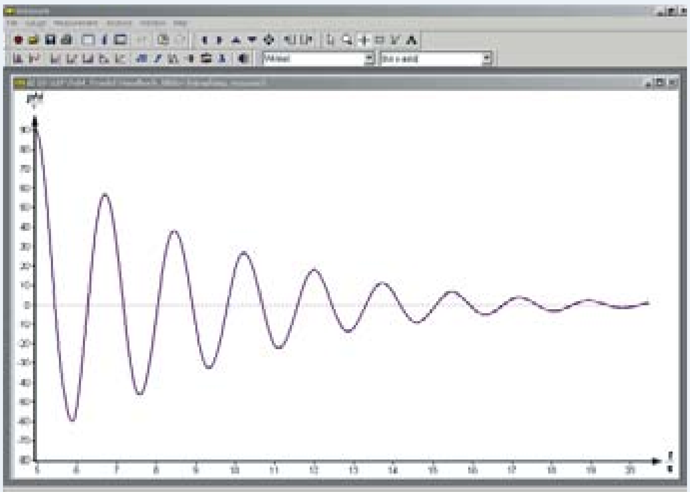
What you need:

Torsion pendulum after Pohl	11214.00	1
Power supply, universal	13500.93	1
Bridge rectifier, 30 VAC/1 ADC	06031.10	1
Stopwatch, digital, 1/100 s	03071.01	1
Digital multimeter 2010	07128.00	1
Connecting cable, 4 mm plug, 32 A, yellow, l = 25 cm	07360.02	2
Connecting cable, 4 mm plug, 32 A, red, l = 75 cm	07362.01	2
Connecting cable, 4 mm plug, 32 A, blue, l = 75 cm	07362.04	3
Cobra3 Basic-Unit, USB	12150.50	1
Power supply 12V/2A	12151.99	1
Software Cobra3, Translation/ Rotation	14512.61	1
Movement sensor with cable	12004.10	1
Adapter BNC socket/4 mm plug pair	07542.27	1
Adapter, BNC socket - 4 mm plug	07542.20	1
Silk thread on spool, l = 200 mm	02412.00	1
Weight holder, 1g, silver bronzing	02407.00	1
Support base -PASS-	02005.55	1
Support rod -PASS-, square, l = 400 mm	02026.55	1
Support rod -PASS-, square, l = 250 mm	02025.55	1
Right angle clamp -PASS-	02040.55	2
PC, Windows® XP or higher		

Complete Equipment Set, Manual on CD-ROM included
Forced Oscillations – Pohl's pendulum
Determination of resonance frequencies by Fourier analysis **P2132711**

Principle:

If an oscillating system is allowed to swing freely it is observed that the decrease of successive maximum amplitudes is highly dependent on the damping. If the oscillating system is stimulated to swing by an external periodic torque, we observe that in the steady state the amplitude is a function of the frequency and the amplitude of the external periodic torque and of the damping. The characteristic frequencies of the free oscillation as well as the resonance curves of the forced oscillation for different damping values are to be determined.
Therefore, the oscillations are recorded with the Cobra3 systemin connection with the movement sensor. The curves of the different oscillations are displayed and the necessary quantities for the determination of the characteristic values can easily becalculated.



Recorded curve of the damped oscillation.

Tasks:

A. Free oscillation

1. To determine the oscillating period and the characteristic frequency of the undamped case.
2. To determine the oscillating periods and the corresponding characteristic frequencies for different damping values. Successive, unidirectional maximum amplitudes are to be plotted as a function of time. The corresponding ratios of attenuation, the damping constants and the logarithmic decrements are to be calculated.
3. To realize the aperiodic case and the creeping.

B. Forced oscillation

1. The resonance curves are to be determined and to be represented graphically using the damping values of A.
2. The resonance frequencies are to be determined and are to be compared with the resonance frequency values found beforehand.
3. The phase shifting between the torsion pendulum and the stimulating external torque is to be observed for a small damping value assuming that in one case the stimulating frequency is far below the resonance frequency and in the other case it is far above it.

Moment of inertia / Steiner's theorem 1.3.28-01

What you can learn about ...

- → Rigid body
- → Moment of inertia
- → Centre of gravity
- → Axis of rotation
- → Torsional vibration
- → Spring constant
- → Angular restoring force

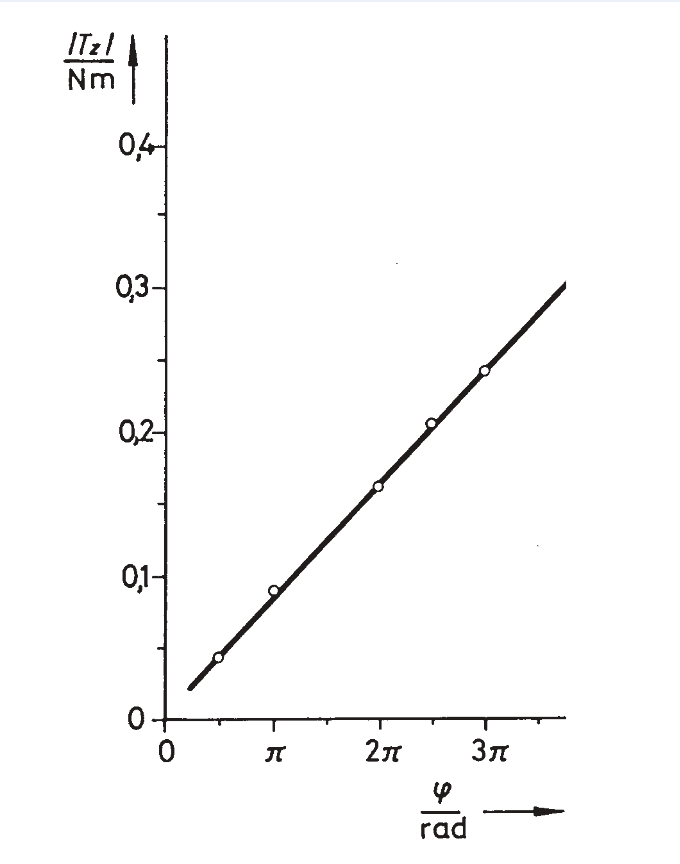
Principle:

The period of vibration of a circular disc which performs torsional vibrations about various parallel axes, is measured. The moment of inertia of the disc is determined as a function of the perpendicular distance of the axis of rotation from the centre of gravity.

What you need:

Rotation axle	02415.01	1
Disk with diametrical holes	02415.07	1
Transparent spring balances, 2 N	03065.03	1
Light barrier with counter	11207.30	1
Power supply 5 V DC/2.4 A with 4 mm plugs	11076.99	1
Tripod base -PASS-	02002.55	1
Barrel base -PASS-	02006.55	1
Rule, plastic, 200 mm	09937.01	1

Complete Equipment Set, Manual on CD-ROM included
Moment of inertia / Steiner's theorem P2132801



Moment (torque) of a spiral spring as a function of the angle of rotation.

Tasks:

1. Determination of the angular restoring constant of the spiral spring.
2. Determination of the moment of inertia of a circular disc as a function of the perpendicular distance of the axis of rotation from the centre of gravity.

1.3.28-11 Moments of inertia of different bodies / Steiner's theorem with Cobra3

What you can learn about ...

- ➔ Rigid body
- ➔ Moment of inertia
- ➔ Centre of gravity
- ➔ Axis of rotation
- ➔ Torsional vibration
- ➔ Spring constant
- ➔ Angular restoring force

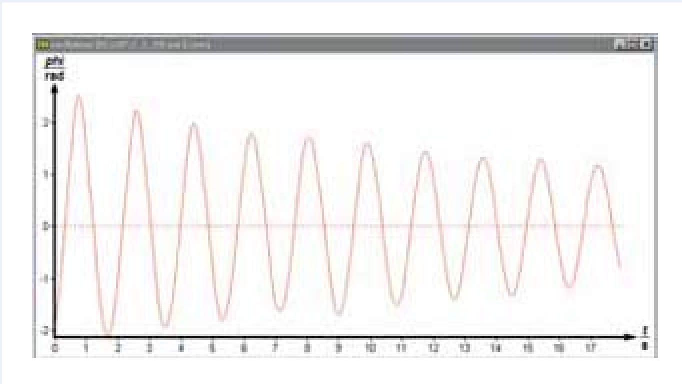
Principle:

The moment of inertia of a solid body depends on its mass distribution and the axis of rotation. Steiner's theorem elucidates this relationship.

What you need:

Cobra3 Basic-Unit, USB	12150.50	1
Power supply 12V/2A	12151.99	1
Software Cobra3, Translation/ Rotation	14512.61	1
Light barrier, compact	11207.20	1
Angular oscillation apparatus	02415.88	1
consisting of:		
Rod with movable masses	02415.06	1
Solid cylinder	02415.05	1
Hollow cylinder	02415.04	1
Disk	02415.03	1
Spehre	02415.02	1
Rotation axle	02415.01	1
Portable Blance, OHAUS CS2000	48892.00	1
Flat cell battery, 9 V	07496.10	1
Silk thread on spool, l = 200 mm	02412.00	1
Weight holder, 1 g, silver bronzing	02407.00	3
Slotted weights, 1 g, polished	03916.00	1
Bench clamp -PASS-	02010.00	1
Tripod base -PASS-	02002.55	1
Stand tube	02060.00	1
Measuring tape, l = 2 m	09936.00	1
Connecting cable, 4 mm plug, 32 A, red, l = 100 cm	07363.01	1
Connecting cable, 4 mm plug, 32 A, blue, l = 100 cm	07363.04	1
Connecting cable, 4 mm plug, 32 A, yellow, l = 100 cm	07363.02	1
PC, Windows® XP or higher		

Complete Equipment Set, Manual on CD-ROM included
Moments of inertia of different bodies / Steiner's theorem with Cobra3 **P2132811**



Typical measuring result

Tasks:

The moments of inertia of different bodies are determined by oscillation measurements. Steiner's theorem is verified.

Torsional vibrations and torsion modulus 1.3.30-00

What you can learn about …

- ➔ Shear modulus
- ➔ Angular velocity
- ➔ Torque
- ➔ Moment of inertia
- ➔ Angular restoring torque
- ➔ G-modulus
- ➔ Modulus of elasticity

Principle:

Bars of various materials will be exciting into torsional vibration. The relationship between the vibration period and the geometrical dimensions of the bars will be derived and the specific shear modulus for the material determined.

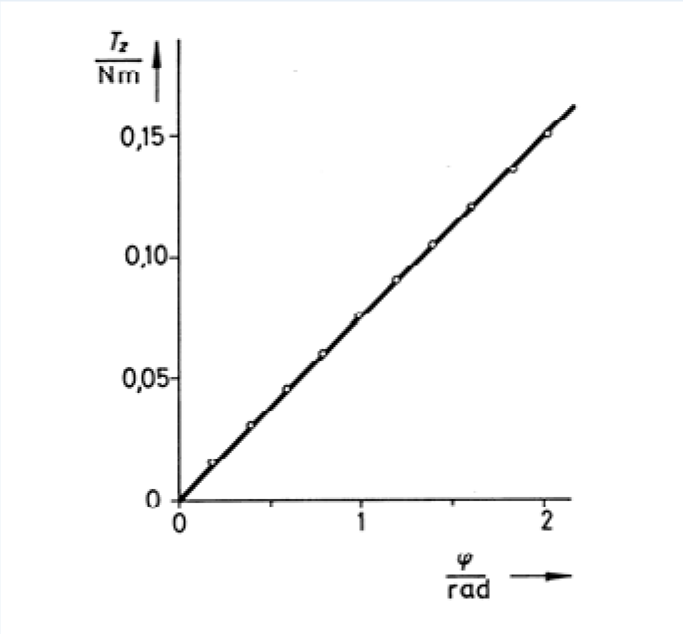
Tasks:

1. Static determination of the torsion modulus of a bar.
2. Determination of the moment of inertia of the rod and weights fixed to the bar, from the vibration period.
3. Determination of the dependence of the vibration period on the length and thickness of the bars.
4. Determination of the shear modulus of steel, copper, aluminium and brass.

What you need:

Torsion apparatus	02421.00	1
Torsion rod, steel, d = 2 mm, l = 500 mm	02421.01	1
Torsion rod, Al, d = 2 mm, l = 500 mm	02421.02	1
Torsion rod, Al, d = 2 mm, l = 400 mm	02421.03	1
Torsion rod, Al, d = 2 mm, l = 300 mm	02421.04	1
Torsion rod, Al, d = 3 mm, l = 500 mm	02421.05	1
Torsion rod, Al, d = 4 mm, l = 500 mm	02421.06	1
Torsion rod, brass, d = 2 mm, l = 500 mm	02421.07	1
Torsion rod, copper, d = 2 mm, l = 500 mm	02421.08	1
Precision spring balance 1 N	03060.01	1
Precision spring balances, 2.5 N	03060.02	1
Stopwatch, digital, 1/100 s	03071.01	1
Sliding weight	03929.00	2
Support base -PASS-	02005.55	1
Support rod -PASS-, square, l = 250 mm	02025.55	1
Support rod -PASS-, square, l = 630 mm	02027.55	1
Right angle clamp -PASS-	02040.55	2

Complete Equipment Set, Manual on CD-ROM included
Torsional vibrations and torsion modulus P2133000



Torque and deflection of a torsion bar.

1.3.31-00 Moment of inertia and torsional vibrations

What you can learn about ...

- → Rigid body
- → Moment of inertia
- → Axis of rotation
- → Torsional vibration
- → Spring constant
- → Angular restoring moment
- → Moment of inertia of a sphere
- → Moment of inertia of a disc
- → Moment of inertia of a cylinder
- → Moment of inertia of a long bar
- → Moment of inertia of 2 point masses

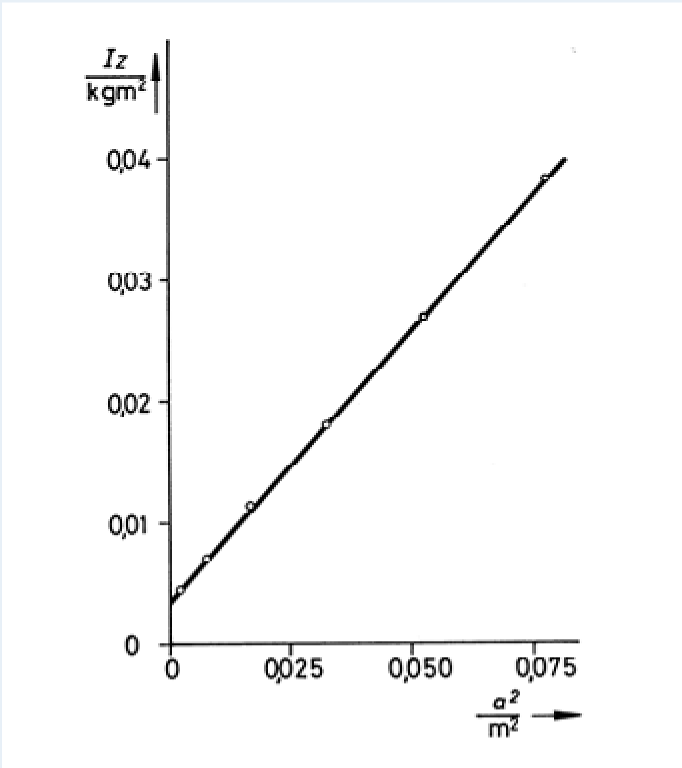
Principle:

Various bodies perform torsional vibrations about axes through their centres of gravity. The vibration period is measured and the moment of inertia determined from this.

What you need:

Rotation axle	02415.01	1
Sphere	02415.02	1
Disk	02415.03	1
Hollow cylinder	02415.04	1
Solid cylinder	02415.05	1
Rod with movable masses	02415.06	1
Precision spring balances, 2.5 N	03060.02	1
Light barrier with counter	11207.30	1
Power supply 5 V DC/2.4 A with 4 mm plugs	11076.99	1
Tripod base -PASS-	02002.55	1
Barrel base -PASS-	02006.55	1

Complete Equipment Set, Manual on CD-ROM included
Moment of inertia and torsional vibrations P2133100



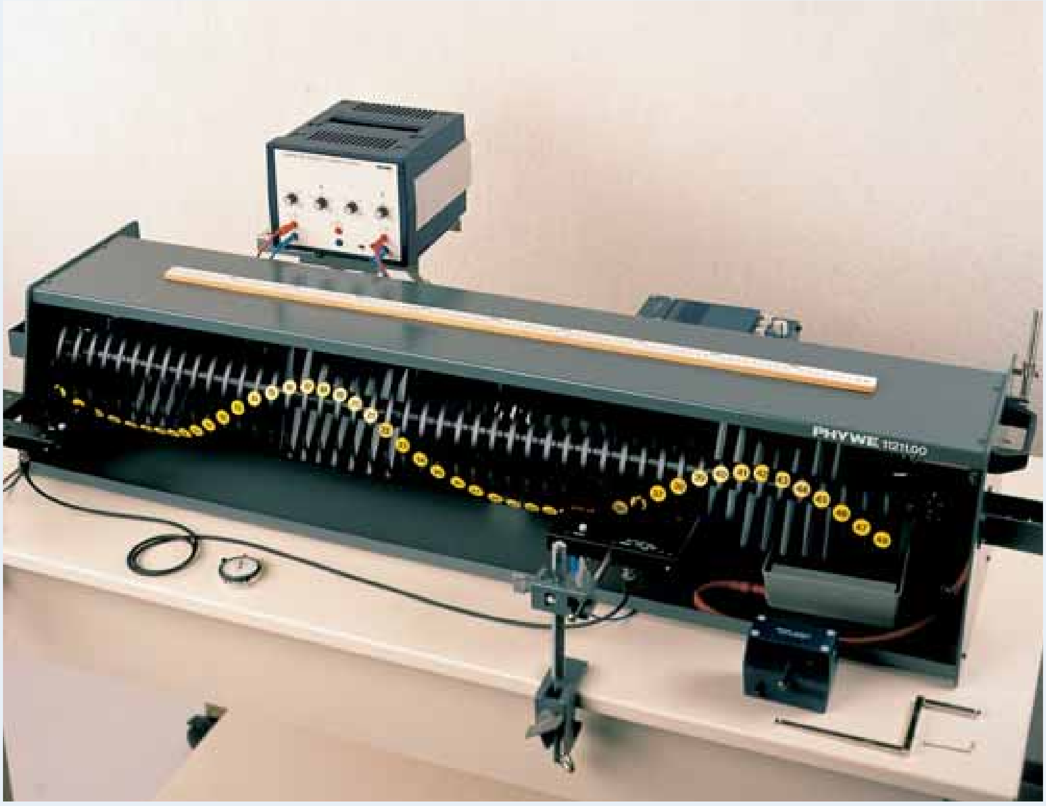
Moment of inertia of two equal masses, of 0.214 kg each, as a function of the distance between them.

Tasks:

The following will be determined:

1. The angular restoring moment of the spiral spring.
2. The moment of inertia
   a) of a disc, two cylinder, a sphere and a bar,
   b) of two point masses, as a function of the perpendicular distance to the axis of rotation. The centre of gravity lies in the axis of rotation.

The propagation of a periodically excited continuous transverse wave 1.3.32-00



What you can learn about …

- → Periodic motion
- → Frequency
- → Wavelength
- → Phase velocity
- → Standing waves
- → Natural frequency
- → Free and fixed end
- → Damping of waves

Principle:

The periodicity of connected stationary oscillators is demonstrated on the example of a continuous, harmonic transverse wave generated by a wave machine. The number of oscillations carried out by different oscillators within a certain time is determined and the velocity of propagation is measured. A relation between frequency, wavelength and phase velocity is established. The formation of standing waves is demonstrated and studied.

What you need:

Wave machine	11211.00	1
Dual power supply 2 x 15 V-/ 2 A	13520.93	1
Light barrier with counter	11207.30	1
Light barrier, compact	11207.20	1
Laboratory motor, 220 VAC	11030.93	1
Gearing 30:1	11029.00	1
Gearing 100:1	11027.00	1
Stopwatch, 15 minutes	03076.01	1
Screened cable, BNC, l = 1500 mm	07542.12	1
Bench clamp -PASS-	02010.00	3
Meter Scale, l = 1000 x 27 mm	03001.00	1
Right angle clamp -PASS-	02040.55	2
Support rod -PASS-, square, l = 400 mm	02026.55	2
Connecting cable, 4 mm plug, 32 A, red, l = 200 cm	07365.01	2
Connecting cable, 4 mm plug, 32 A, blue, l = 200 cm	07365.04	2
Connecting cable, 4 mm plug, 32 A, blue, l = 150 cm	07364.04	1
Connecting cable, 4 mm plug, 32 A, yellow, l = 150 cm	07364.02	1
Adapter, BNC plug/4 mm socket	07542.26	1
Adapter BNC socket/4 mm plug pair	07542.27	1

Complete Equipment Set, Manual on CD-ROM included
The propagation of a periodically excited continuous transverse wave P2133200

f_k Hz	k	$\frac{f_k}{k}$	λ
0.38	1	0.38	$2L/1$
0.74	2	0.37	$2L/2$
0.94	3	0.31	$2L/3$
1.43	4	0.36	$2L/4$

The resonance frequencies measured with increasing speed of rotation.

Tasks:

1. The frequency of the oscillators 1, 10, 20, 30 and 40 is to be determined with the electronic counter of the light barrier and the stopwatch for a particular frequency of excitation.
2. By means of a path-time measurement the phase velocity of a transverse wave is to be determined.
3. For three different frequencies the corresponding wavelengths are to be measured and it is to be shown that the product of frequency and wavelength is a constant.
4. The four lowest natural frequencies with two ends of the oscillator system fixed are to be detected.
5. The four lowest natural frequencies with one end of the oscillator system fixed and the other one free are to be detected.

1.3.33-00 Phase velocity of rope waves

What you can learn about ...

- ➔ Wavelength
- ➔ Phase velocity
- ➔ Group velocity
- ➔ Wave equation
- ➔ Harmonic wave

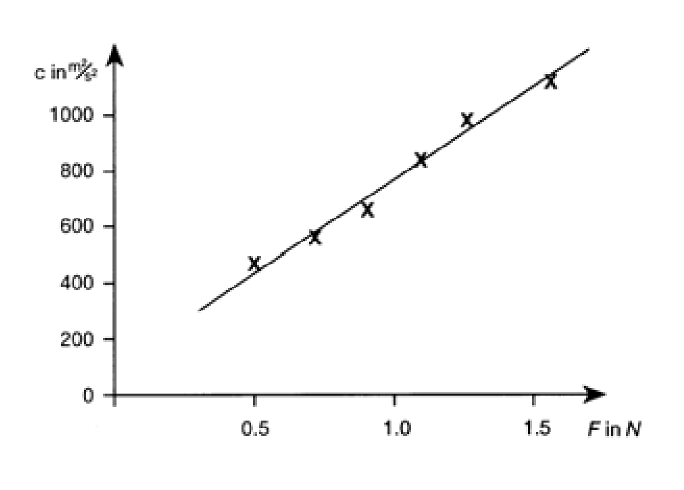
Principle:

A quadrangular rubber rope is inserted through the demonstration motor and a linear polarised fixed wave is generated. With the help of a stroboscope, the frequency and the wave length are determined. Then the phase velocity of rope waves with a fixed tensile stress is ascertained. Subsequently, the mathematical relationship between the phase velocity of the rope and the tensile on the rope is examined.

What you need:

Grooved wheel after Hoffmann	02860.00	1
Square section rubber strip, l = 10 m	03989.00	1
Laboratory motor, 220 VAC	11030.93	1
Gearing 10:1	11028.00	1
Cotton cord, d = 2,5 mm, l = 10 mm	02091.00	1
Support base -PASS-	02005.55	1
Support rod -PASS-, square, l = 250 mm	02025.55	1
Support rod -PASS-, square, l = 1000 mm	02028.55	1
Right angle clamp -PASS-	02040.55	3
Rod with hook	02051.00	2
Pulleys, fixed, on rod, d = 10 mm	02260.00	1
Precision spring balances, 10.0 N	03060.03	1
Bench clamp -PASS-	02010.00	1
Silk thread on spool, l = 200 mm	02412.00	1
Measuring tape, l = 2 m	09936.00	1
Digital stroboscopes	21809.93	1

Complete Equipment Set, Manual on CD-ROM included
Phase velocity of rope waves P2133300



The square of phase velocity depending upon the force F applied on the rope.

Tasks:

1. With constant tensile stress, the frequency f, which depends on the wavelength λ of the wave that propagates itself along the rope. The frequency is plotted as a function of $1/\lambda$. From this graph, the phase velocity c is determined.
2. The phase velocity c of the rope waves, which depends on the tensile stress on the rope is to be measured. The quadrant of the phase velocity is plotted as a function of tensile stress.

Wave phenomena in a ripple tank 1.3.34-00

What you can learn about …

- ➔ Generation of surface waves
- ➔ Propagation of surface waves
- ➔ Dependency of wave velocity
- ➔ Reflection of waves
- ➔ Refraction of waves
- ➔ Concave, convex lenses, mirrors

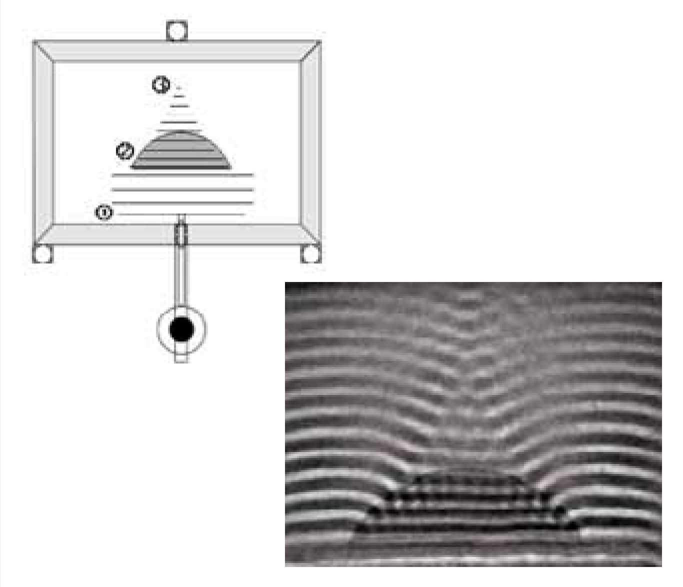
Principle:

In the ripple tank water waves are generated by a vibration generator. Circular waves are then used to investigate the dependency of the vibration frequency on the wavelength. With the aid of plane waves the dependency of the velocity of the waves' propagation on the depth of the water can be determined. Moreover, the reflection of waves as well as the refraction of waves at a plate, a prism, a concave lens and at a convex lens can be clearly demonstrated. It is shown, that water waves are a proved method to demonstrate the behaviour of waves in general.

What you need:

Ripple tank with LED-light source , complete	11260.99	1
External vibration gegerator	11260.10	1
Connecting cord, 32 A, l = 500 mm, red	07361.01	1
Connecting cord, 32 A, l = 500 mm, blue	07361.04	1
Software "Measure Dynamics"	14440.61	1
Optional equipment for demonstration purposes in classes or lectures:		
Demo set for ripple tank (USB-Camera, Fixing unit)	11260.20	1
PC, Windows® XP or higher		
or		
Demo set with mirror for ripple tank	11260.30	1

Complete Equipment Set, Manual on CD-ROM included
Wave phenomena in a ripple tank P2133400



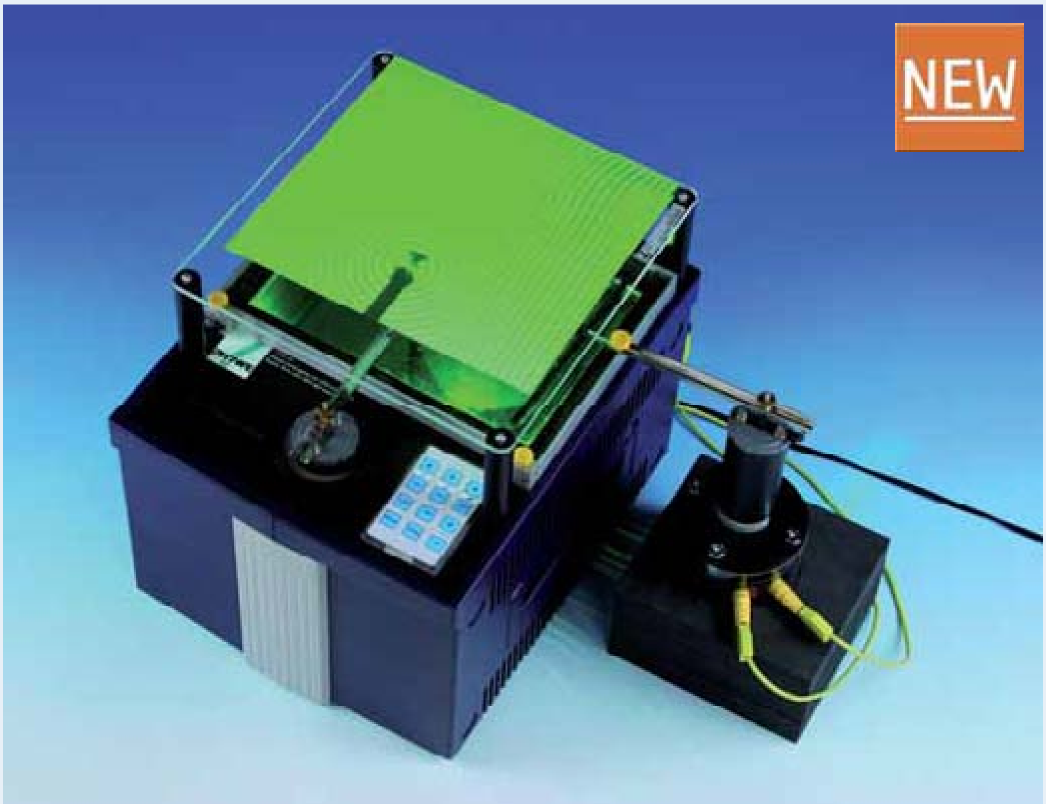
Examination of the behaviour of a concave lens with the ripple tank.

Tasks:

1. Use the single dipper to generate circular waves. By using a ruler the wavelength can be determined. The measurement is made for different frequencies.
2. Plane waves are generated with the integrated wave generator. By using two barriers show the reflection of waves.
3. Use a plate to simulate a zone of lower water depth and measure the wavelength before and above the plate.
4. Observe the refraction of water waves at several objects (plate, prism, concave and convex lens).

Order No. 16040.02

1.3.35-00 Interference and diffraction of water waves with the ripple tank



What you can learn about …
- ➔ Diffraction of water waves
- ➔ Interference of waves
- ➔ Huygens‘ principle
- ➔ Principle of "phased arrays antennas"
- ➔ Doppler effect

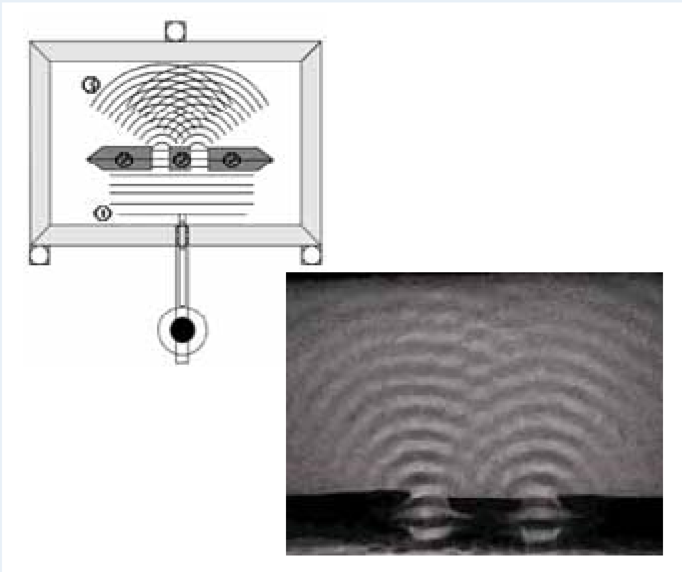
Principle:

Different types of circular water waves are generated simultaneously. The resulting interference is observed. By increasing the number of circular waves which interfere Huygens‘ Principle can be verified. With the aid of plane water waves, diffraction phenomena of waves at different obstacles (slit, edge, double-slit etc.) can be investigated. In another experiment the principle of "phased arrays antennas" can be analysed by generating two circular waves that interfere and by observing the resulting interference on varying the phase of one of the circular waves.

What you need:

Ripple Tank with LED-light source , complete	11260.99	1
External vibration generator for ripple tank	11260.10	1
Connecting cable, 32 A, l = 50 cm, red	07361.01	1
Connecting cable, 32 A, l = 50 cm, blue	07361.04	1
Optional equipment for demonstration purposes in classes or lectures:		
Demo set for Ripple Tank (USB-Camera, Fixing unit)	11260.20	1
PC, Windows® XP or higher		
or		
Demo set with mirror for ripple tank	11260.30	1

Complete Equipment Set, Manual on CD-ROM included
Interference and diffraction of water waves with the ripple tank P2133500



Interference with the double slit.

Tasks:

1. Generate two circular waves and observe the resulting interference. Increase the number of circular waves that interfere up to ten by using all plugs of the "comb". Recognize Huygens‘ Principle by investigating the resulting interference for each case.
2. Generate plane water waves and use a barrier to demonstrate interference and diffraction at an edge. Then form a slit and observe interference and diffraction behind the slit. Repeat this experiment for a double-slit.
3. By using the integrated vibration generator as well as the external vibration generator, generate two circular waves and observe the interference. Vary the phase of the external wave generator with respect to the internal one and observe the resulting interference to understand the principle of "phased arrays antennas".
4. The external wave generator is connected to the water ripple tank and circular waves are generated. By moving the external wave generator the Doppler Effect is visualized.

Order No. 16040.02

Density of liquids 1.4.01-00

What you can learn about …

- ➔ Hydrogen bond
- ➔ H_2O anomaly
- ➔ Volume expansion
- ➔ Melting
- ➔ Evaporation
- ➔ Mohr balance

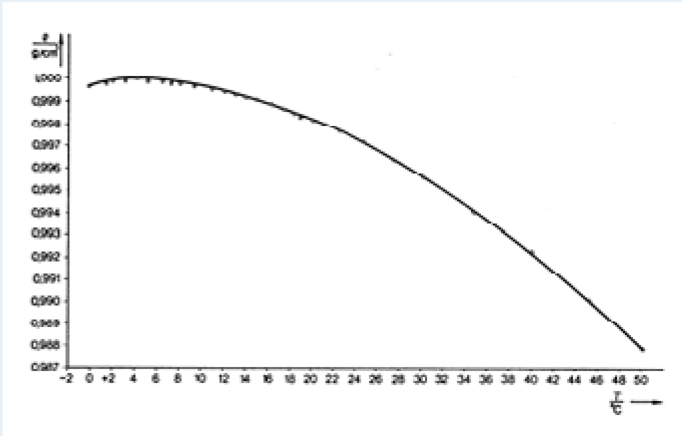
Principle:

The density of water and glycerol is determined as a function of temperature using the Mohr balance.

What you need:

Westphal/Mohr density balance	45016.00	1
Immersion thermostat TC10	08492.93	1
Accessory set for TC10	08492.01	1
Bath for thermostat, Makrolon	08487.02	1
Glycerol, 250 ml	30084.25	2
Water, distilled 5 l	31246.81	1
Sodium chloride, 500 g	30155.50	1

Complete Equipment Set, Manual on CD-ROM included
Density of liquids P2140100



Density of water as a function of temperature.

Tasks:

The density of water and glycerol is measured in 1 to 2° steps over a temperature range from 0 to 20°C, then in larger steps up to 50°C.

1.4.02-00 Surface of rotating liquids

What you can learn about …

- → Angular velocity
- → Centrifugal force
- → Rotary motion
- → Paraboloid of rotation
- → Equilibrium

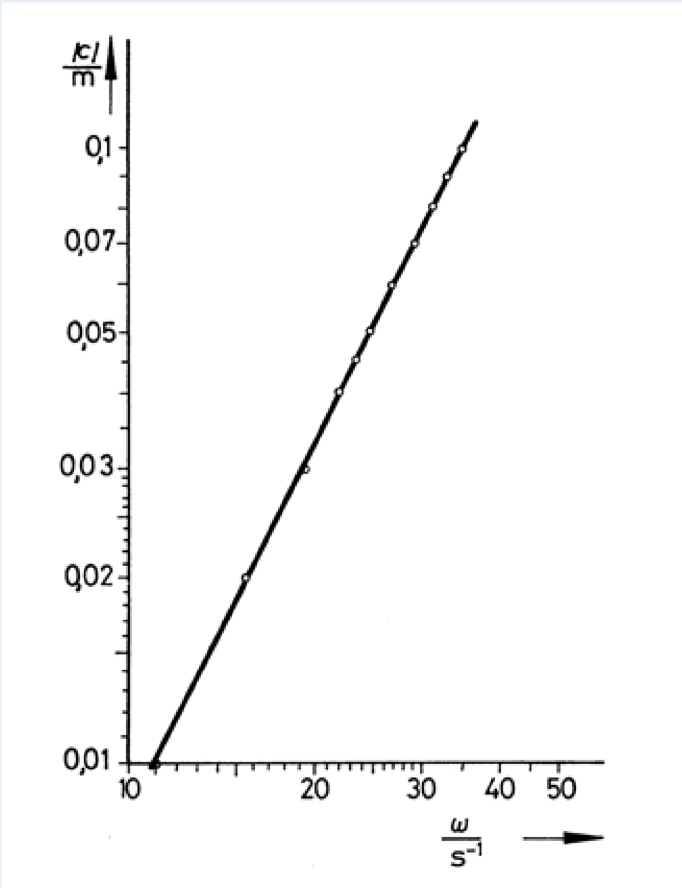
Principle:

A vessel containing liquid is rotated about an axis. The liquid surface forms a paraboloid of rotation, the parameters of which will be determined as a function of the angular velocity.

What you need:

Rotating liquid cell	02536.01	1
Bearing unit	02845.00	1
Driving belt	03981.00	1
Motor with gearing, 12 VDC	11610.00	1
Power supply 0-12 V DC/ 6 V, 12 V AC	13505.93	1
Light barrier with counter	11207.30	1
Power supply 5 V DC/2.4 A with 4 mm plugs	11076.99	1
Bench clamp -PASS-	02010.00	2
Barrel base -PASS-	02006.55	1
Methylene blue sol., alkal. 250 ml	31568.25	1

Complete Equipment Set, Manual on CD-ROM included
Surface of rotating liquids P2140200



Location of the lowest point $|c|$ of the liquid as a function of the angular velocity.

Tasks:

On the rotating liquid surface, the following are determined:

1. the shape,
2. the location of the lowest point as a function of the angular velocity,
3. the curvature.

Viscosity of Newtonian and non-Newtonian liquids (rotary viscometer) 1.4.03-00

What you can learn about …

- ➔ Shear stress
- ➔ Internal friction
- ➔ Viscosity
- ➔ Newtonian liquid
- ➔ **non**-Newtonian liquid

Principle:

The viscosity of liquids is to be determined with a rotary viscometer, in which a variable-speed motor drives a cylinder immersed in the liquid to be investigated via a spiral spring. The viscosity of the liquid generates a moment of rotation at the cylinder which can be measured with the aid of the torsion of the spiral spring and read on a scale.

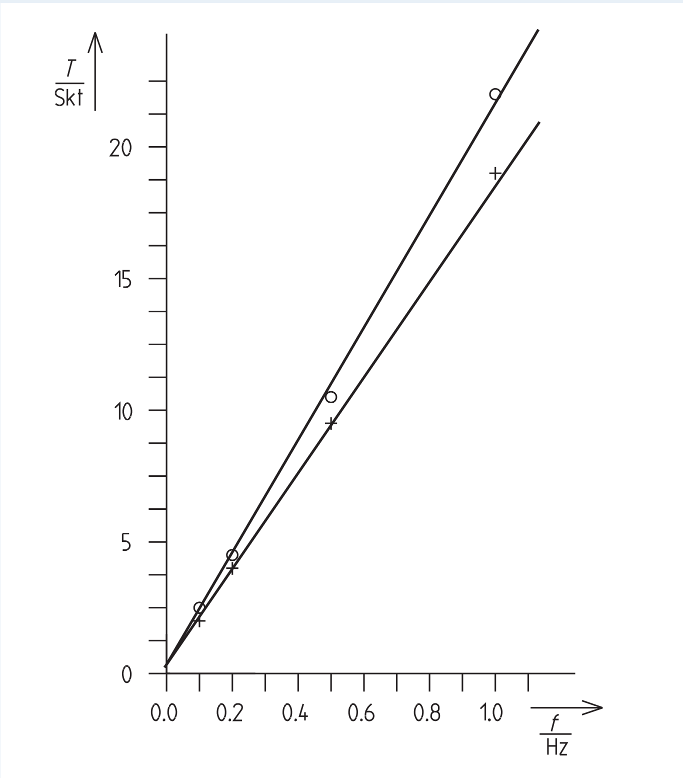
Tasks:

1. Determine the gradient of the rotational velocity as a function of the torsional shearing stress for two Newtonian liquids (glycerine, liquid paraffin).
2. Determine the flow curve for a non-Newtonian liquid (chocolate).
3. Investigate the temperature dependence of the viscosity of Castor oil and glycerine.

What you need:

Rotary viscometer, 3-6,000,000 mPas, 110...240 V	18222.99	1
Right angle clamp	37697.00	1
Support rod, stainless steel, l = 500 mm, M10 thread	02022.20	1
Spring balance holder	03065.20	1
Support rod with hole, l = 100 mm	02036.01	1
Magnetic heating stirrer	35750.93	1
Electronic temperature control	35750.01	1
Magnetic stirrer bar, l = 30mm	46299.02	1
Separator for magnetic bars	35680.03	1
Glass beaker, 600 ml, short	36015.00	3
Glass beaker, 250 ml, tall	36004.00	2
Glass rod, l = 200 mm, d = 5 mm	40485.03	2
Glycerol, 250 ml	30084.25	2
Liquid paraffin, 250 ml	30180.25	1
Castor oil, 250 ml	31799.27	2
Acetone, chem. pure, 250 ml	30004.25	3

Complete Equipment Set, Manual on CD-ROM included
Viscosity of Newtonian and non-Newtonian liquids (rotary viscometer) P2140300



Moment of rotation as a function of the frequency for a Newtonian liquid (+ Glycerine, o Liquid paraffin).

1.4.04-00 Viscosity measurements with the falling ball viscometer

What you can learn about ...

- ➔ Liquid
- ➔ Newtonian liquid
- ➔ Stokes law
- ➔ Fluidity
- ➔ Dynamic and kinematic viscosity
- ➔ Viscosity measurements

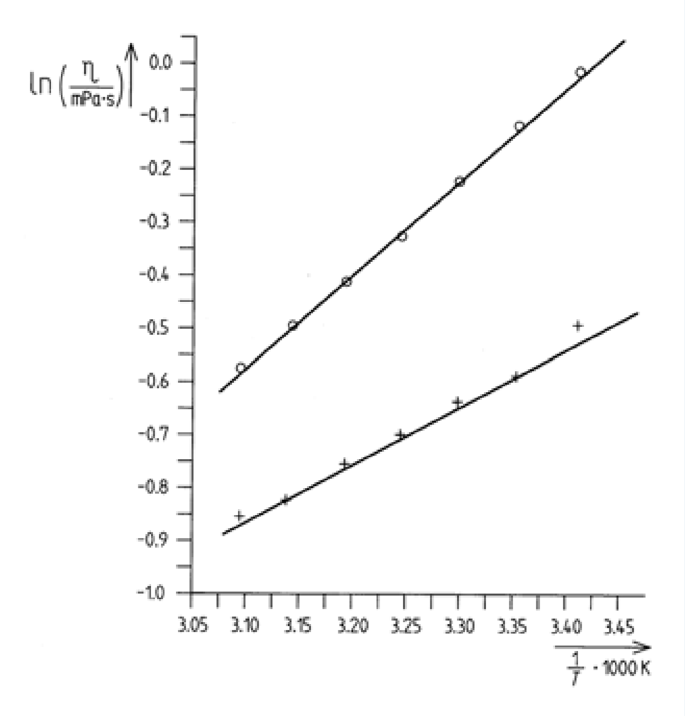
Principle:

Due to internal friction among their particles, liquids and gases have different viscosities. The viscosity, a function of the substance's structure and its temperature, can be experimentally determined, for example, by measuring the rate of fall of a ball in a tube filled with the liquid to be investigated.

What you need:

Falling ball viscosimeter	18220.00	1
Immersion thermostat C10	08492.93	1
Accessory set for TC10	08492.01	1
Bath for thermostat, Makrolon	08487.02	1
Retort stand, h = 750 mm	37694.00	1
Right angle clamp	37697.00	1
Universal clamp with joint	37716.00	1
Pyknometer, 25 ml, calibrated	03023.00	1
Volumetric flasks with standard joint and PP stopper, BORO 3.3, 100 ml	36548.00	9
Beaker, DURAN®, tall form, 150 ml	36003.00	11
Beaker, DURAN®, short form, 250 ml	36013.00	1
Pasteur pipettes, l = 145 ml	36590.00	1
Rubber caps, 10 pcs	39275.03	1
Hose clip, d = 8-12 mm	40996.01	6
Rubber tubing, d_i = 6 mm, l = 1 m	39282.00	6
Stopwatch, digital, 1/100 s	03071.01	1
Set of Precision Balance	49224.88	1
Thermometer	18220.02	1
Wash bottle, plastic, 500 ml	33931.00	2
Methanol 500 ml	30142.50	2
Water, distilled 5 l	31246.81	1

Complete Equipment Set, Manual on CD-ROM included
Viscosity measurements with the falling ball viscometer P2140400



Temperature dependence of the dynamic viscosity η of water (o) and methanol (+), respectively.

Tasks:

Measure the viscosity

1. of methanol-water mixtures of various composition at a constant temperature,
2. of water as a function of the temperature and
3. of methanol as a function of temperature.

From the temperature dependence of the viscosity, calculate the energy barriers for the displaceability of water and methanol.

Surface tension by the ring method (Du Nouy method) 1.4.05-00

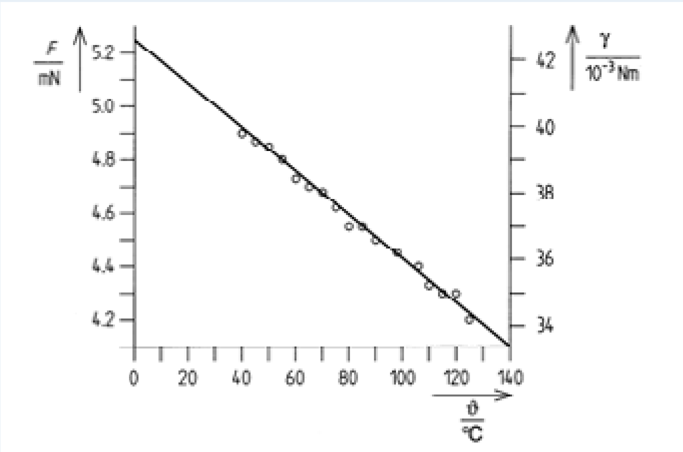
What you can learn about …
- → Surface energy
- → Interface
- → Surface tension
- → Adhesion
- → Critical point
- → Eötvös equation

Principle:
The force is measured on a ring shortly before a liquid film tears using a torsion meter. The surface tension is calculated from the diameter of the ring and the tear-off force.

Tasks:
1. Determine the surface tension of olive oil as a function of temperature.
2. Determine the surface tension of water/methanol mixtures as functions of the mixture ratio.

What you need:

Torsion dynamometer, 0.01 N	02416.00	1
Surface tension measuring ring	17547.00	1
Retort stand, 210 mm x 130 mm, h = 500 mm	37692.00	1
Magnetic stirrer	35750.93	1
Support rod with hole, stainless steel, l = 50 cm, M10 thread	02022.20	1
Magnetic stirring rod, cylindrical, l = 15 mm	46299.01	1
Universal clamp	37715.00	2
Right angle clamp	37697.00	2
Right angle clamp -PASS-	02040.55	1
Crystallizing dishes, BORO 3.3., 1000 ml	46245.00	2
Crystallizing dishes, BORO 3.3., 560 ml	46244.00	2
Laboratory thermometers, -10...+250°C	38065.00	1
Silk thread on spool, l = 200 mm	02412.00	1
Glass tube, AR-glass, straight, d = 8 mm, l = 150 mm, 10 pcs.	36701.64	1
Glass stopcocks, 1 way, straight	36705.00	1
Rubber tubing, d_i = 6 mm, l = 1 m	39282.00	2
Volumetric pipettes, 10 ml	36578.00	1
Volumetric pipettes, 20 ml	36579.00	1
Safety pipettor Flip	36592.00	1
Pipette dish	36589.00	1
Graduated cylinder, BORO 3.3, 100 ml	36629.00	1
Water jet pump, plastic	02728.00	1
Ethyl alcohol, absolute, 500 ml	30008.50	1
Olive oil, pure, 100 ml	30177.10	5
Water, distilled 5 l	31246.81	1



Temperature dependency of surtace tension of olive oil.

Complete Equipment Set, Manual on CD-ROM included
Surface tension by the ring method (Du Nouy method) P2140500

1.4.06-11 Surface tension by the pull-out method with Cobra3

What you can learn about …

- ➔ Surface energy
- ➔ Surface tension
- ➔ Surface adhesion
- ➔ Bounding surface

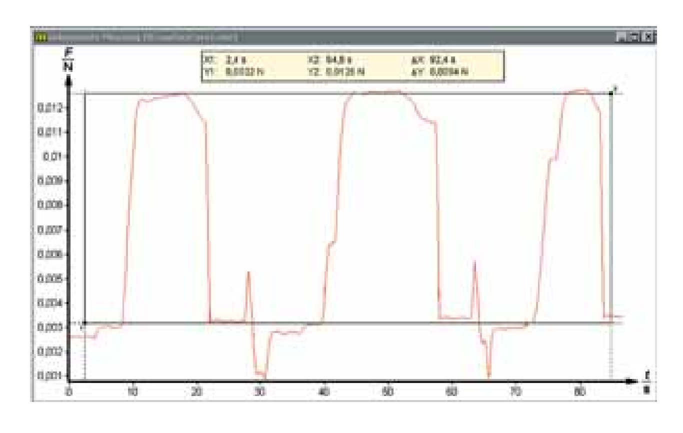
Principle:

The force exerted on a measuring ring shortly before the liquid film is torn away is determined with a force meter. The surface tension is calculated from the diameter of the ring and the tearing force.

What you need:

Surface tension measuring ring	17547.00	1
Cobra3 Basic-Unit, USB	12150.50	1
Power supply 12V/2A	12151.99	1
Software Cobra3 Force/Tesla	14515.61	1
Newton measuring module	12110.00	1
Newton Sensor	12110.01	1
Right angle clamp -PASS-	02040.55	1
Tripod base -PASS-	02002.55	1
Support rod -PASS-, square, l = 250 mm	02025.55	1
Lab jack, 160 x 130 mm	02074.00	1
Petri dishes, d = 200 mm	64796.00	1
PC, Windows® XP or higher		

Complete Equipment Set, Manual on CD-ROM included
Surface tension by the pull-out method with Cobra3 P2140611



Typical measurement values.

Tasks:

Determination of the surface tension of water and other liquids.

Barometric height formula 1.4.07-00

What you can learn about …

- ➔ Kinetic gas theory
- ➔ Pressure
- ➔ Equation of state
- ➔ Temperature
- ➔ Gas constant

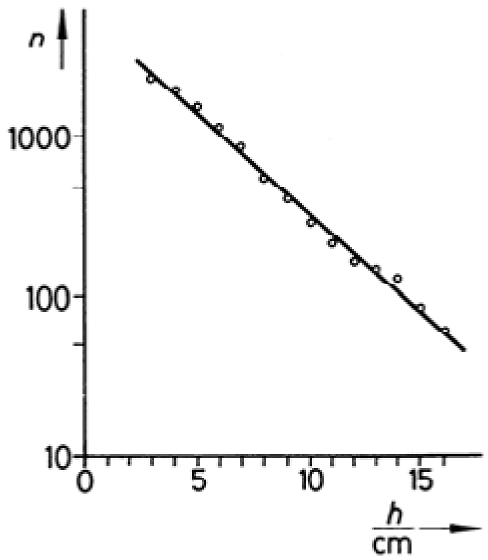
Principle:

Glass or steel balls are accelerated by means of a vibrating plate, and thereby attain different velocities (temperature model). The particle density of the balls is measured as a function of the height and the vibrational frequency of the plate.

What you need:

Kinetic gas theory apparatus	09060.00	1
Variable transformer with rectifier 15 V~/12 V-, 5 A	13530.93	1
Light barrier with counter	11207.30	1
Power supply 5 V DC/2.4 A with 4 mm plugs	11076.99	1
Digital stroboscopes	21809.93	1
Stopwatch, digital, 1/100 s	03071.01	1
Tripod base -PASS-	02002.55	2
Support rod -PASS-, square, l = 400 mm	02026.55	1
Right angle clamp -PASS-	02040.55	1
Connecting cable, 4 mm plug, 32 A, red, l = 75 cm	07362.01	1
Connecting cable, 4 mm plug, 32 A, blue, l = 75 cm	07362.04	1

Complete Equipment Set, Manual on CD-ROM included
Barometric height formula P2140700



Number of steel balls (m = 0.034 g), as a function of the height h, which pass through the volume element ΔV in 30 seconds (vibrational frequency 50 Hz).

Tasks:

Measurement of the particle density as a function of:

1. the height, at fixed frequency
2. the vibrational frequency of the exciting plate, at fixed height.

1.4.08-00 Lift and drag (resistance to flow)

What you can learn about ...

- → Resistance to pressure
- → Frictional resistance
- → Drag coefficient
- → Turbulent flow
- → Laminar flow
- → Reynolds number
- → Dynamic pressure
- → Bernoulli equation
- → Aerofoil
- → Induced resistance
- → Circulation
- → Angle of incidence
- → Polar diagram

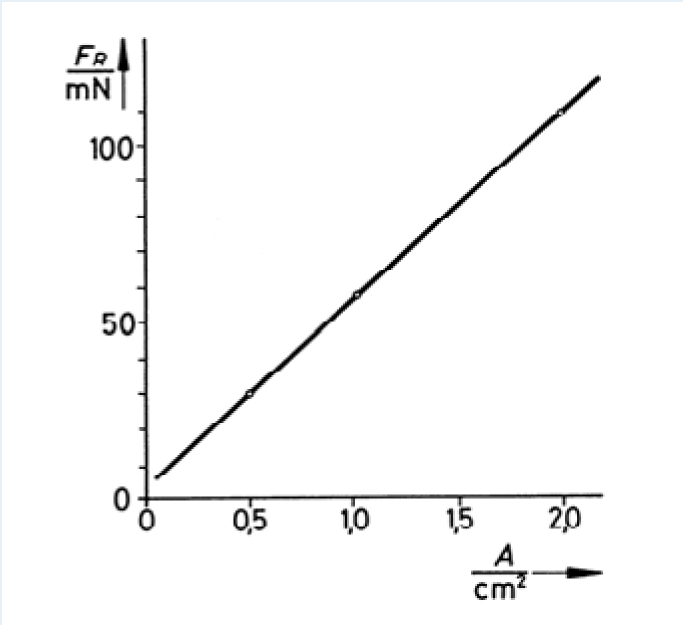
A) Objects of different cross-section and shape are placed in a laminar air stream. The drag is examined as a function of the flow velocity and the geometry of the objects.

B) A rectangular plate or an aerofoil in a stream of air experiences a buoyant force (lift) and a resistance force (drag). These forces are determined in relation to area, rate of flow and angle of incidence.

What you need:

Aerodynamic bodies, set of 14	02787.00	1
Aerofoil model	02788.00	1
Pitot tube, Prandtl type	03094.00	1
Precision manometer	03091.00	1
Holder with bearing points	02411.00	1
Double shaft holder	02780.00	1
Precision pulley	11201.02	1
Transparent spring balances, 0.2 N	03065.01	1
Vernier calipers, stainless steel	03010.00	1
Blower, mains voltage 220 V	02742.93	1
Power regulator	32287.93	1
Pipe probe	02705.00	1
Universal clamp with joint	37716.00	1
Support base -PASS-	02005.55	1
Support rod -PASS-, square, l = 1000 mm	02028.55	1
Barrel base -PASS-	02006.55	1
Right angle clamp -PASS-	02040.55	4
Rod with hook	02051.00	2
Stand tube	02060.00	2
Pointed rod	02302.00	1
Silk thread on spool, l = 200 mm	02412.00	1
Rule, plastic, 200 mm	09937.01	1
Rubber tubing, d_i = 6 mm, l = 1 m	39282.00	1

Complete Equipment Set, Manual on CD-ROM included
Lift and drag (resistance to flow) P2140800



Drag of an object as a function of its cross-sectional area A (q = 0.85 hPa).

Tasks:

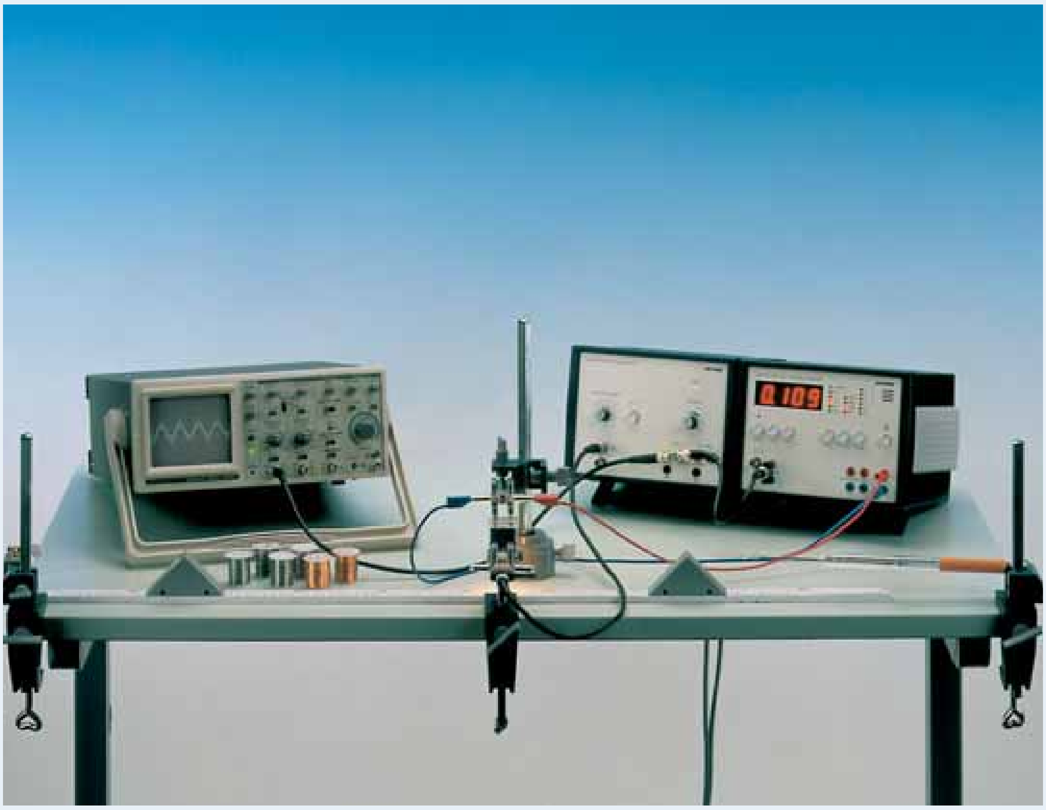
A) Determination of the drag as a function of:

1. the cross-section of different bodies,
2. the flow velocity,
3. determination of the drag coefficients cw for objects of various shape.

B) Determination of the lift and the drag of flat plates as a function of:

1. the plate area
2. the dynamic pressure
3. the angle of incidence (polar diagram)
4. Determination of the pressure distribution over the aerofoil for various angles of incidence.

Vibration of strings 1.5.01-00



What you can learn about …

- ➔ Natural vibration
- ➔ Mass-spring system
- ➔ Harmonic sound intervals

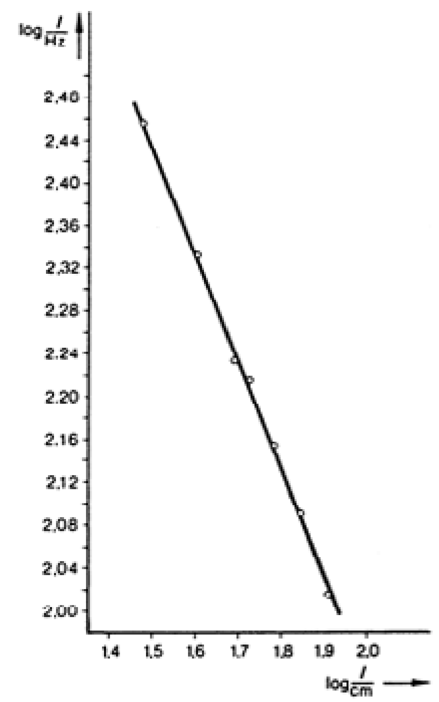
Principle:

A tensioned metal string is made to vibrate. The vibrations of the string are optically scanned, the vibration process observed on the oscilloscope and the dependence of the frequency on the string tension and string length and the density of the material are investigated.

What you need:

String tensioning device with rod	03431.01	1
Nickel wire, d = 0.3 mm	06090.00	1
Kanthal wire, 19.1 Ω/m, d = 0.3 mm, l = 100 m	06092.00	1
Constantan wire, 6.9 Ω/m, d = 0.3 mm	06101.00	1
Constantan wire, 0.98 Ω/m, d = 0.4 mm	06102.00	1
Copper wire, d = 0.4 mm	06106.02	1
Copper wire, d = 0.5 mm	06106.03	1
Barrel base -PASS-	02006.55	1
Bench clamp -PASS-	02010.00	3
Support rod -PASS-, square, l = 250 mm	02025.55	3
Right angle clamp -PASS-	02040.55	3
Rod with hook	02051.00	1
Sign holder	02066.00	2
Fishing line on spool, d = 0,5 mm, l = 100 mm	02090.00	1
Meter Scale, l = 1000 x 27 mm	03001.00	1
Precision spring balances, 100.0 N	03060.04	1
Striking hammer	03429.00	1
Photoelement for optical base plate	08734.00	1
Lamp socket E 10, G1	17049.00	1
Filament lamps, 6 V/0.5 A	35673.03	1
Distributor	06024.00	2
Oscilloscope 30 MHz, 2 channels	11459.95	1
LF amplifier, 220 V	13625.93	1
Universal counter	13601.99	1
Plug with push-on sleeve	07542.04	1
Adapter, BNC socket - 4 mm plug	07542.20	1
Adapter, BNC plug/4 mm socket	07542.26	2
T type connector, BNC, socket, socket, plug	07542.21	1
Adapter BNC socket/4 mm plug pair	07542.27	1
Screened cable, BNC, l = 750 mm	07542.11	1
Screened cable, BNC, l = 30 cm	07542.10	1
Connecting cable, 4 mm plug, 32 A, red, l = 75 cm	07362.01	1
Connecting cable, 4 mm plug, 32 A, blue, l = 75 cm	07362.04	1

Complete Equipment Set, Manual on CD-ROM included
Vibrations of strings P2150100



Fundamental frequency f as a function of string length l at a given tensioning force F = 30 N.

Tasks:

1. To measure the frequency of a string (e.g. constantan, 0.4 mm dia.) as a function of the tensioning force and the length of the string.
2. To measure the frequency for various types and cross-sections of string, at a fixed tension and string length.

1.5.03-11 Velocity of sound in air with Cobra3

What you can learn about …

- ➔ Linear relationship between the propagation time of sound and its respective path
- ➔ Longitudinal waves
- ➔ Velocity of sound

Principle:

The speed of sound in air is determined by measurements of sound travel times.

What you need:

Cobra3 Basic-Unit, USB	12150.50	1
Power supply 12V/2A	12151.99	1
Software Cobra3, Timer/Counter	14511.61	1
Measuring microphone with amplifier	03543.00	1
Flat cell battery, 9 V	07496.10	1
Support rod with hole, stainless steel, l = 10 cm	02036.01	2
Support	09906.00	1
Barrel base -PASS-	02006.55	2
Measuring tape, l = 2 m	09936.00	1
Connecting cable, 4 mm plug, 32 A, red, l = 75 cm	07362.01	1
Connecting cable, 4 mm plug, 32 A, blue, l = 75 cm	07362.04	1
Connecting cable, 4 mm plug, 32 A, red, l = 25 cm	07360.01	1
Connecting cable, 4 mm plug, 32 A, blue, l = 25 cm	07360.04	1
PC, Windows® XP or higher		

Complete Equipment Set, Manual on CD-ROM included
Velocity of sound in air with Cobra3 P2150311

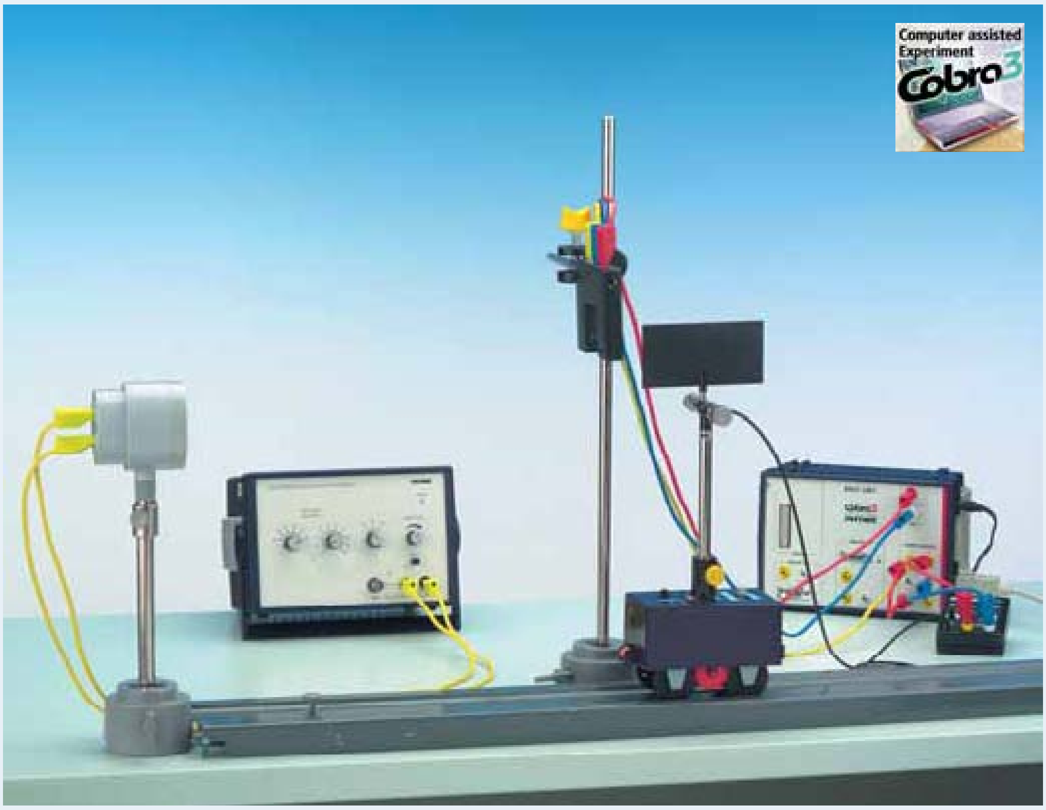
v /(m/s)
338.448
338.438
338.753
337.230
337.258

Table 1

Tasks:

Determination of the velocity of sound in air.

Acoustic Doppler effect 1.5.04-11



What you can learn about …

- → Propagation of sound waves
- → Doppler shift of frequency

Principle:

If a source of sound is in motion relative to its medium of propagation, the frequency of the waves that are emitted is displaced due to the Doppler effect.

What you need:

Measuring microphone	03542.00	1
Flat cell battery, 9 V	07496.10	1
Loudspeaker/Sound head	03524.00	1
Car, motor driven	11061.00	1
Attachment for car	11061.02	1
Battery cell, 1.5 V, baby size, type C	07922.01	2
Barrel base -PASS-	02006.55	2
Stand tube	02060.00	1
Connecting cable, 4 mm plug, 32 A, yellow, l = 100 cm	07363.02	1
1 Track, l = 900 mm	11606.00	1
Connecting cord, 32 A, l = 1500 mm, red	07364.01	1
Connecting cable, 4 mm plug, 32 A, red, l = 10 cm	07359.01	1
Cobra3 Basic-Unit, USB	12150.50	1
Power supply 12V/2A	12151.99	1
Software Cobra3, Timer/Counter	14511.61	1
Function generator	13652.93	1
Plug with socket and crosshole, 2 pcs.	07206.01	1
Diaphragm, l = 100 mm	11202.03	1
Support rod, stainless steel 18/8, l = 600 mm	02037.00	1
Light barrier, compact	11207.20	1
Bosshead	02043.00	1
Support	09906.00	1
Connecting cable, 4 mm plug, 32 A, red, l = 100 cm	07363.01	2
Connecting cable, 4 mm plug, 32 A, blue, l = 100 cm	07363.04	2
Adapter BNC socket/4 mm plug pair	07542.27	1
Double socket, pair red and black	07264.00	1
Spring balance holder	03065.20	1
PC, Windows® XP or higher		

Complete Equipment Set, Manual on CD-ROM included
Acoustic Doppler effect P2150411

	Movement toward the sound source	Movement away from the sound source
v /m/s	0.162	0.157
v /m/s	0.159	0.156
v /m/s	0.158	0.157
v /m/s	0.159	0.156
Mean /m/s	0.160	0.157
Mean $f_{measured}$/Hz	16199	16184
$f_{calculated}$/Hz	16199.6	16184.5

Table

Tasks:

The frequency changes are measured and analysed for different relative velocities of source and observer.

1.5.05-15 Chladni figures with FG-Module

What you can learn about …
- Wavelength
- Stationary waves
- Natural vibrations
- Two-dimensional standing waves

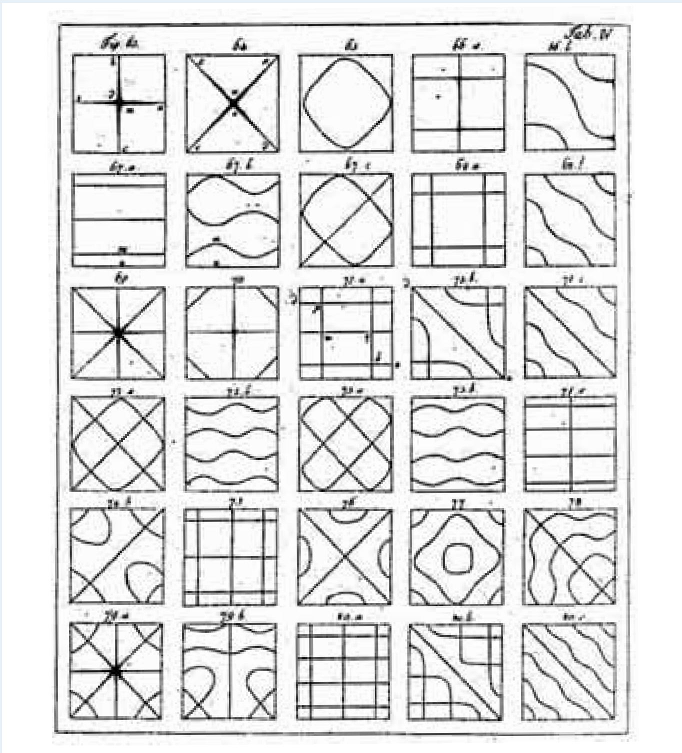
Principle:

To show the two-dimensional standing waves on the surface of a square or circular plate.

What you need:

Cobra3 Basic-Unit, USB	12150.50	1
Power supply 12V/2A	12151.99	2
Software Cobra3 PowerGraph	14525.61	1
Measuring module Function Generator	12111.00	1
LF amplifier, 220 V	13625.93	1
Loudspeaker/Sound head	03524.00	1
Sound pattern plates	03478.00	1
Support base, variable	02001.00	1
Bosshead	02043.00	1
Support rod, stainless steel 18/8, l = 250 mm, d = 10 mm	02031.00	1
Stand tube	02060.00	1
Adapter BNC socket/4 mm plug pair	07542.27	1
Screened cable, BNC, l = 750 mm	07542.11	1
Connecting cable, 4 mm plug, 32 A, red, l = 50 cm	07361.01	1
Connecting cable, 4 mm plug, 32 A, blue, l = 50 cm	07361.04	1
PC, Windows® XP or higher		

Complete Equipment Set, Manual on CD-ROM included
Chladni figures with FG-Module P2150515



Two dimensional oscillation of quadratic plates.

Tasks:

A frequency generator is connected to a sound head. The sound head drives a Chaldni plate. White sand is sprinkled randomly to cover the entire black surface of the plate.
Drive the plate at a predetermined harmonic frequency and the sand will migrate into the nodal regions. A well defined standing wave pattern can be clearly seen in the first photo. The circular and square Chladni plates will create characteristic patterns. Adjust the oscillator slowly in the 0.2 to 2 kHz frequency range and watch for the pattern to emerge when a harmonic is tuned.

Velocity of sound using Kundt's tube   1.5.06-01/15

Set-up of experiment P2150615 with FG-Module

What you can learn about ...

- ➔ Longitudinal waves
- ➔ Sound velocity in gases and solids
- ➔ Frequency
- ➔ Wavelength
- ➔ Stationary waves
- ➔ Natural vibrations

Principle:

A metal rod is made to vibrate longitudinally by rubbing it with a cloth. The gas column in a glass tube is caused to vibrate naturally as a result of resonance, through the radiation of sound from a disc attached to the end of the rod.

The ratio of the velocities of sound in the gas and in the vibration generator is determined by measuring the wavelength.

What you need:

		Exp. P2150601 with vibration generator	Experiment P2150615 with FG-Module
Cobra3 Basic-Unit, USB	12150.50		1
Power supply 12V/2A	12151.99		2
Software Cobra3 PowerGraph	14525.61		1
Measuring module Function Generator	12111.00		1
LF amplifier, 220 V	13625.93		1
Loudspeaker/Sound head	03524.00		1
Support base, variable	02001.00		1
Adapter BNC socket/4 mm plug pair	07542.27		1
Screened cable, BNC, l = 750 mm	07542.11		1
Connecting cable, 4 mm plug, 32 A, red, l = 50 cm	07361.01		1
Connecting cable, 4 mm plug, 32 A, blue, l = 50 cm	07361.04		1
Glass tubes, AR-glass, d = 38 mm, l = 640 mm	03918.00	1	1
Cork powder, 3 g	03477.00	1	1
Universal clamp	37718.00	4	2
Charging strip	03474.01	1	
Tuning piston	03474.02	1	
Vibration generator, brass	03476.01	1	
Vibration generator, steel	03476.02	1	
Lycopodium powder, 10 g	02715.00	1	
Laboratory thermometers, -10...+ 30°C	05949.00	1	
Bench clamp -PASS-	02010.00	4	
Meter Scale, l = 1000 x 27 mm	03001.00	1	
Pressure-reducing valves, CO_2 / He	33481.00	1	
Steel cylinders, carbon dioxide, 10 l	41761.00	1	
Wrench for steel cylinders	40322.00	1	
Glass tube, AR-glass, straight, d = 8 mm, l = 80 mm, 10 pcs.	36701.65	1	
Rubber stopper, d = 38/31 mm, 1 hole, d = 7 mm	39260.01	1	
Rubber tubing, d_i = 6 mm, l = 1 m	39282.00	1	
PC, Windows® XP or higher			

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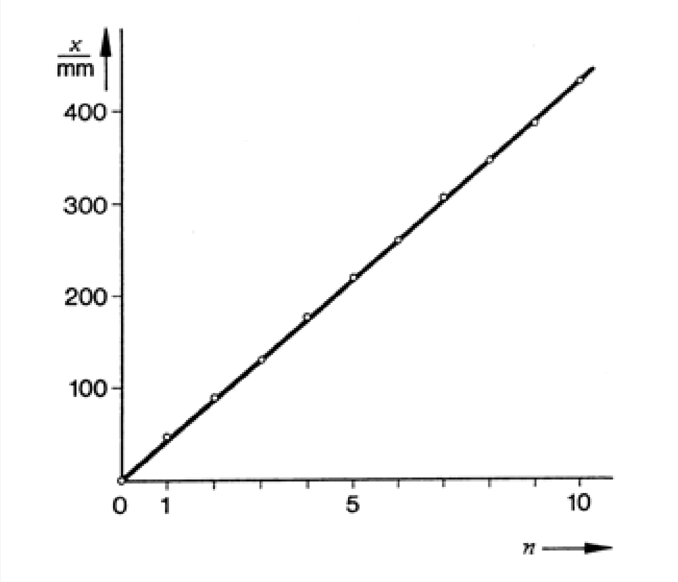
Velocity of sound using Kundt's tube   P21506 01/15



Positions of the vibration nodes as a function of the number of nodes.

Tasks:

1. To measure the wavelength of stationary waves using a steel or a brass rod as the vibration generator. The longitudinal velocity of sound in the material of the vibration generator is determined, given the velocity of sound in air.
2. To measure the wavelength for CO_2, and to determine the sound velocity in CO_2 from the ratios of the wavelengths in air determined in 1. above.

1.5.07-01/15 Wavelengths and frequencies with a Quincke tube

Set-up of experiment P2150715 with FG-Module

What you can learn about ...

- → Transverse and longitudinal waves
- → Wavelength
- → Ampli tude
- → Frequency
- → Phase shift
- → Interference
- → Velocity of sound in air
- → Loudness
- → Weber-Fechner law

Principle:

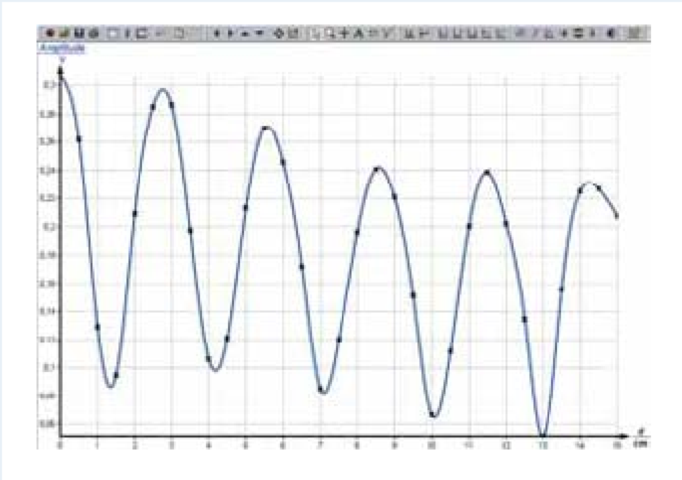
If a sound wave of a particular frequency is divided into two coherent components (like, for example, light waves in an interferometer experiment), and if the path of one of the component waves is altered, it is possible to calculate the wavelength of the sound wave and its frequency from the interference phenomena recorded with a microphone.

What you need:

		Experiment P2150701 with multimeter	Experiment P2150715 with FG-Module
Interference tube, Quincke type	03482.00	1	1
Measuring microphone	03542.00	1	
Power frequency generator, 1 MHz	13650.93	1	
Digital multimeter 2010	07128.00	1	
Adapter BNC socket/4 mm plug pair	07542.27	1	
Loudspeaker/Sound head	03524.00	1	1
Vernier calipers, stainless steel	03010.00	1	1
Connecting cable, 4 mm plug, 32 A, blue, l = 150 cm	07364.04	1	1
Connecting cable, 4 mm plug, 32 A, red, l = 150 cm	07364.01	1	1
Support base -PASS-	02005.55	1	1
Support rod -PASS-, square, l = 630 mm	02027.55	2	2
Right angle clamp -PASS-	02040.55	5	5
Cobra3 Basic-Unit, USB	12150.50		1
Power supply 12V/2A	12151.99		2
Measuring module Function Generator	12111.00		1
Software Cobra3 PowerGraph	14525.61		1
LF amplifier, 220 V	13625.93		1
Connection box	06030.23		1
Carbon resistor 10 Ω, 1W, G1	39104.01		1
Measuring microphone with amplifier	03543.00		1
Support	09906.00		1
Connecting cable, 4 mm plug, 32 A, red, l = 50 cm	07361.01		1
Connecting cable, 4 mm plug, 32 A, blue, l = 50 cm	07361.04		1
Connecting cable, 4 mm plug, 32 A, red, l = 10 cm	07359.01		1
PC, Windows® XP or higher			

Complete Equipment Set, Manual on CD-ROM included

Wavelengths and frequencies with a Quincke tube P21507 01/15



Interference of sound waves in a Quincke tube. Sound amplitude as a function of the displacement d.

Tasks:

1. Record of the extension of a Quincke tube for given frequencies in the range 2000 Hz to 6000 Hz.
2. Calculation of the frequencies from the wavelengths determined, comparison with the given frequencies.

Resonance frequencies of Helmholtz resonators with Cobra3 1.5.08-11

What you can learn about …

- → Cavity resonator
- → Resonance frequency
- → Acoustic resonant circuit

Principle:

Acoustic cavity resonators posses a characteristic frequency which is determined by their geometrical form. In this case the resonator is excited to vibrations in its resonance frequency by background noise.

What you need:

Cobra3 Basic-Unit, USB	12150.50	1
Power supply 12V/2A	12151.99	1
Software Cobra3 Fourier Analysis	14514.61	1
Measuring microphone with amplifier	03543.00	1
Flat cell battery, 9 V	07496.10	1
Glass tubes, AR-glass, d = 12 mm, l = 300 mm	45126.01	1
Tripod base -PASS-	02002.55	1
Support rod, stainless steel 18/8, l = 500 mm	02032.00	1
Universal clamp	37718.00	2
Bosshead	02043.00	2
Measuring tape, l = 2 m	09936.00	1
Long-neck round-bottom flask, 1000 ml	36050.00	1
Long-neck round-bottom flask, 1000 ml	36046.00	1
Connecting cable, 4 mm plug, 32 A, blue, l = 50 cm	07361.04	1
Connecting cable, 4 mm plug, 32 A, red, l = 50 cm	07361.01	1
PC, Windows® XP or higher		

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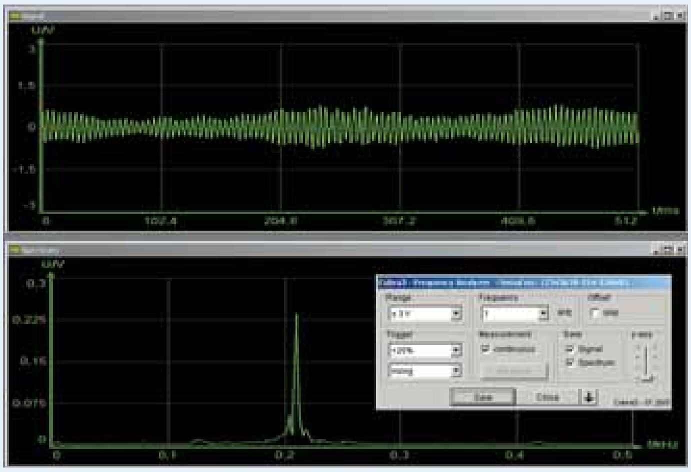
Resonance frequencies of Helmholtz resonators with Cobra3 P2150811



Time signal, spectrum and parameter settings for measurements on the empty 1000 ml round-bottomed flask.

Tasks:

Determination of different resonance frequencies of a resonator depending on the volume.

1.5.09-11 Interference of acoustic waves, stationary waves and diffraction at a slot with Cobra3

What you can learn about ...

- → Interference
- → Reflection
- → Diffraction
- → Acoustic waves
- → Stationary waves
- → Huygens-Fresnel principle
- → Use of an interface

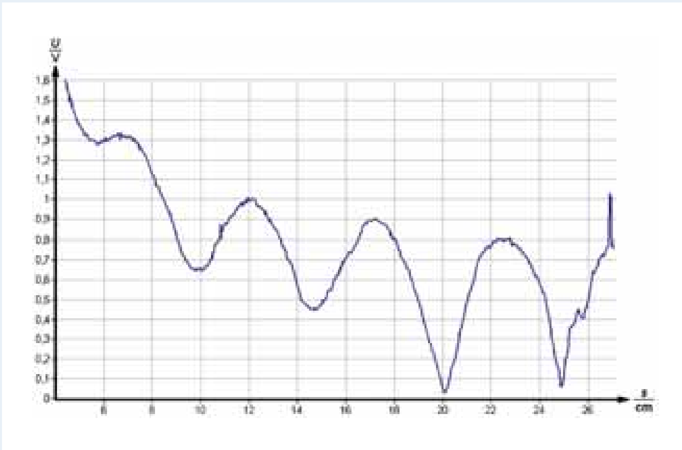
Principle:

- – Two acoustic sources emit waves of the same frequency and if their distance is a multiple of the wave-length, an interference structure becomes apparent in the space where the waves are super imposed.
- – An acoustic wave impinges perpendicularly onto a reflector, the incident and the reflected wave are super imposed to a stationary wave. In case of reflection, a pressure antinode will always occur at the point of reflection.
- – An acoustic wave impinges on a sufficiently narrow slot, it is diffracted into the geometrical shadow spaces. The diffraction and the interference pattern occurring behind the slot can be explained by means of the Huygens-Fresnel principle and confirm the wave characteristics of sound.

What you need:

Loudspeaker/Sound head	03524.00	2
Measuring microphone	03542.00	1
Flat cell battery, 9 V	07496.10	1
Screen, metal, 300 mm x 300 mm	08062.00	2
Function generator	13652.93	1
Right angle clamp -PASS-	02040.55	1
Stand tube	02060.00	4
Barrel base -PASS-	02006.55	4
Bench clamp -PASS-	02010.00	1
Plate holder, opening width 0...10 mm	02062.00	1
Meter Scale, l = 1000 x 27 mm	03001.00	1
Silk thread on spool, l = 200 mm	02412.00	1
Weight holder, 1 g, silver bronzing	02407.00	1
Connecting cable, 4 mm plug, 32 A, red, l = 100 cm	07363.01	1
Connecting cable, 4 mm plug, 32 A, blue, l = 100 cm	07363.04	1
Movement sensor with cable	12004.10	1
Adapter BNC socket/4 mm plug pair	07542.27	2
Adapter, BNC socket - 4 mm plug	07542.20	1
Power supply 12V/2A	12151.99	1
Cobra3 Basic-Unit, USB	12150.50	1
Software Cobra3 Force/Tesla	14515.61	1
Connecting cable, 4 mm plug, 32 A, red, l = 50 cm	07361.01	1
Connecting cable, 4 mm plug, 32 A, blue, l = 50 cm	07361.04	1
PC, Windows® XP or higher		

Complete Equipment Set, Manual on CD-ROM included
Interference of acoustic waves, stationary waves and diffraction at a slot with Cobra3 P2150911



Measurement example, stationary waves.

Tasks:

1. To measure the interference of acoustic waves.
2. To analyze the reflection of acoustic waves – stationary waves.
3. To measure the diffraction at a slot of acoustic waves.

Optical determination of velocity of sound in liquids 1.5.10-00

What you can learn about ...

- ➔ Ultrasonics
- ➔ Sound velocity
- ➔ Frequency
- ➔ Wavelength
- ➔ Sound pressure
- ➔ Stationary waves
- ➔ Debye-Sears effect

Principle:

A stationary ultrasonic wave in a glass cell full of liquid is traversed by a divergent beam of light. The sound wavelength can be determined from the central projection of the sound field on the basis of the refractive index which changes with the sound pressure.

What you need:

Ultrasonic generator	13920.99	1
Laser, He-Ne 1.0 mW, 230 VAC	08181.93	1
Glass cell, 150 x 55 x 100 mm	03504.00	1
Lens holder	08012.00	1
Lens, mounted, f = +20 mm	08018.01	1
Screen, metal, 300 mm x 300 mm	08062.00	1
Optical profile bench, l = 1000 mm	08282.00	1
Base for optical profile bench, adjustable	08284.00	2
Slide mount for optical profil bench, h = 80 mm	08286.02	1
Slide mount for optical profil bench, h = 30 mm	08286.01	4
Swinging arm	08256.00	1
Table top on rod	08060.00	1
Laboratory thermometers, -10...+ 30°C	05949.00	1
Right angle clamp -PASS-	02040.55	1
Support rod, stainless steel 18/8, l = 250 mm, d = 10 mm	02031.00	1
Universal clamp	37718.00	1
Glycerol, 250 ml	30084.25	3
Water, distilled 5 l	31246.81	1

Complete Equipment Set, Manual on CD-ROM included
Optical determination of velocity of sound in liquids P2151000

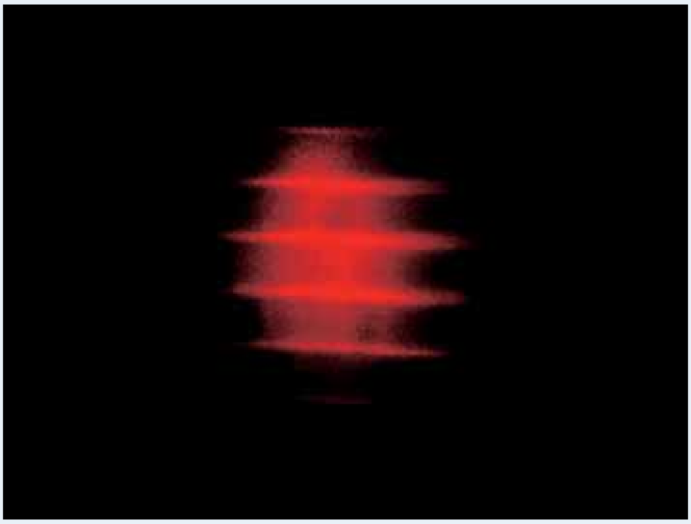


Image of a screen.

Tasks:

To determine the wavelength of sound in liquids, and from this calculate the sound velocity, from the structure of the centrally projected image.

1.5.11-00 Phase and group velocity of ultrasonics in liquids

What you can learn about …

- ➔ Longitudinal waves
- ➔ Velocity of sound in liquids
- ➔ Wavelength
- ➔ Frequency
- ➔ Piezo electric effect
- ➔ Piezo electric ultrasonics transformer

Principle:

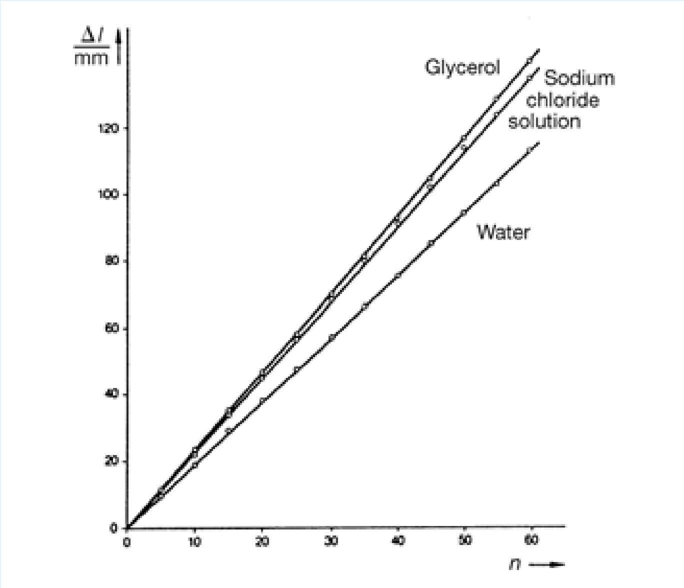
The sound waves transmitted to a liquid by the ultrasonic generator are picked up by a piezo electric ultrasonic pick-up and the signal from transmitter and receiver compared on an oscilloscope.

The wavelength is determined and the phase velocity calculated from the relative phase position of the signals. The group velocity is determined from measurements of the sound pulse delay time.

What you need:

Ultrasonic pickup	13920.00	1
Ultrasonic generator	13920.99	1
Glass cell, 150 x 55 x 100 mm	03504.00	1
Insulating support	07924.00	1
Optical profile bench, l = 600 mm	08283.00	1
Base for optical profile bench, adjustable	08284.00	2
Slide mount for optical profil bench, h = 30 mm	08286.01	2
Slide mount for optical profil bench, h = 80 mm	08286.02	1
Table top on rod	08060.00	1
Swinging arm	08256.00	1
Right angle clamp -PASS-	02040.55	1
Support rod, stainless steel 18/8, l = 500 mm	02032.00	1
Universal clamp	37718.00	1
Oscilloscope 30 MHz, 2 channels	11459.95	1
Connecting cable, 4 mm plug, 32 A, red, l = 10 cm	07359.01	1
Screened cable, BNC, l = 750 mm	07542.11	2
Adapter BNC socket/4 mm plug pair	07542.27	1
Laboratory thermometers, -10...+ 30°C	05949.00	1
Glycerol, 250 ml	30084.25	3
Sodium chloride, 500 g	30155.50	1
Water, distilled 5 l	31246.81	1

Complete Equipment Set, Manual on CD-ROM included
Phase and group velocity of ultrasonics in liquids P2151100



Detector displacement Δl as a function of the number n of wavelengths covered, for water, glycerol and sodium chloride solution (temperature ϑ = 25 °C).

Tasks:

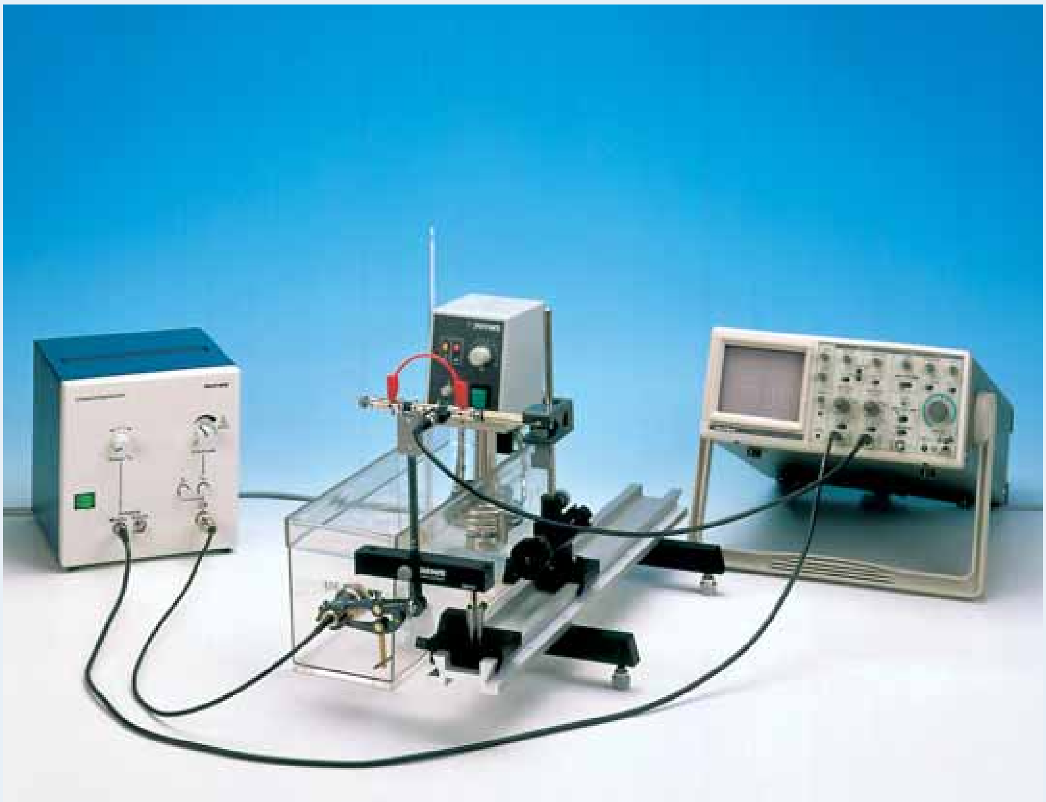
The signals from the ultrasonic generator and the ultrasonic pick-up are recorded on the oscilloscope.

1. To measure the relative phase position of the signal from the ultrasonic pick-up as a function of its distance from the ultrasonic generator (which is in the sine mode), and to determine the ultrasonic wavelength and the phase velocity when the frequency is known.

2.1. To determine the oscilloscope's coefficient of sweep with the aid of the ultrasonic frequency.

2.2. With the generator in the pulsed mode, to record the delay time of the sound pulses as a function of the distance between a generator and the pick-up, and to determine the group velocity.

Temperature dependence of the Velocity of sound in liquids 1.5.12-00



What you can learn about ...

- → Wavelength
- → Frequency
- → Velocity of sound in liquids
- → Compressibility
- → Density
- → Ultrasonics
- → Piezoelectric effect
- → Piezoelectric ultrasonic transducer

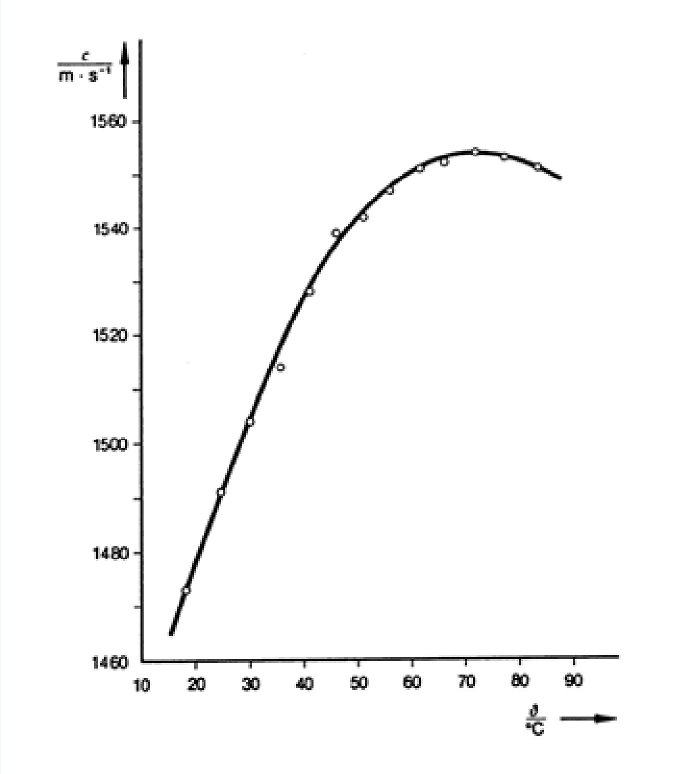
Principle:

Sound waves are radiated into a liquid by an ultrasonic transmitter and detected with a piezoelectric transducer. The wavelength of the sound is found by comparing the phase of the detector signal for different sound paths and, when the frequency is known, the velocity of sound as a function of the temperature of the liquid is determined.

What you need:

Ultrasonic pickup	13920.00	1
Ultrasonic generator	13920.99	1
Sliding device, horizontal	08713.00	1
Optical profile bench, l = 600 mm	08283.00	1
Base for optical profile bench, adjustable	08284.00	2
Slide mount for optical profil bench, h = 30 mm	08286.01	1
Swinging arm	08256.00	1
Insulating support	07924.00	1
Immersion thermostat TC10	08492.93	1
Accessory set for TC10	08492.01	1
Bath for thermostat, Makrolon	08487.02	1
Laboratory thermometers, -10...+100°C	38056.00	1
Oscilloscope 30 MHz, 2 channels	11459.95	1
Support rod, stainless steel 18/8, l = 100 mm	02030.00	2
Right angle clamp -PASS-	02040.55	2
Universal clamp with joint	37716.00	1
Screened cable, BNC, l = 750 mm	07542.11	2
Adapter BNC socket/4 mm plug pair	07542.27	1
Glycerol, 250 ml	30084.25	1
Water, distilled 5 l	31246.81	1
Connecting cable, 4 mm plug, 32 A, red, l = 10 cm	07359.01	1
Slide mount	08286.00	1

Complete Equipment Set, Manual on CD-ROM included
Temperature dependence of the Velocity of sound in liquids P2151200



Velocity of sound in water as a function of the temperature.

Tasks:

The wavelength is found from the phase position of the sound pickup signal relative to the generator signal as a function of the sound path and the velocity of the sound is determined when the ultrasonic frequency is known. The measurement is made for water and glycerol as the temperatures of the liquids are changed step-by-step.

1.5.13-00 Stationary ultrasonic waves, determination of wavelength

What you can learn about …

- ➔ Longitudinal waves
- ➔ Superposition of waves
- ➔ Reflection of longitudinal waves
- ➔ Stationary longitudinal waves

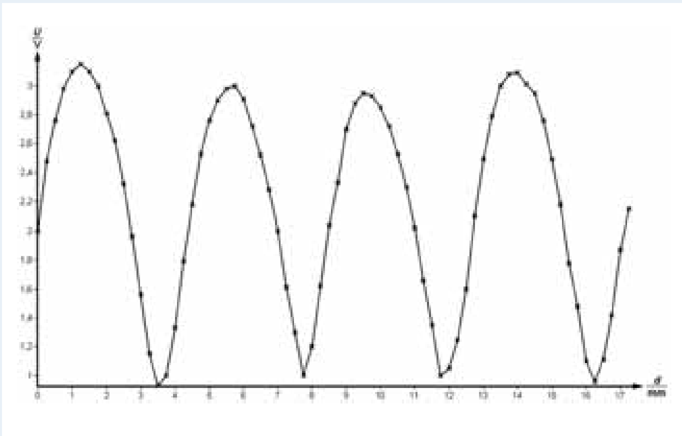
Principle:

An ultrasonic wave is subjected to surface reflection from a metal plate. The reflected wave superimposes on the incident wave, coincident in phase and amplitude, to form a standing wave. The intensity of this wave along the direction of propagation is measured using a movable ultrasonic receiver.

What you need:

Ultrasound operation unit	13900.00	1
Power supply 5 VDC/2.4 A with DC-socket 2.1 mm	13900.99	1
Ultrasonic transmitter	13901.00	1
Ultrasonic receiver on stem	13902.00	1
Digital multimeter 2010	07128.00	1
Optical profile bench, l = 600 mm	08283.00	1
Base for optical profile bench, adjustable	08284.00	2
Slide mount for optical profil bench, h = 80 mm	08286.02	1
Slide mount for optical profil bench, h = 30 mm	08286.01	2
Sliding device, horizontal	08713.00	1
Swinging arm	08256.00	1
Screen, metal, 300 mm x 300 mm	08062.00	1
Connecting cable, 4 mm plug, 32 A, red, l = 50 cm	07361.01	1
Connecting cable, 4 mm plug, 32 A, blue, l = 50 cm	07361.04	1

Complete Equipment Set, Manual on CD-ROM included
Stationary ultrasonic waves, determination of wavelength P2151300



The change in the sound pressure intensity in the direction of propagation as a function of the distance.

Tasks:

1. Determine the intensity of a standing ultrasonic wave by moving an ultrasonic receiver along the direction of propagation.
2. Plot a graph of the measured values as a function of the distance.
3. Determine the wavelength of the ultrasonic wave.

Absorption of ultrasonic in air 1.5.14-00

What you can learn about …

- ➔ Longitudinal waves
- ➔ Plane waves
- ➔ Spherical waves
- ➔ Propagation of sound waves
- ➔ Sound pressure
- ➔ Alternating sound pressure
- ➔ Sound intensity
- ➔ Absorption coefficient of ultrasonic waves
- ➔ Law of absorption

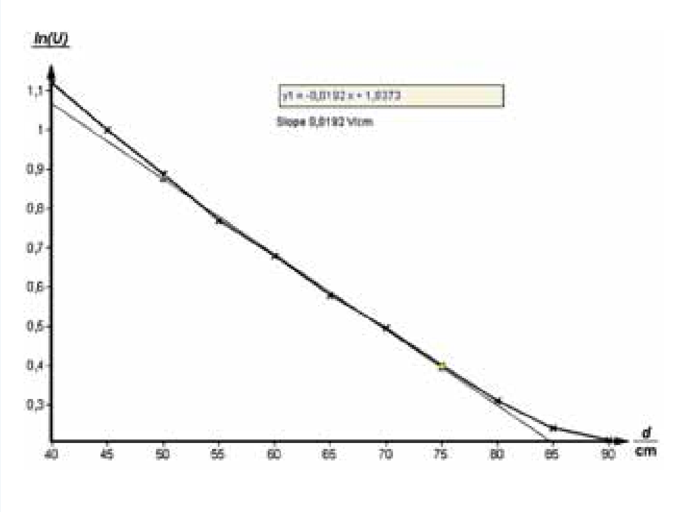
Principle:

Sound needs a material medium with which it can enter into reciprocal action for its propagation, whereby a loss of energy occurs. The amplitude, and so also the intensity, decreases along the propagation path.

What you need:

Ultrasound operation unit	13900.00	1
Power supply 5 VDC/2.4 A with DC-socket 2.1 mm	13900.99	1
Ultrasonic transmitter	13901.00	1
Ultrasonic receiver on stem	13902.00	1
Digital multimeter 2010	07128.00	1
Optical profile bench, l = 1500 mm	08281.00	1
Base for optical profile bench, adjustable	08284.00	2
Slide mount for optical profil bench, h = 80 mm	08286.02	2
Connecting cable, 4 mm plug, 32 A, red, l = 50 cm	07361.01	1
Connecting cable, 4 mm plug, 32 A, blue, l = 50 cm	07361.04	1

Complete Equipment Set, Manual on CD-ROM included
Absorption of ultrasonic in air P2151400



The change in sound pressure intensity as a function of the distance from the source of sound.

Tasks:

1. Move an ultrasonic receiver along the direction of propagation of a sound wave to measure the sound intensity as a function of the distance from the source of the sound.
2. Plot linear and logarithmic graphs of the values of the sound intensity as a function of the distance.
3. Confirm the law of absorption and determine the absorption coefficient.
4. Verify that the emitted wave is a spherical wave near to the transmitter.

1.5.15-15 Ultrasonic diffraction at different single and double slit systems

What you can learn about ...

- → Longitudinal waves
- → Huygens' principle
- → Interference
- → Fraunhofer and Fresnel diffraction

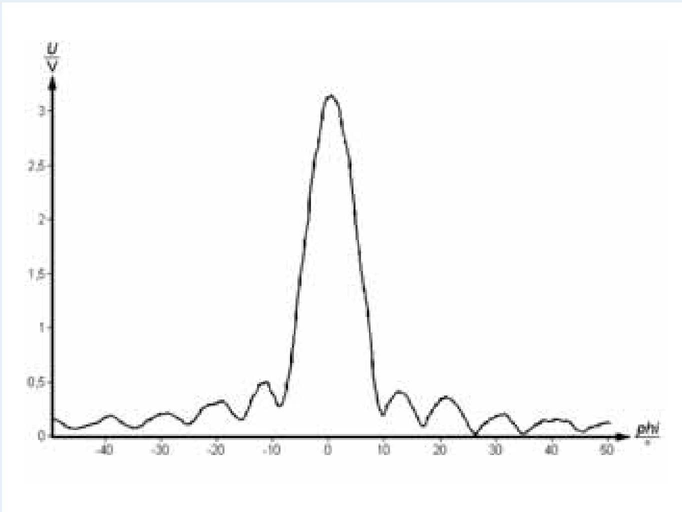
Principle:

A plane ultrasonic wave is subjected to diffraction at single slits of various widths and at various double slits. The intensity of the diffracted and interfering partial waves are automatically recorded using a motor-driven, swivel ultrasound detector and a PC.

What you need:

Goniometer with reflecting mirror	13903.00	1
Goniometer Operation Unit	13903.99	1
Ultrasound operation unit	13900.00	1
Power supply 5 VDC/2.4 A with DC-socket 2.1 mm	13900.99	1
Ultrasonic transmitter	13901.00	1
Ultrasonic receiver on stem	13902.00	1
Object holder for goniometer	13904.00	1
Diffraction objects for ultrasonic	13905.00	1
Data cable 2 x SUB-D, plug/socket, 9 pole	14602.00	1
Measuring tape, l = 2 m	09936.00	1
Screened cable, BNC, l = 750 mm	07542.11	1
Adapter BNC socket/4 mm plug pair	07542.27	1
Software Goniometer	14523.61	1
PC, Windows® XP or higher		

Complete Equipment Set, Manual on CD-ROM included
Ultrasonic diffraction at different single and double slit systems P2151515



The angular distribution of the intensity of a plane ultrasonic wave diffracted at a slit.

Tasks:

1. Record the intensity of an ultrasonic wave diffracted by various slits and double slits as a function of diffraction angle.
2. Determine the angular positions of the maximum and minimum values and compare them with the theoretical results.

Ultrasonic diffraction at different multiple slit systems 1.5.16-15

What you can learn about …

- ➔ Longitudinal waves
- ➔ Huygens' principle
- ➔ Interference
- ➔ Fraunhofer and Fresnel diffraction

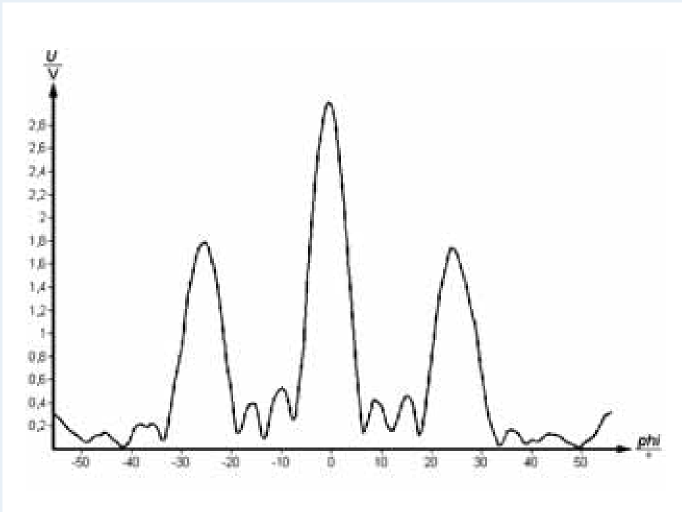
Principle:

An ultrasonic plane wave is subjected to diffraction at various multiple slits. The intensity of the diffracted and interfering partial waves are automatically recorded using a motor-driven, swivel ultrasound detector and a PC.

What you need:

Goniometer with reflecting mirror	13903.00	1
Goniometer Operation Unit	13903.99	1
Ultrasound operation unit	13900.00	1
Power supply 5 VDC/2.4 A with DC-socket 2.1 mm	13900.99	1
Ultrasonic transmitter	13901.00	1
Ultrasonic receiver on stem	13902.00	1
Object holder for goniometer	13904.00	1
Diffraction objects for ultrasonic	13905.00	1
Data cable 2 x SUB-D, plug/socket, 9 pole	14602.00	1
Measuring tape, l = 2 m	09936.00	1
Vernier calipers, stainless steel	03010.00	1
Screened cable, BNC, l = 750 mm	07542.11	1
Adapter BNC socket/4 mm plug pair	07542.27	1
Software Goniometer	14523.61	1
PC, Windows® XP or higher		

Complete Equipment Set, Manual on CD-ROM included
Ultrasonic diffraction at different multiple slit systems P2151615



The angular distribution of the intensity of a plane ultrasonic wave diffracted by a fourfold slit.

Tasks:

1. Determine the angular distribution of a plane ultrasonic wave diffracted by various multiple slits.
2. Determine the angular positions of the maximum and mininum values and compare them with the theoretical values.

1.5.17-15 Diffraction of ultrasonic waves at a pin hole and a circular obstacle

What you can learn about …

- ➔ Longitudinal waves
- ➔ Huygens' principle
- ➔ Interference
- ➔ Fraunhofer and Fresnel diffraction
- ➔ Fresnel's zone construction
- ➔ Poisson's spot
- ➔ Babinet's theorem
- ➔ Bessel function

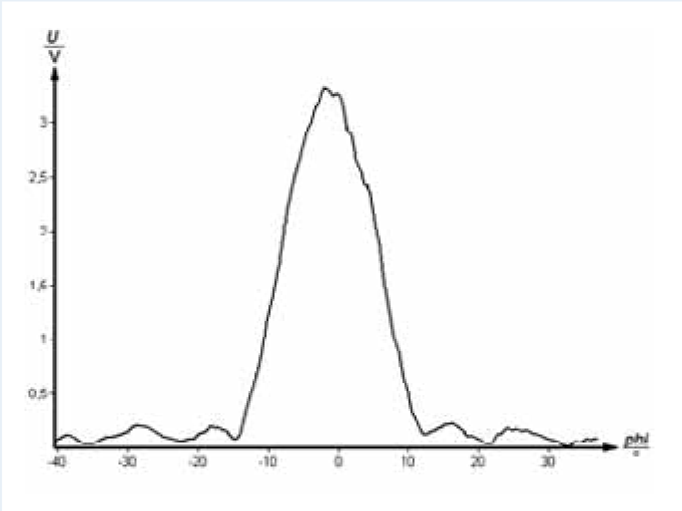
Principle:

An ultrasonic plane wave is subjected to diffraction by a pin-hole obstacle and a complementary circular obstacle. The intensity distribution of the diffracted and interfering partial waves are automatically recorded using a motor-driven, swivel ultrasound detector and a PC.

What you need:

Goniometer with reflecting mirror	13903.00	1
Goniometer Operation Unit	13903.99	1
Ultrasound operation unit	13900.00	1
Power supply 5 VDC/2.4 A with DC-socket 2.1 mm	13900.99	1
Ultrasonic transmitter	13901.00	1
Ultrasonic receiver on stem	13902.00	1
Object holder for goniometer	13904.00	1
Pin hole and circular obstacle for ultrasonic	13906.00	1
Data cable 2 x SUB-D, plug/socket, 9 pole	14602.00	1
Measuring tape, l = 2 m	09936.00	1
Screened cable, BNC, l = 750 mm	07542.11	1
Adapter BNC socket/4 mm plug pair	07542.27	1
Software Goniometer	14523.61	1
PC, Windows® XP or higher		

Complete Equipment Set, Manual on CD-ROM included
Diffraction of ultrasonic waves at a pin hole and a circular obstacle P2151715



The angular distribution of the intensity of a plane ultrasonic wave diffracted by a pin-hole obstacle.

Tasks:

1. Determine the angular distribution of an ultrasonic wave diffracted by a pin-hole and circular obstacle.
2. Compare the angular positions of the minimum intensities with the theoretical values.

Ultrasonic diffraction at Fresnel lenses / Fresnel's zone contruction 1.5.18-00

What you can learn about …

- ➔ Longitudinal waves
- ➔ Huygens' principle
- ➔ Interference
- ➔ Fraunhofer and Fresnel diffraction
- ➔ Fresnel's zone construction
- ➔ Zone plates

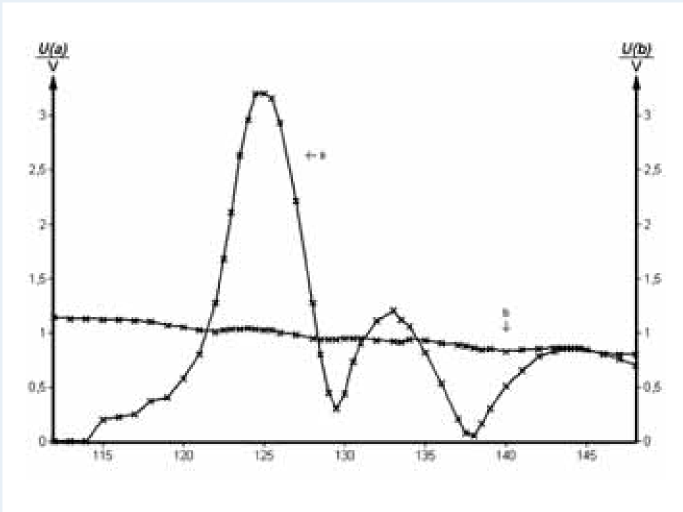
Principle:

An ultrasonic plane wave strikes a Fresnel zone plate. The ultrasonic intensity is determined as a function of the distance behind the plate, using an ultrasonic detector that can be moved in the direction of the zone plate axis.

What you need:

Ultrasound operation unit	13900.00	1
Power supply 5 VDC/2.4 A with DC-socket 2.1 mm	13900.99	1
Ultrasonic transmitter	13901.00	1
Ultrasonic receiver on stem	13902.00	1
Fresnel zone plates for ultrasonic	13907.00	1
Digital multimeter 2010	07128.00	1
Optical profile bench, l = 1500 mm	08281.00	1
Base for optical profile bench, adjustable	08284.00	2
Slide mount	08286.00	3
Stand tube	02060.00	3
Plate holder, opening width 0…10 mm	02062.00	1
Connecting cable, 4 mm plug, 32 A, red, l = 50 cm	07361.01	1
Connecting cable, 4 mm plug, 32 A, blue, l = 50 cm	07361.04	1

Complete Equipment Set, Manual on CD-ROM included
Ultrasonic diffraction at Fresnel lenses / Fresnel's zone contruction P2151800



Graph of the intensity of the ultrasound as a function of the distance from a Fresnel zone plate(curve a); curve b without zone plate.

Tasks:

1. Determine and plot graphs of the intensity of the ultrasonic behind different Fresnel zone plates as a function of the distance behind the plates.
2. Carry out the same measurement series without a plate.
3. Determine the image width at each distance of the transmitter from the zone plate and compare the values obtained with those theoretically expected.

1.5.19-15 Interference of two identical ultrasonic transmitters

What you can learn about …

- ➔ Longitudinal waves
- ➔ Sound pressure
- ➔ Huygens' principle
- ➔ Interference
- ➔ Fraunhofer and Fresnel diffraction

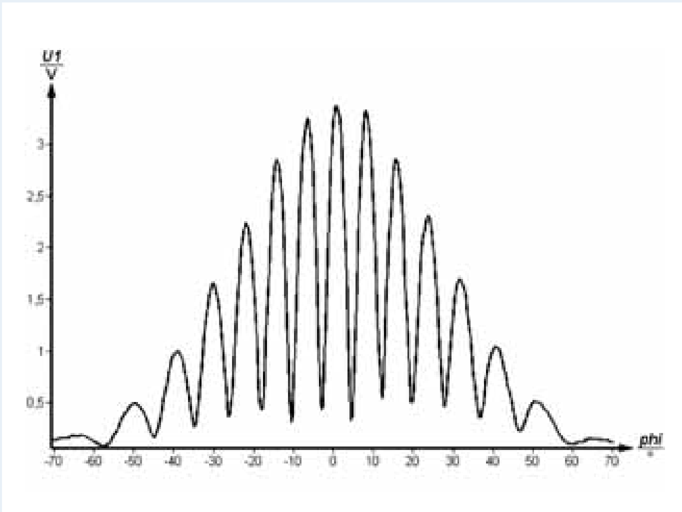
Principle:

Ultrasonic waves of the same frequence, amplitude and direction of propagation are generated by two sources positioned parallel to each other. The sources can vibrate both in-phase and out-of phase. The angular distribution of the intensity of the waves, which interfere with each other, is automatically recorded using a motor-driven ultrasonic detector and a PC.

What you need:

Goniometer with reflecting mirror	13903.00	1
Goniometer Operation Unit	13903.99	1
Ultrasound operation unit	13900.00	1
Power supply 5 VDC/2.4 A with DC-socket 2.1 mm	13900.99	1
Ultrasonic transmitter	13901.00	2
Ultrasonic receiver on stem	13902.00	1
Barrel base -PASS-	02006.55	2
Data cable 2 x SUB-D, plug/socket, 9 pole	14602.00	1
Measuring tape, l = 2 m	09936.00	1
Screened cable, BNC, l = 750 mm	07542.11	1
Adapter BNC socket/4 mm plug pair	07542.27	1
Software Goniometer	14523.61	1
PC, Windows® XP or higher		

Complete Equipment Set, Manual on CD-ROM included
Interference of two indentical ultrasonic transmitters P2151915



Angular distribution of the intensity of two interfering ultrasonic waves having the same phase, amplitude, frequency and direction of propagation.

Tasks:

1. Determine the angular distribution of the sound pressure of two ultrasonic transmitters vibrating in-phase.
2. Determine the angular positions of the interference minima and compare the values found with those theoretically expected.
3. Repeat the measurements with the two ultrasonic transmitters vibrating out-of-phase.
4. Repeat the first measurement and additionally determine with the angular distribution of the sound pressure of each single transmitter.

Interference of ultrasonic waves by a Lloyd mirror 1.5.20-00

What you can learn about …

- ➔ Longitudinal waves
- ➔ Superposition of waves
- ➔ Reflection of longitudinal waves
- ➔ Interference

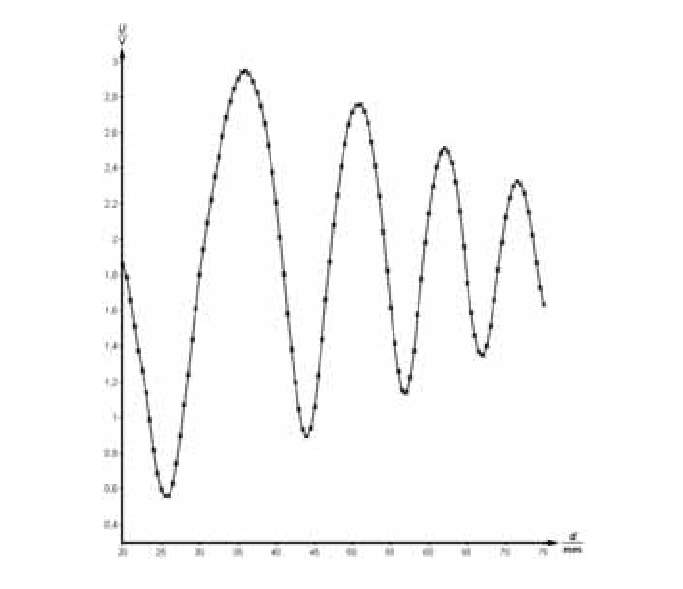
Principle:

A partial packet of radiation passes directly from a fixed ultrasonic transmitter to a fixed ultrasonic receiver. A further partial packet hits against a metal screen that is positioned parallel to the connecting line between the transmitter and receiver, and is reflected in the direction of the receiver. The two packets of radiation interfere with each other at the receiver. When the reflector is moved parallel to itself, the difference in the path lengths of the two packets changes. According to this difference, either constructive or destructive interference occurs.

What you need:

Ultrasound operation unit	13900.00	1
Power supply 5 VDC/2.4 A with DC-socket 2.1 mm	13900.99	1
Ultrasonic transmitter	13901.00	1
Ultrasonic receiver on stem	13902.00	1
Digital multimeter 2010	07128.00	1
Optical profile bench, l = 600 mm	08283.00	1
Base for optical profile bench, adjustable	08284.00	2
Slide mount for optical profil bench, h = 80 mm	08286.02	2
Slide mount	08286.00	1
Sliding device, horizontal	08713.00	1
Swinging arm	08256.00	1
Screen, metal, 300 mm x 300 mm	08062.00	1
Measuring tape, l = 2 m	09936.00	1
Connecting cable, 4 mm plug, 32 A, red, l = 50 cm	07361.01	1
Connecting cable, 4 mm plug, 32 A, blue, l = 50 cm	07361.04	1

Complete Equipment Set, Manual on CD-ROM included
Interference of ultrasonic waves by a Lloyd mirror P2152000



The received signal as a function of the reflector distance d.

Tasks:

1. The sliding device is to be used to move the reflector screen positioned parallel to the connecting line between the transmitter and receiver parallel to itself in steps of d = (0.5-1) mm. The reflector voltage U is to be recorded at each step.
2. The d values of the various maxima and minima are to be determined from the $U = U(d)$ graph and compared with the theoretically expected values.

1.5.21-15 Determination of the velocity of sound (sonar principle)

What you can learn about …

- ➔ Longitudinal waves
- ➔ Sound pressure
- ➔ Phase- and group velocity
- ➔ Sonar principle

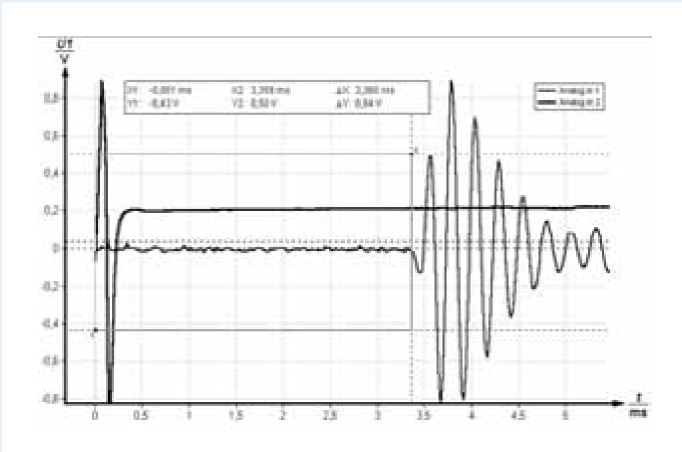
Principle:

An ultrasonic transmitter emits sound pulses onto a reflector, from which recording of them by a receiver shows a time delay. The velocity of sound is calculated from the path length and transmission time of the sound pulses.

What you need:

Ultrasound operation unit	13900.00	1
Power supply 5 VDC/2.4 A with DC-socket 2.1 mm	13900.99	1
Ultrasonic transmitter	13901.00	1
Ultrasonic receiver on stem	13902.00	1
Cobra3 Basic-Unit, USB	12150.50	1
Power supply 12V/2A	12151.99	1
Barrel base -PASS-	02006.55	3
Screen, metal, 300 mm x 300 mm	08062.00	1
Measuring tape, l = 2 m	09936.00	1
Meter Scale, l = 1000 x 27 mm	03001.00	1
Screened cable, BNC, l = 750 mm	07542.11	2
Adapter BNC socket/4 mm plug pair	07542.27	2
Software Cobra3 Universal recorder	14504.61	1
PC, Windows® XP or higher		

Complete Equipment Set, Manual on CD-ROM included
Determination of the velocity of sound (sonar principle) **P2152115**



Measured time between the transmitted and the received reflected ultra sonic waves.

Tasks:

1. Determine transmission times for different distances apart of the transmitter and the receiver.
2. Plot a graph of the path lengths of the sound pulses against their transmission time.
3. Determine the velocity of sound from the graph.

Ultrasonic Michelson-Interferometer 1.5.22-00

What you can learn about …

- ➔ Longitudinal waves
- ➔ Reflection of longitudinal waves
- ➔ Superposition of waves
- ➔ Interference
- ➔ Interferometer

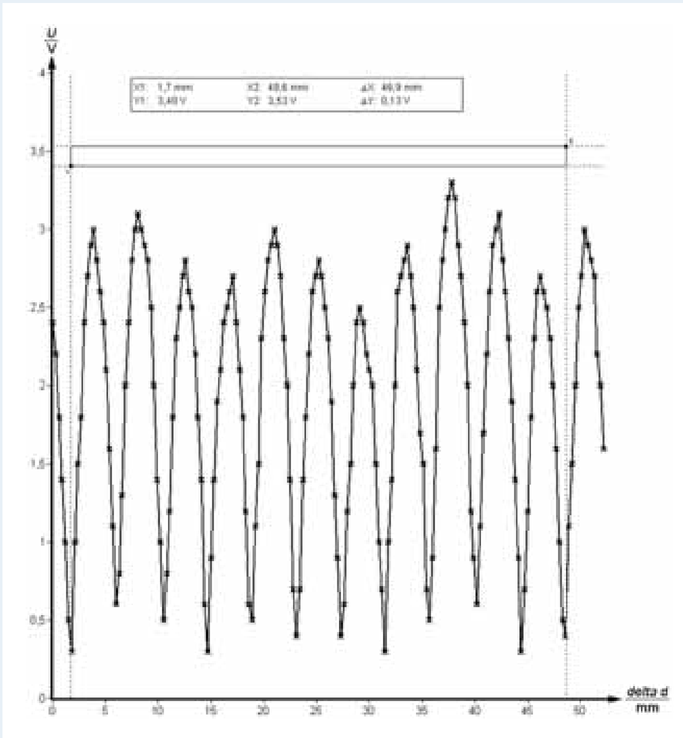
Principle:

A "semi-permeable" membrane divides an ultrasonic wave into two partial packets which travel at right angles to each other. They are subsequently reflected at different hard metal reflectors, one of which is fixed in position, and the other of which can be displaced in the direction of the beam, before being reunited. Shifting the displaceable reflector changes the path length of the corresponding packet, so that superpositioning of the reunited partial packets gives maxima and minima of the alternating sound pressure according to the differenc in the distance travelled. The wavelength of the ultrasound can be determined from these.

What you need:

Ultrasound operation unit	13900.00	1
Power supply 5 VDC/2.4 A with DC-socket 2.1 mm	13900.99	1
Ultrasonic transmitter	13901.00	1
Ultrasonic receiver on stem	13902.00	1
Multi range meter, analogue	07028.01	1
Optical profile bench, l = 600 mm	08283.00	1
Base for optical profile bench, adjustable	08284.00	2
Slide mount for optical profil bench, h = 80 mm	08286.02	2
Slide mount for optical profil bench, h = 30 mm	08286.01	1
Sliding device, horizontal	08713.00	1
Screen, metal, 300 mm x 300 mm	08062.00	2
Screen, translucent, 250 mm x 250 mm	08064.00	1
Barrel base -PASS-	02006.55	2
Stand tube	02060.00	2
Measuring tape, l = 2 m	09936.00	1
Connecting cable, 4 mm plug, 32 A, red, l = 50 cm	07361.01	1
Connecting cable, 4 mm plug, 32 A, blue, l = 50 cm	07361.04	1

Complete Equipment Set, Manual on CD-ROM included
Ultrasonic Michelson-Interferometer P2152200

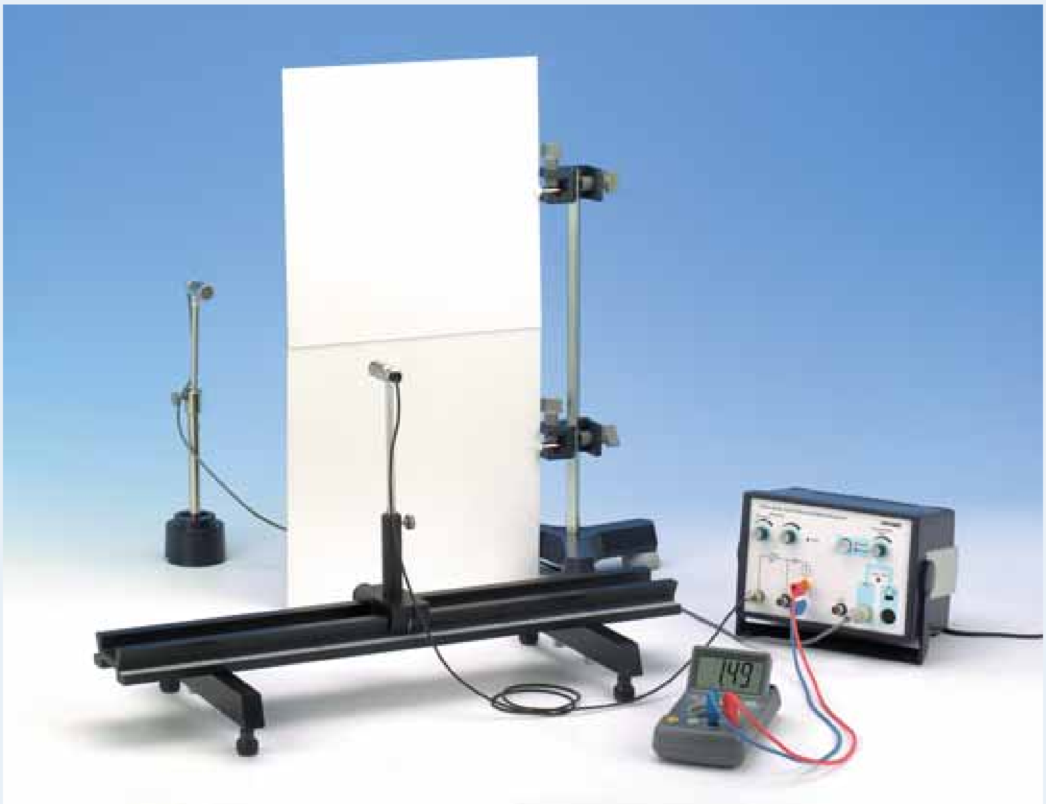


Intensity of the alternating sound pressure as a function of the displacement Δd of reflector screen Sc_2.

Tasks:

1. Determine the intensity of the alternating sound pressure in dependence on the displacement of one of the reflectors.
2. Calculate the wavelength of the ultrasound from the measurement curve.

1.5.23-00 Ultrasonic diffraction by a straight edge



What you can learn about ...

- ➔ Longitudinal waves
- ➔ Superposition of waves
- ➔ Huygens' principle
- ➔ Interference
- ➔ Fraunhofer and Fresnel diffraction
- ➔ Fresnel zones
- ➔ Fresnel integrals
- ➔ Cornu's spiral

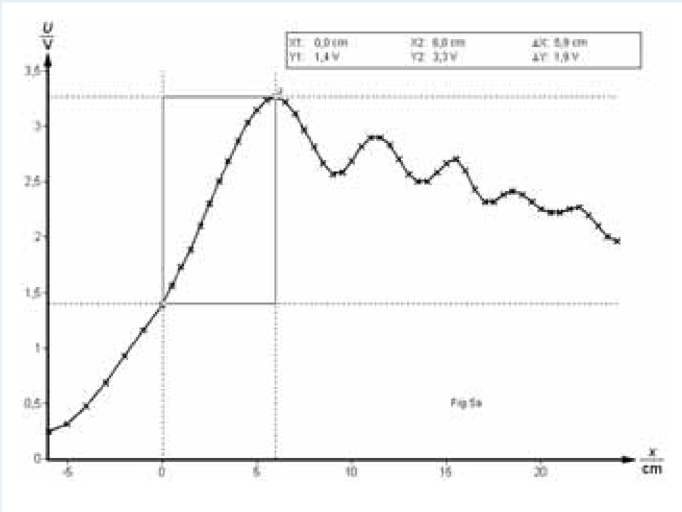
Principle:

An ultrasonic wave hits a straight edge which limits the wave field to one side. According to Huygens' principle, the edge is a point source for secondary waves, and these penetrate also into the shaded area of the edge. In the transmission range, secondary waves interfere with the primary waves, so that a succession of maxima and minima of the alternating sound pressure are created transverse to the edge.

What you need:

Ultrasound operation unit	13900.00	1
Power supply 5 VDC/2.4 A with DC-socket 2.1 mm	13900.99	1
Ultrasonic transmitter	13901.00	1
Ultrasonic receiver on stem	13902.00	1
Multi range meter, analogue	07028.01	1
Optical profile bench, l = 600 mm	08283.00	1
Base for optical profile bench, adjustable	08284.00	2
Slide mount for optical profil bench, h = 80 mm	08286.02	1
Screen, metal, 300 mm x 300 mm	08062.00	2
Barrel base -PASS-	02006.55	1
Tripod base -PASS-	02002.55	1
Right angle clamp -PASS-	02040.55	2
Support rod -PASS-, square, l = 400 mm	02026.55	1
Stand tube	02060.00	1
Measuring tape, l = 2 m	09936.00	1
Connecting cable, 4 mm plug, 32 A, red, l = 50 cm	07361.01	1
Connecting cable, 4 mm plug, 32 A, blue, l = 50 cm	07361.04	1

Complete Equipment Set, Manual on CD-ROM included
Ultrasonic diffraction by a straight edge P2152300



Diffraction at an edge: Course of intensity of the alternating sound pressure as function of position coordinate x.

Tasks:

1. Determine the intensity distribution of an ultrasonic wave diffracted at a straight edge as a function of the transverse distance from the edge.
2. Compare the positions of the maxima and minima found in the experiment to those theoretically expected.
3. Repeat the measurement of the intensity distribution of the ultrasonic wave without the straight edge.

Ultrasonic Doppler effect 1.5.24-15

What you can learn about …

- Propagation of sound waves
- Superimposition of sound waves
- Doppler shift of frequency
- Longitudinal waves

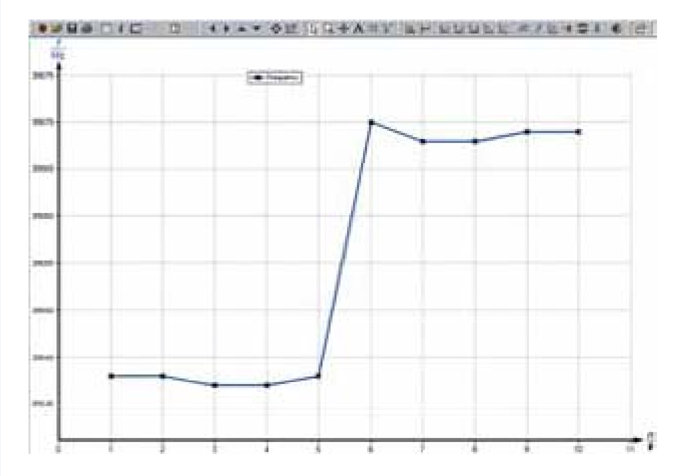
Principle:

If a source of sound is in motion relative to its medium of propagation, the frequency of the waves that are emitted is displaced due to the Doppler effect.

What you need:

Ultrasound operation unit	13900.00	1
Power supply 5 VDC/2.4 A with DC-socket 2.1 mm	13900.99	1
Ultrasonic transmitter	13901.00	1
Ultrasonic receiver on stem	13902.00	1
Car, motor driven	11061.00	1
Attachment for car	11061.02	1
Battery cell, 1.5 V, baby size, type C	07922.01	2
Barrel base -PASS-	02006.55	2
Stand tube	02060.00	1
Connecting cord, 32 A, l = 1000 mm, red	07363.01	1
Connecting cable, 32 A, l = 1000 mm, yellow	07363.02	1
Connecting cable, 32 A, l = 1000 mm, blue	07363.04	1
Connecting cable, 32 A, l = 100 mm, yellow	07359.02	1
Screened cable, BNC, l = 750 mm	07542.11	1
Adapter BNC socket/4 mm plug pair	07542.27	1
Track, l = 900 mm	11606.00	1
Cobra3 Basic-Unit, USB	12150.50	1
Power supply 12V/2A	12151.99	1
Software Cobra3, Timer/Counter	14511.61	1
Double socket, 1 pair, red and black	07264.00	1
Spring balance holder	03065.20	1
Screen with plug, l = 100 mm	11202.03	1
Support rod, stainless steel, l = 600 mm	02037.00	1
Light barrier, compact	11207.20	1
Bosshead	02043.00	1
PC, Windows® XP or higher		

Complete Equipment Set, Manual on CD-ROM included
Ultrasonic Doppler effect P2152415

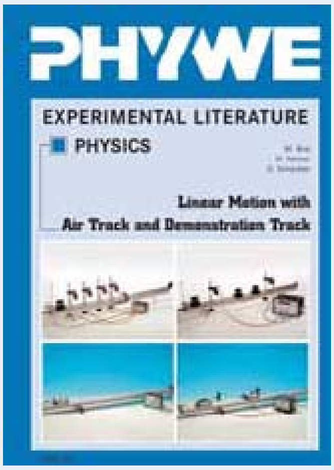


Doppler shift of frequency.

Tasks:

The frequency changes are measured and analysed for different relative velocities of source and observer.

Physics Experiments – Linear Motion



In the experimental literature "Linear Motion" you will find detailed descriptions of experiments regarding the following concepts:

- Uniform acceleration and deceleration
- Momentum (elastic and inelastic collision)
- Newton's laws
- Potential and kinetic energy
- Grade resistance/inclined plane

Almost all experiments can be performed either with the 2 m long air track 11202.17 or with the 1.5 m long demonstration track 11305.00. For the measurements and data recording you can use the Cobra3 interface 12150.00, the 4-4 Timer 13605.99 or the 6-decade digital counter 13603.93.

Physics Experiments – Linear Motion • No. 16001.02 • 15 Experiments described

1.1 P1198511
The linear uniform motion

2.1 P1198615
Uniformly accelerated motion with an accelerating mass

2.2 P1198702
Uniformly accelerated motion with a jet glider

2.3 P1198805
Uniformly accelerated motion with an inclined track

2.4 P1198906
Uniformly decelerated motion

2.5 P1199000
The free fall

3.1 P1199115
Law of inertia (Newton's 1st law)

3.2 P1199201
Fundamental law of dynamics (Newton's 2nd Law)

3.3 P1199306
Law of reciprocal actions (Newton's 3rd Law)

3.4 P1199405
Equivalence of inert mass and heavy mass

3.5 P1198115
Velocity-independent and velocity-dependent friction with Demo-Track and Cobra3

3.6 P1198215
The inertial force F = m · a with Demo-Track and Cobra3

4.1 P1199502
Impulse and momentum

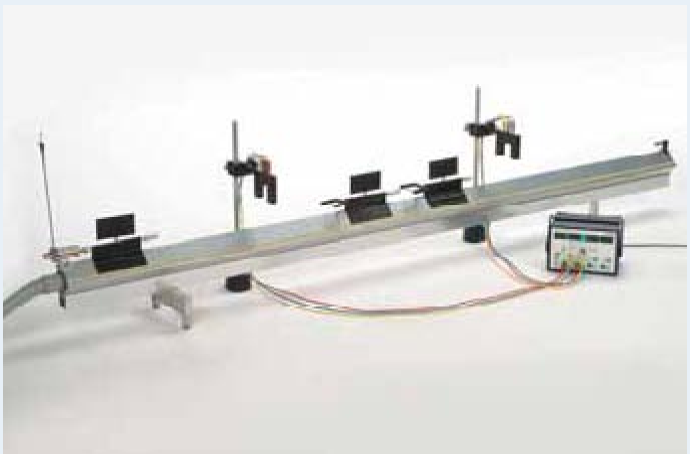
4.2 P1199605
Conservation of momentum in elastic collisions

4.3 P1199711
Conservation of momentum in inelastic collisions

4.4 P1199801
Conservation of momentum in multiple elastic collisions

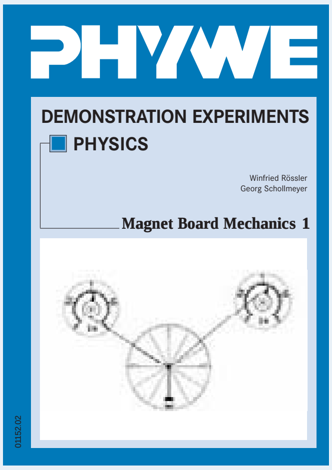
4.5 P1199902
Conservation of momentum in multiple inelastic collisions

Newton's second law with Cobra3 and demonstration track.



Conservation of momentum in multiple inelastic collisions with 4-4 Timer and air track.

Physics Demonstration Experiments – Magnet Board Mechanics 1



The use of the demonstration board for physics offers the following advantages for the lecturer:

- Minimal preparation time
- Lucid and simple set-up
- Labelling of the experiment directly on the board
- Magnet-held arrows, linear and angular scales
- Stable storage box
- Both sides of board can be used for mechanics and optics
- Galvanised sheet steel board in aluminium profile frame
- Mechanics side: lacquered
- Optic side: white foil with lined grid

Physics Demonstration Experiments – Magnet Board Mechanics 1 • No. 01152.02 • 31 described Experiments

Please ask for a complete equipment list Ref. No. 21701

1 Forces

MT 1.1 (12516)
Mass and weight

MT 1.2 (12517)
Extension of a rubber band and helical spring

MT 1.3 (12518)
Hooke's law

MT 1.4 (12519)
Making and calibrating a dynamometer

MT 1.5 (12520)
Bending a leaf spring

MT 1.6 (12521)
Force and counterforce

MT 1.7 (12522)
Composition of forces having the same line of application

MT 1.8 (12523)
Composition of non-parallel forces

MT 1.9 (12524)
Resolution of a force into two non-parallel forces

MT 1.10 (12525)
Resolution of forces on an inclined plane

MT 1.11 (12526)
Resolution of forces on a crane

MT 1.12 (12527)
Restoring force on a displaced pendulum

MT 1.13 (12528)
Determination of the centre of gravity of an irregular plate

MT 1.14 (12529)
Frictional force

MT 1.15 (12530)
Determination of the coefficient of friction on an inclined plane

2 Simple machines

MT 2.1 (12531)
Double-sided lever

MT 2.2 (12532)
One-sided lever

MT 2.3 (12533)
Double-sided lever and more than two forces

MT 2.4 (12534)
Reaction at the supports

MT 2.5 (12535)
Moment of rotation (torque)

MT 2.6 (12536)
Beam balance

MT 2.7 (12537)
Sliding weight balance

MT 2.8 (12538)
Fixed pulley

MT 2.9 (12539)
Free pulley

MT 2.10 (12540)
Block and tackle

MT 2.11 (12541)
Step wheel

MT 2.12 (12542)
Toothed-gearing

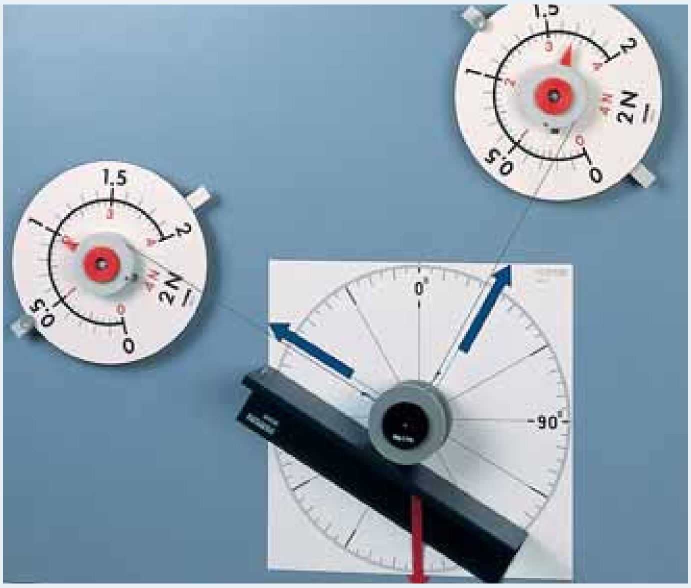
MT 2.13 (12543)
Belt drives

3 Oscillations

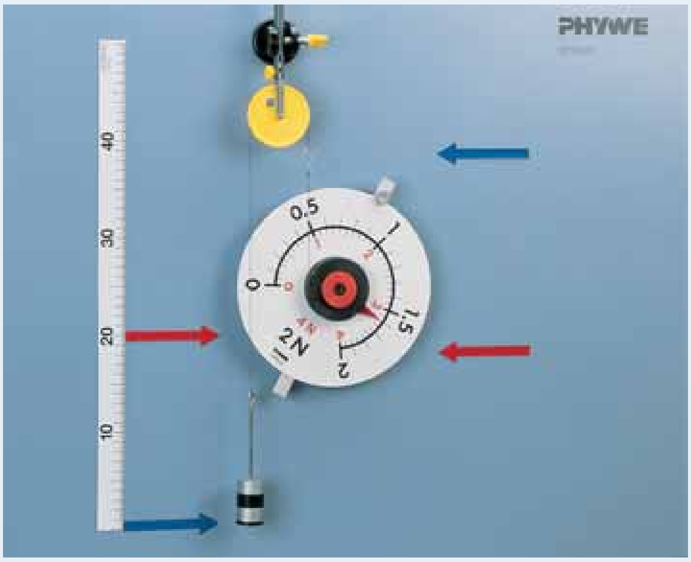
MT 3.1 (12544)
Thread pendulum

MT 3.2 (12545)
Spring pendulum

MT 3.3 (12546)
Physical pendulum
(reversible pendulum)

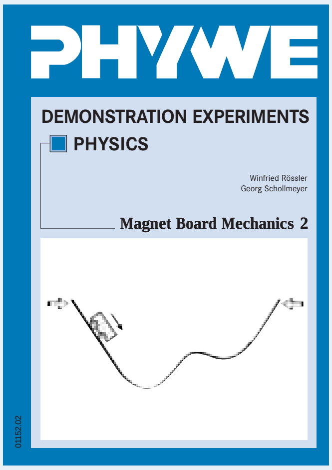


Resolution of forces on an inclined plane (MT 1.10)



Fixed pulley (MT 2.8)

Physics Demonstration Experiments – Magnet Board Mechanics 2



The use of the demonstration board for physics offers the following advantages for the lecturer:

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- Lucid and simple set-up
- Labelling of the experiment directly on the board
- Magnet-held arrows, linear and angular scales
- Stable storage box
- Both sides of board can be used for mechanics and optics
- Galvanised sheet steel board in aluminium profile frame
- Mechanics side: lacquered
- Optic side: white foil with lined grid

Physics Demonstration Experiments – Magnet Board Mechanics 2 • No. 01153.02 • 18 described Experiments

Please ask for a complete equipment list Ref. No. 21702

4 Movement

MT 4.1 (12960)
Uniform rectilinear movement

MT 4.2 (12961)
Uniform accelerated recti linear movement

MT 4.3 (12962)
Horizontal and sloping trajectories

MT 4.4 (12963)
Newton's basic principle

5 Forms of Mechanical Energy

MT 5.1 (12964)
Energy transformation during upward and downward runs

MT 5.2 (12965)
Kinetic energy

MT 5.3 (12966)
Energy of refraction

6 Mechanics of Fluids and Gases

MT 6.1 (12967)
U-tube manometer

MT 6.2 (12968)
Hydrostatic pressure

MT 5.3 (12969)
Communicating vessels

MT 6.4 (12970)
Hydraulic press

MT 6.5 (12971)
Artesian well

MT 6.6 (12972)
Archimedes principle

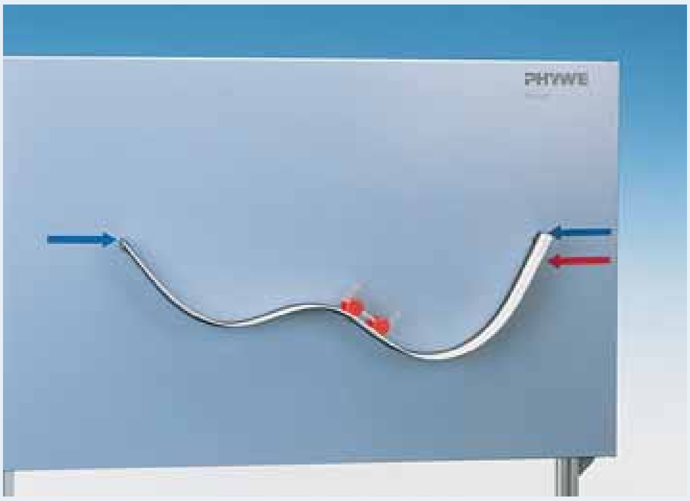
MT 6.7 (12973)
Density determination by measuring buoyancy

MT 6.8 (12974)
Discharge velocity of a vessel

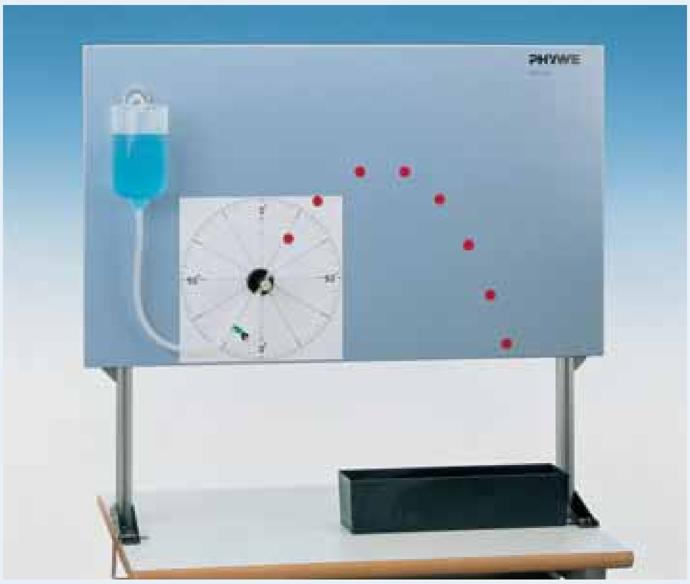
MT 6.9 (12975)
Pressure in flowing fluids

MT 6.10 (12976)
Pressure in gases

MT 6.11 (12977)
Boyle and Mariotte's law



Energy transformation during upward and downward runs (MT 5.1)



Horizontal and sloping trajectories (MT 4.3)

Optics

2

2

Optics

Contents

Measuring the velocity of light 2.1.01-01

What you can learn about ...

- ➔ Refractive index
- ➔ Wavelength
- ➔ Frequency
- ➔ Phase
- ➔ Modulation
- ➔ Electric field constant
- ➔ Magnetic field constant

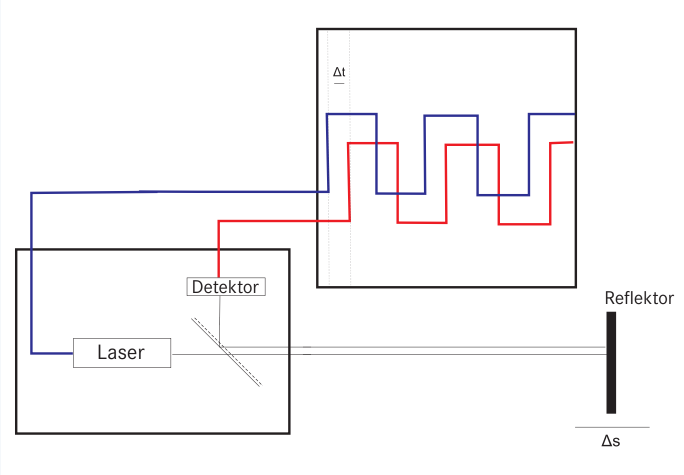
Principle:

The intensity of the light is modulated with a high frequency and the phase relationship of the transmitter and receiver signal compared. The velocity of light is calculated from the relationship between the changes in the phase, the modulation frequency and the light path.

What you need:

Speed of Light meter (complete set)	11226.88	1
Screened cable, BNC, l = 750 mm	07542.11	2
Digital Oscilloscope 25 MHz, 2 channels	11456.99	1

Complete Equipment Set, Manual on CD-ROM included
Measuring the velocity of light P2210101



Principle of measurement.

Tasks:

1. To determine the velocity of light in air.
2. To determine the velocity of light in water and to calculate the refractive index.
3. To determine the velocity of light in acrylic glass and to calculate the refractive index.

2.1.02-00 Laws of lenses and optical instruments

What you can learn about ...

- → Law of lenses
- → Magnification
- → Focal length
- → Object distance
- → Telescope
- → Microscope
- → Path of a ray
- → Convex lens
- → Concave lens
- → Real image
- → Virtual image

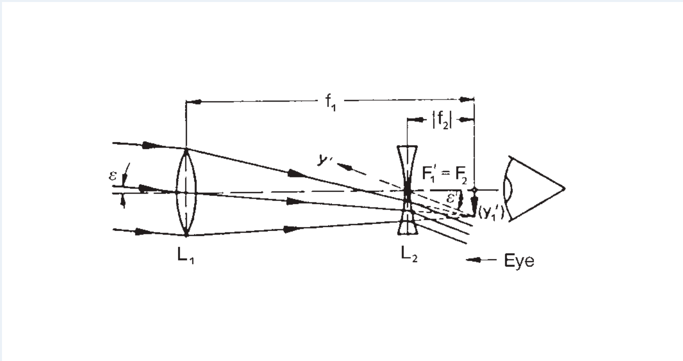
Principle:

The focal lengths of unknown lenses are determined by measuring the distances of image and object and by Bessel's method. Simple optical instruments are then constructed with these lenses.

What you need:

Lens, mounted, f = +20 mm	08018.01	1
Lens, mounted, f = +50 mm	08020.01	1
Lens, mounted, f = +100 mm	08021.01	1
Lens, mounted, f = +300 mm	08023.01	1
Lens, mounted, f = -50 mm	08026.01	1
Lens, mounted, f = -200 mm	08028.01	1
Screen, translucent, 250 mm x 250 mm	08064.00	1
Screen with arrow slit	08133.01	1
Ground glass screen, 50 mm d = 50 mm	08136.01	1
Double condenser, f = 60 mm	08137.00	1
Object micrometer 1mm i.100 parts	62171.19	1
Ctenocephalus, msl	87337.10	1
Slide -Emperor Maximilian-	82140.00	1
Optical profile bench, l = 1000 mm	08282.00	1
Base for optical profile bench, adjustable	08284.00	2
Slide mount for optical profil bench, h = 30 mm	08286.01	5
Slide mount for optical profil bench, h = 80 mm	08286.02	1
Diaphragm holder for optical base plate	08040.00	2
Lens holder	08012.00	2
Condenser holder	08015.00	1
Swinging arm	08256.00	1
Experimenting lamp 5, with stem	11601.10	1
Power supply 0-12 V DC/ 6 V, 12 V AC	13505.93	1
Connecting cable, 4 mm plug, 32 A, blue, l = 50 cm	07361.04	2
Rule, plastic, 200 mm	09937.01	1

Complete Equipment Set, Manual on CD-ROM included
Laws of lenses and optical instruments P2210200



Path of a ray in Galileo telescope.

Tasks:

1. To determine the focal length of two unknown convex lenses by measuring the distances of image and object.
2. To determine the focal length of a convex lens and of a combination of a convex and a concave lens using Bessel's method.
3. To construct the following optical instruments:
   1. Slide projector; image scale to be determined
   2. Microscope; magnification to be determined
   3. Kepler-type telescope
   4. Galileo's telescope (opera glasses).

Dispersion and resolving power of the prism and grating spectroscope 2.1.03-00

What you can learn about …

- → Maxwell relationship
- → Dispersion
- → Polarizability
- → Refractive index
- → Prism
- → Rowland grating
- → Spectrometer-goniometer

Principle:

The refractive indices of liquids, crown glass and flint glass are determined as a function of the wavelength by refraction of light through the prism at minimum deviation. The resolving power of the glass prisms is determined from the dispersion curve.

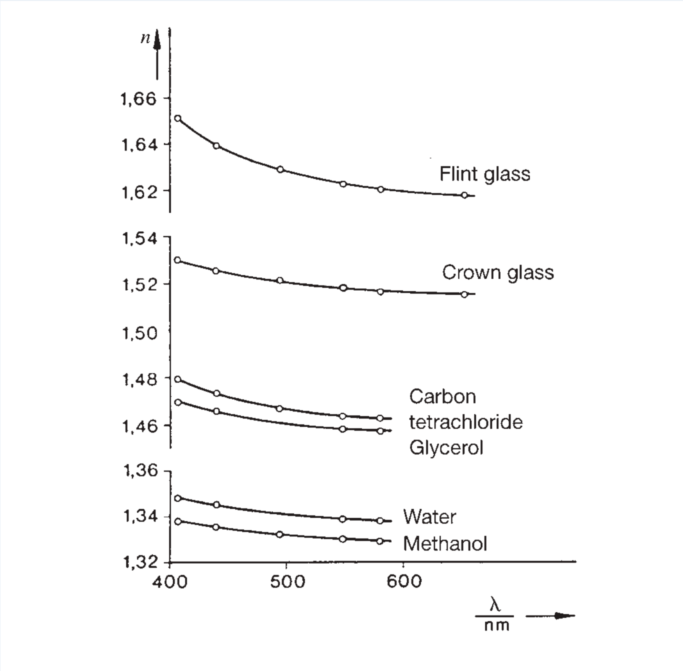
Tasks:

1. To adjust the spectrometer-goniometer.
2. To determine the refractive index of various liquids in a hollow prism.
3. To determine the refractive index of various glass prism.
4. To determine the wavelengths of the mercury spectral lines.
5. To demonstrate the relationship between refractive index and wavelength (dispersion curve).
6. To calculate the resolving power of the glass prisms from the slope of the dispersion curves.
7. Determination of the grating constant of a Rowland grating based on the diffraction angle (up to the third order) of the high intensity spectral lines of mercury.
8. Determination of the angular dispersion of a grating.
9. Determination of the resolving power required to separate the different Hg-Lines. Comparison with theory.

What you need:

Spectrometer/goniometer with verniers	35635.02	1
Lamp holder, pico 9, for spectral lamps	08119.00	1
Spectral lamp Hg 100, pico 9 base	08120.14	1
Power supply for spectral lamps	13662.97	1
Prism, 60°, Crownglass, h = 30 mm	08231.00	1
Hollow prism 60°, l = 60 mm, h = 60 mm	08240.00	1
Diffraction grating, 4 lines/mm	08532.00	1
Diffraction grating, 8 lines/mm	08534.00	1
Diffraction grating,10 lines/mm	08540.00	1
Diffraction grating, 50 lines/mm	08543.00	1
Diffraction grating, 600 lines/mm	08546.00	1
Vernier calipers, stainless steel	03010.00	1
Barrel base -PASS-	02006.55	1
Right angle clamp -PASS-	02040.55	1
Support rod -PASS-, square, l = 250 mm	02025.55	1
Bench clamp -PASS-	02010.00	1
Stand tube	02060.00	1
Wash bottle, plastic, 250 ml	33930.00	1
Glycerol, 250 ml	30084.25	1
Methanol 500 ml	30142.50	1
Cyclohexane for synthesis, 100 ml	31236.10	1

Complete Equipment Set, Manual on CD-ROM included
Dispersion and resolving power of the prism and grating spectroscope P2210300



Dispersion curves of various substances.

2.2.01-00 Interference of light

What you can learn about …

- → Wavelength
- → Phase
- → Fresnel biprism
- → Fresnel mirror
- → Virtual light source

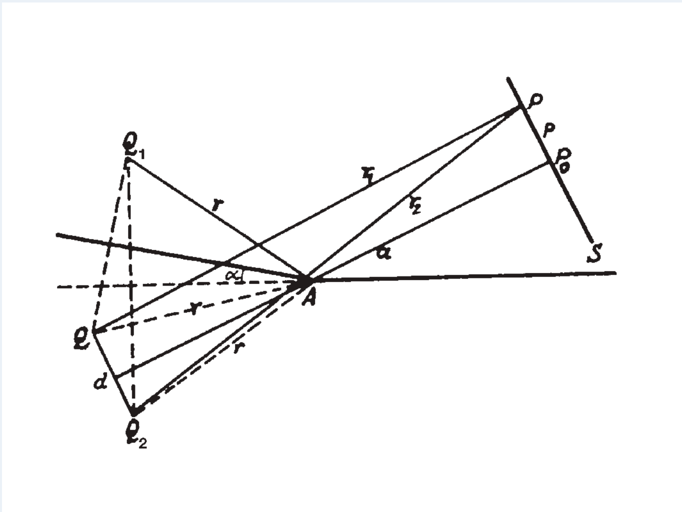
Principle:

By dividing up the wave-front of a beam of light at the Fresnel mirror and the Fresnel biprism, interference is produced. The wavelength is determined from the interference patterns.

What you need:

Fresnel biprisms	08556.00	1
Prism table with holder	08254.00	1
Fresnel mirror	08560.00	1
Lens, mounted, f = +20 mm	08018.01	1
Lens, mounted, f = +300 mm, achromatic	08025.01	1
Lens holder	08012.00	2
Swinging arm	08256.00	1
Slide mount for optical profil bench, h = 30 mm	08286.01	2
Slide mount for optical profil bench, h = 80 mm	08286.02	2
Optical profile bench, l = 1000 mm	08282.00	1
Base for optical profile bench, adjustable	08284.00	2
Laser, He-Ne 1.0 mW, 230 VAC	08181.93	1
Measuring tape, l = 2 m	09936.00	1

Complete Equipment Set, Manual on CD-ROM included
Interference of light P2220100



Geometrical arrangement, using the Fresnel mirror.

Tasks:

Determination of the wavelength of light by interference

1. with Fresnel mirror,
2. with Fresnel biprism.

Newton's rings 2.2.02-00

What you can learn about …

- → Coherent light
- → Phase relationship
- → Path difference
- → Interference in thin films
- → Newton's ring apparatus

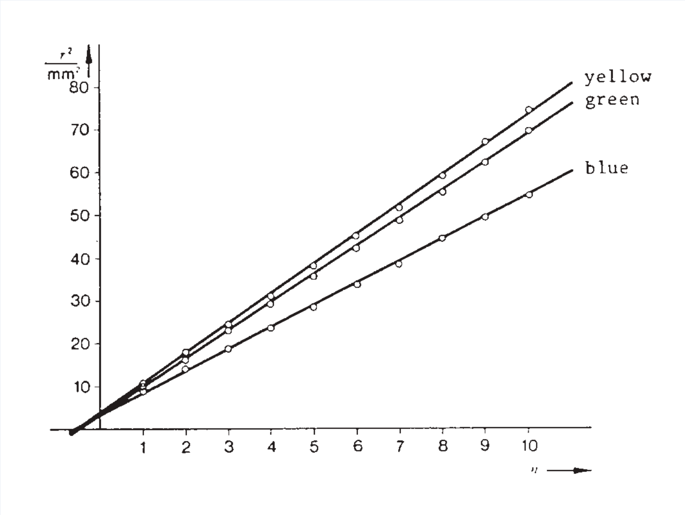
Principle:

In a Newton's rings apparatus, monochromatic light interferes in the thin film of air between the slightly convex lens and a plane glass plate. The wavelengths are determined from the radii of the interference rings.

What you need:

Newton rings apparatus	08550.00	1
Lens, mounted, f = + 50 mm	08020.01	1
Interference filters, set of 3	08461.00	1
Screen, translucent, 250 mm x 250 mm	08064.00	1
Mercury vapour high pressure lamp, 50 W	08144.00	1
Power supply 230V/50 Hz for 50 W Hg-lamp	13661.97	1
Double condenser, f = 60 mm	08137.00	1
Lens holder	08012.00	2
Slide mount for optical profil bench, h = 30 mm	08286.01	4
Slide mount for optical profil bench, h = 80 mm	08286.02	1
Optical profile bench, l = 1000 mm	08282.00	1
Base for optical profile bench, adjustable	08284.00	2
Rule, plastic, 200 mm	09937.01	1
Condenser holder	08015.00	1

Complete Equipment Set, Manual on CD-ROM included
Newton's rings P2220200



Radius of the interference rings as a function of the order number for various wavelengths.

Tasks:

Using the Newton's rings apparatus, to measure the diameter of the rings at different wavelengths and:

1. to determine the wavelengths for a given radius of curvature of the lens
2. to determine the radius of curvature at given wavelengths.

2.2.02-05 Newton's rings with optical base plate

What you can learn about …

- ➔ Coherent light
- ➔ Phase relation
- ➔ Path difference
- ➔ Interference at thin layers
- ➔ Newton's colour glass

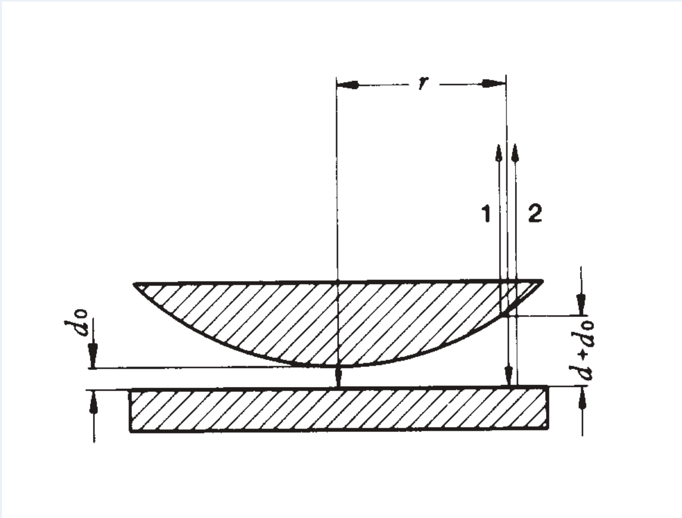
Principle:

The air wedge formed between a slightly convex lens and a plane glass plate (Newton's colour glass) is used to cause interference of monochromatic light. The wavelength is determined from the radii of the interference rings.

What you need:

Optical base plate with rubber feet	08700.00	1
He-Ne-laser, 5 mW with holder*	08701.00	1
Power supply for laser head 5 mW*	08702.93	1
Adjusting support 35×35 mm	08711.00	1
Surface mirror 30×30 mm	08711.01	1
Achromatic objective 20× N.A. 0.45	62174.20	1
Pinhole 30 micron	08743.00	1
Sliding device, horizontal	08713.00	1
xy shifting device	08714.00	2
Adapter ring device	08714.01	1
Magnetic foot for optical base plate	08710.00	5
Newton colourglass for optical base plate	08730.02	1
Lensholder for optical base plate	08723.00	1
Lens, mounted, f = +50 mm	08020.01	1
Screen, transparent with holder for optical base plate	08732.00	1
Measuring tape, l = 2 m	09936.00	1
*Alternative to laser 5 mW, power supply and shutter:		
Laser, He-Ne 0.2/1.0 mW, 220 V AC	08180.93	1
or		
Diodelaser 0.2/1 mW; 635 nm	08760.99	1

Complete Equipment Set, Manual on CD-ROM included
Newton's rings with optical base plate P2220205



Generation of Newton's rings.

Tasks:

The diameters of interference rings produced by Newton's colour glass are measured and these are used to:

1. determine the wavelength for a given radius of curvature of the lens,
2. determine the radius of curvature for a given wavelength.

Interference at a mica plate according to Pohl 2.2.03-00

What you can learn about …

- Interference of equal inclination
- Interference of thin layers
- Plane parallel plate
- Refraction
- Reflection
- Optical path difference

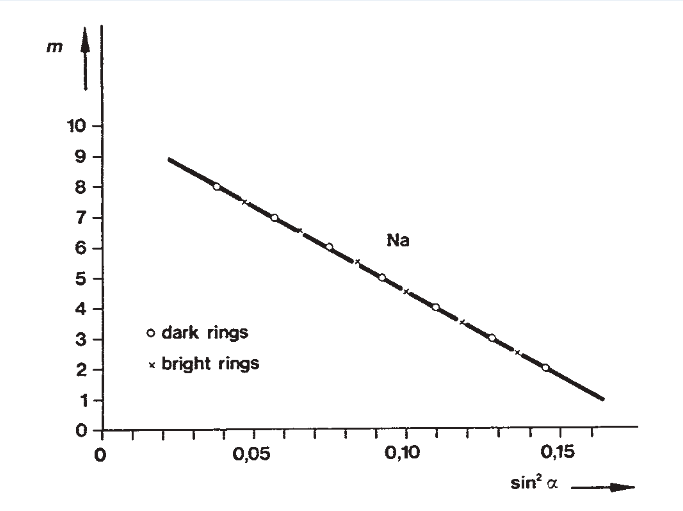
Principle:

Monochromatic light falls on a plane parallel mica plate. The light rays, reflected at the front surface as well as at the rear surface, will interfere to form a pattern of concentric rings. The radii of the rings depend on the geometry of the experimental set-up, the thickness of the mica plate and the wavelength of the light.

What you need:

Mica plate	08558.00	1
Colour filter, 440 nm	08411.00	1
Colour filter, 525 nm	08414.00	1
Colour filter, 580 nm	08415.00	1
Spectral lamp Hg 100, pico 9 base	08120.14	1
Spectral lamp Na, pico 9 base	08120.07	1
Lamp holder, pico 9, for spectral lamps	08119.00	1
Swinging arm	08256.00	2
Plate holder with tension spring	08288.00	2
Screen, metal, 300 mm x 300 mm	08062.00	2
Stand tube	02060.00	2
Optical profile bench, l = 600 mm	08283.00	1
Base for optical profile bench, adjustable	08284.00	2
Slide mount for optical profil bench, h = 80 mm	08286.02	2
Bench clamp -PASS-	02010.00	2
Measuring tape, l = 2 m	09936.00	1
Power supply for spectral lamps	13662.97	1

Complete Equipment Set, Manual on CD-ROM included
Interference at a mica plate according to Pohl P2220300



Interference order m as a function of $\sin^2\alpha$ for Na-light.

Tasks:

The experiment will be performed with the light of a Na-lamp and with the light of different wavelengths of a Hg-vapour tube.

1. The thickness of the mica plate is determined from the radii of the interference rings and the wavelength of the Na-lamp.
2. The different wavelengths of the Hg-vapour tube are determined from the radii of the interference rings and the thickness of the mica plate.

2.2.04-00 Fresnel's zone construction / zone plate

What you can learn about …

- ➔ Huygens-Fresnel principle
- ➔ Fresnel and Fraunhofer diffraction
- ➔ Interference
- ➔ Coherence
- ➔ Fresnel's zone construction
- ➔ Zone plates

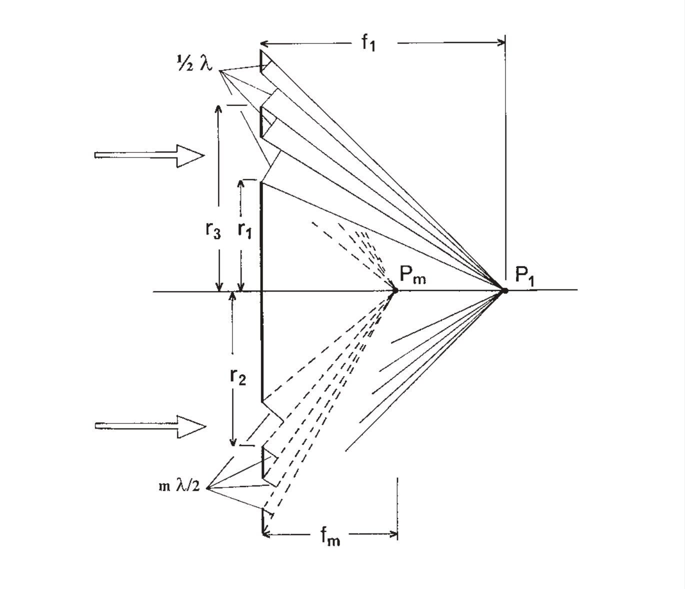
Principle:

A zone plate is illuminated with parallel laser light. The focal points of several orders of the zone plate are projected on a ground glass screen.

What you need:

Laser, He-Ne 1.0 mW, 230 VAC	08181.93	1
Fresnel zone plate, after Fresnel	08577.03	1
Lens holder	08012.00	4
Lens, mounted, f = +20 mm	08018.01	1
Lens, mounted, f = +50 mm	08020.01	1
Lens, mounted, f = +100 mm	08021.01	1
Lens, mounted, f = -50 mm	08026.01	1
Object holder 50 mm x 50 mm	08041.00	2
Ground glass screen, 50 mm d = 50 mm	08136.01	1
Polarisation filter, 50 mm, d = 50 mm	08613.00	1
Optical profile bench, l = 1000 mm	08282.00	1
Base for optical profile bench, adjustable	08284.00	2
Slide mount for optical profil bench, h = 30 mm	08286.01	7

Complete Equipment Set, Manual on CD-ROM included
Fresnel's zone construction / zone plate P2220400



Geometry of the zone plate.

Tasks:

1. The laser beam must be widened so that the zone plate is well illuminated. It must be assured that the laser light beam runs parallel over several meters.
2. The focal points of several orders of the zone plate are projected on a ground glass screen. The focal lengths to be determined are plotted against the reciprocal value of their order.
3. The radii of the zone plate are calculated.

Michelson interferometer 2.2.05-00

What you can learn about …

- → Interference
- → Wavelength
- → Refractive index
- → Velocity of light
- → Phase
- → Virtual light source

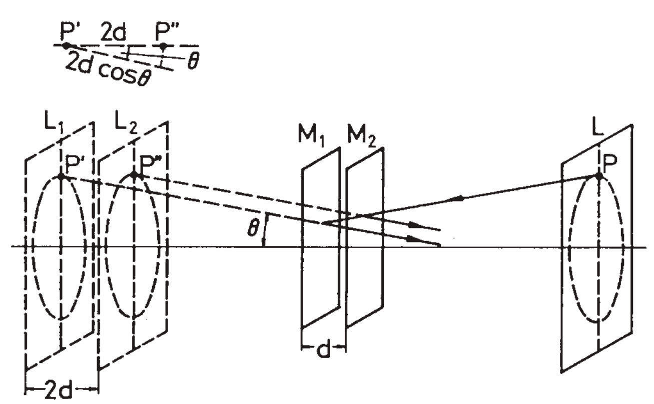
Principle:

In the Michelson arrangement interference will occur by the use of 2 mirrors. The wavelength is determined by displacing one mirror using the micrometer screw.

What you need:

Michelson interferometer	08557.00	1
Laser, He-Ne 1.0 mW, 230 VAC	08181.93	1
Swinging arm	08256.00	1
Lens, mounted, f = +20 mm	08018.01	1
Lens mounted, f = +5 mm	08017.01	1
Lens holder	08012.00	1
Slide mount for optical profil bench, h = 30 mm	08286.01	3
Optical profile bench, l = 600 mm	08283.00	1
Base for optical profile bench, adjustable	08284.00	2
Screen, metal, 300 mm x 300 mm	08062.00	1
Barrel base -PASS-	02006.55	1

Complete Equipment Set, Manual on CD-ROM included
Michelson interferometer P2220500



Formation of circles on interference.

Tasks:

Determination of the wavelength of the light of the used laser.

2.2.05-05 Michelson interferometer with optical base plate

What you can learn about …

- ➔ Interference
- ➔ Wavelength
- ➔ Refraction index
- ➔ Light velocity
- ➔ Phase
- ➔ Virtual light source
- ➔ Coherence

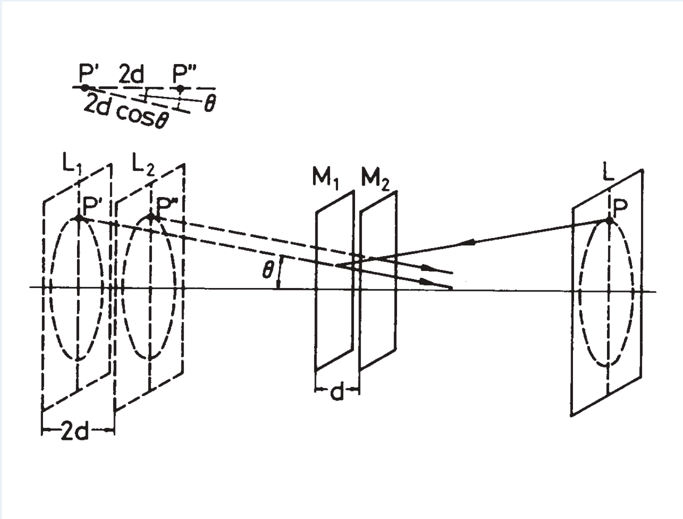
Principle:

In a Michelson interferometer, a light beam is split into two partial beams by a semi transparent glass plate (amplitude splitting). These beams are reflected by two mirrors and brought to interference after they passed through the glass plate a second time.

What you need:

Optical base plate with rubber feet	08700.00	1
He-Ne-laser, 5 mW with holder*	08701.00	1
Power supply for laser head 5 mW*	08702.93	1
Adjusting support 35×35 mm	08711.00	1
Surface mirror 30×30 mm	08711.01	1
Magnetic foot for optical base plate	08710.00	4
Michelson interferometer	08557.00	1
Achromatic objective 20× N.A. 0.45	62174.20	1
Pinhole 30 micron	08743.00	1
Sliding device, horizontal	08713.00	1
xy shifting device	08714.00	2
Adapter ring device	08714.01	1
Screen, white, 150×150 mm	09826.00	1
*Alternative to laser 5 mW, power supply and shutter:		
Laser, He-Ne 0.2/1.0 mW, 220 V AC	08180.93	1
or		
Diodelaser 0.2/1 mW; 635 nm	08760.99	1

Complete Equipment Set, Manual on CD-ROM included
Michelson interferometer with optical base plate P2220505



Formation of interference rings.

Tasks:

The wavelength of the used laser light is determined through the observation of the change in the interference pattern upon changing the length of one of the interferometer arms.

Coherence and width of spectral lines with Michelson interferometer 2.2.06-00

What you can learn about ...

- ➔ Fraunhofer and Fresnel diffraction
- ➔ Interference
- ➔ Spatial and time coherence
- ➔ Coherence conditions
- ➔ Coherence length for non punctual light sources
- ➔ Coherence time
- ➔ Spectral lines (shape and half width value)
- ➔ Broadening of lines due to Doppler effect and pressure broadening
- ➔ Michelson interferometer
- ➔ Magnification

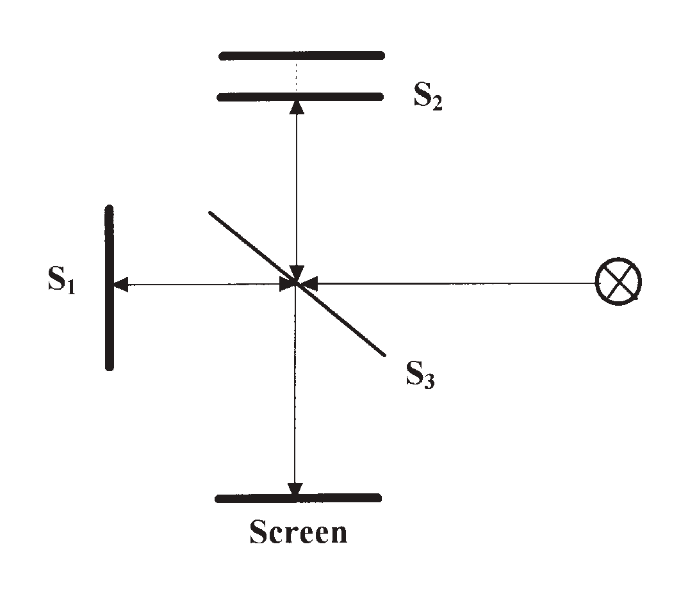
Principle:

The wavelengths and the corresponding lengths of coherence of the green spectral lines of an extreme high pressure Hg vapour lamp are determined by means of a Michelson interferometer.

What you need:

Michelson Interferometer	08557.00	1
High pressure mercury vapour lamp CS 50 W	08144.00	1
Power supply for Hg-CS/50 W Lamp	13661.97	1
Optical profile bench, l = 100 cm	08282.00	1
Base for optical profile bench	08284.00	2
Slide mount, h = 30 mm	08286.01	5
Lens holder	08012.00	3
Object holder 50 x 50 mm	08041.00	1
Swingin arm	08256.00	1
Barrel base -PASS-	02006.55	2
Stand tube	02060.00	2
Mounted lens f = 20 mm	08018.01	1
Mounted lens f = 200 mm	08024.01	1
Iris diaphragm	08045.00	1
Coloured filter, green, 525 nm	08414.00	1
Ground-glass screen 50 x 50 mm	08136.01	1
Diaphragm holder, attachable	11604.09	1
Measuring magnifier	09831.00	1
Slit, adjustable up to 1 mm	11604.07	1
Diaphragm with 4 double slits	08523.00	1

Complete Equipment Set, Manual on CD-ROM included
Coherence and width of spectral lines with Michelson interferometer P2220600



Beam path in Michelson's interferometer.

Different double slit combinations are illuminated to verify the coherence conditions of non punctual light sources. An illuminated auxiliary adjustable slit acts as a non punctual light source.

Tasks:

1. Determination of the wavelength of the green Hg spectral line as well as of its coherence length.
2. The values determined in 1. are used to calculate the coherence time and the half width value of the spectral line.
3. Verification of the coherence condition for non punctual light sources.

2.2.07-00 Determination index of air and CO_2 with Michelson interferometer

What you can learn about ...

- ➔ Interference
- ➔ Wavelength
- ➔ Phase
- ➔ Refraction index
- ➔ Light velocity
- ➔ Virtual light source

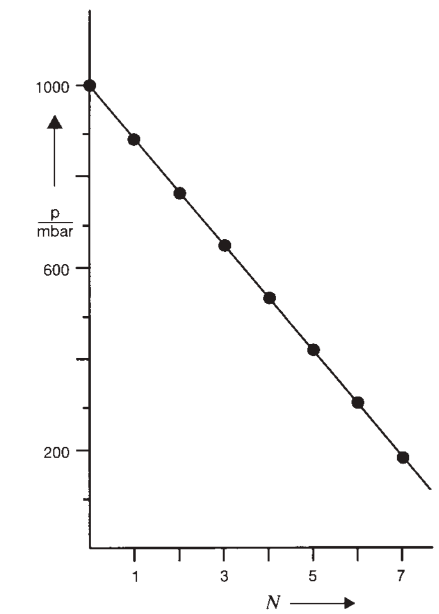
Principle:

A measurement cuvette set in the beam path of a Michelson interferometer can be evacuated or filled with CO_2. The refraction indexes of air or CO_2 are determined through the assessed modification of the interference pattern.

What you need:

Michelson interferometer	08557.00	1
Laser, He-Ne 1.0 mW, 230 VAC	08181.93	1
Glass cell, diam. 21,5 mm	08625.00	1
Manual vacuum pump with manometer	08745.00	1
Optical profile bench, l = 600 mm	08283.00	1
Base for optical profile bench, adjustable	08284.00	2
Slide mount for optical profil bench, h = 30 mm	08286.01	3
Slide mount for optical profil bench, h = 80 mm	08286.02	1
Swinging arm	08256.00	1
Lens holder	08012.00	1
Lens mounted, f = +5 mm	08017.01	1
Compressed gas, CO_2, 21 g	41772.06	1
Fine control valve for pressure bottles	33499.00	1
Right angle clamp -PASS-	02040.55	1
Barrel base -PASS-	02006.55	1
Screen, metal, 300 mm x 300 mm	08062.00	1
Tubing connect., Y-shape, d = 8-9 mm	47518.03	1
PVC tubing, d = 7 mm	03985.00	1

Complete Equipment Set, Manual on CD-ROM included
Determination index of air and CO_2 with Michelson interferometer — P2220700



Number N of minima changes as a function of air pressure in the measuring cuvette.

Determination of the index of refraction of CO_2 with Michelson's interferometer with optical base plate 2.2.07-05

What you can learn about …

- ➔ Interference
- ➔ Wavelength
- ➔ Index of refraction
- ➔ Light velocity
- ➔ Phase
- ➔ Virtual light source
- ➔ Coherence

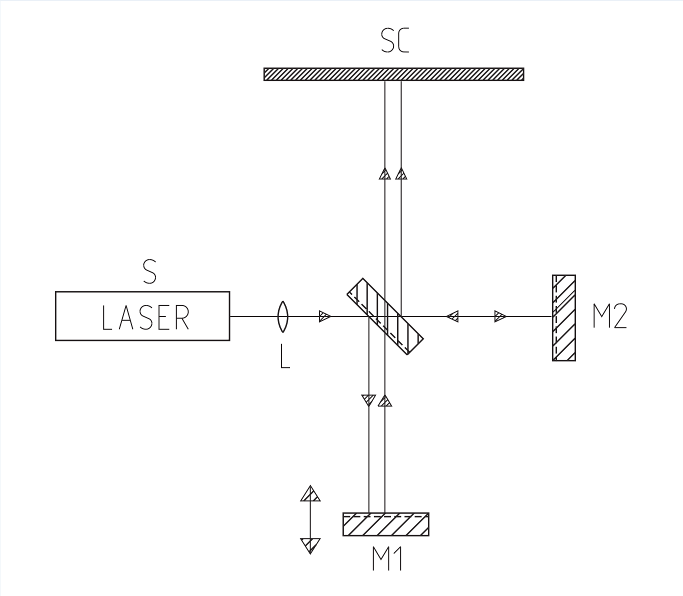
Principle:

Light is caused to interfere by means of a beam splitter and two mirrors according to Michelson's set up. Substituting the air in a measurement cuvette located in one of the interferometer arms by CO_2 gass allows to determine the index of refraction of CO_2.

What you need:

Optical base plate with rubber feet	08700.00	1
He-Ne-laser, 5 mW with holder*	08701.00	1
Power supply for laser head 5 mW*	08702.93	1
Adjusting support 35×35 mm	08711.00	1
Surface mirror 30×30 mm	08711.01	1
Magnetic foot for optical base plate	08710.00	5
Michelson interferometer	08557.00	1
Achromatic objective 20× N.A. 0.45	62174.20	1
Pinhole 30 micron	08743.00	1
Sliding device, horizontal	08713.00	1
xy shifting device	08714.00	2
Adapter ring device	08714.01	1
Screen, white, 150×150 mm	09826.00	1
Glass cell, diameter 21.5 mm	08625.00	1
Compressed gas, CO_2, 21 g	41772.06	1
Pipette, with rubber bulb	64701.00	1
Universal clamp with joint	37716.00	1
Silicone tubing, d = 5 mm	39297.00	1
*Alternative to laser 5 mW, power supply and shutter:		
Laser, He-Ne 0.2/1.0 mW, 220 V AC	08180.93	1
or		
Diodelaser 0.2/1 mW; 635 nm	08760.99	1

Complete Equipment Set, Manual on CD-ROM included
Determination of the index of refraction of CO_2 with Michelson's interferometer with optical base plate **P2220705**



Michelson's set up for interference.

Tasks:

A Michelson Interferometer is set up and adjusted so that interference rings can be observed. CO_2 gas is filled into a measurement cuvette that was filled before with air. From changes in the interference pattern the difference of the refraction index between air and CO_2 is determined.

2.2.09-00 Michelson interferometer – High Resolution

What you can learn about …

- ➔ Interference
- ➔ Wavelength
- ➔ Diffraction index
- ➔ Speed of light
- ➔ Phase
- ➔ Virtual light source

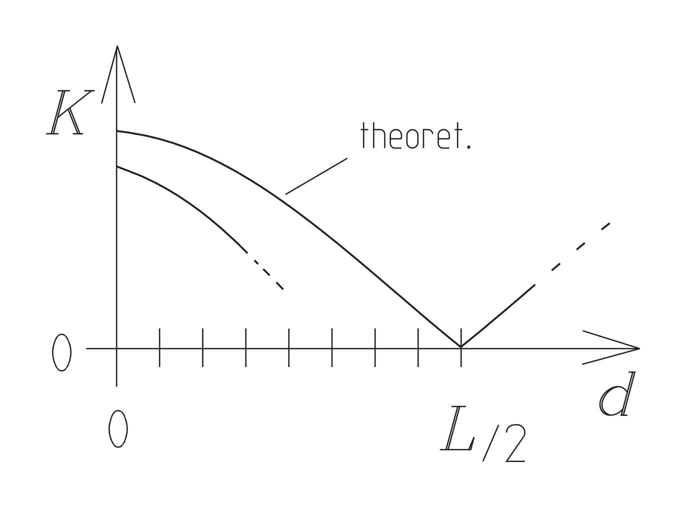
Principle:

With the aid of two mirrors in a Michelson arrangement, light is brought to interference. While moving one of the mirrors, the alteration in the interference pattern is observed and the wavelength of the laser light determined.

What you need:

Optical base plate with rubber feet	08700.00	1
He-Ne-laser, 5 mW with holder*	08701.00	1
Power supply for laser head 5 mW*	08702.93	1
Adjusting support 35×35 mm	08711.00	4
Surface mirror 30×30 mm	08711.01	4
Magnetic foot for optical base plate	08710.00	6
Holder for diaphragm/beam splitter	08719.00	1
Beam splitter 1/1, non polarizing	08741.00	1
Lens, mounted, f = +20 mm	08018.01	1
Lensholder for optical base plate	08723.00	1
Screen, white, 150×150 mm	09826.00	1
Interferometer plate with precision drive	08715.00	1
Photoelement for optical base plate	08734.00	1
Digital multimeter	07134.00	1
Flat cell battery, 9 V	07496.10	1
Measuring tape, l = 2 m	09936.00	1
*Alternative to laser 5 mW, power supply and shutter:		
Laser, He-Ne 0.2/1.0 mW, 220 V AC	08180.93	1

Complete Equipment Set, Manual on CD-ROM included
Michelson interferometer – High Resolution P2220900



Experimentally determined contrast function in comparison to the theoretical contrast function K of a 2-mode laser.

Tasks:

1. Construction of a Michelson interferometer using separate components.
2. The interferometer is used to determine the wavelength of the laser light.
3. The contrast function K is qualitatively recorded in order to determine the coherence length with it.

Doppler effect with the Michelson interferometer 2.2.10-00

What you can learn about …

- ➔ Interference
- ➔ Wavelength
- ➔ Diffraction index
- ➔ Speed of light
- ➔ Phase
- ➔ Virtual light source
- ➔ Temporal coherence
- ➔ Special relativity theory
- ➔ Lorentz transformation

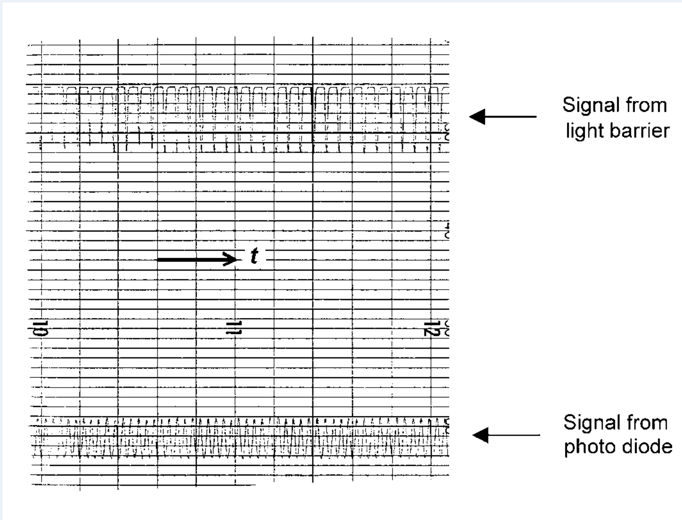
Principle:

With the aid of two mirrors in a Michelson arrangement, light is brought to interference. While moving one of the mirrors, the alteration in the interference pattern is observed and the modulation frequency is measured using the Doppler effect.

What you need:

Optical base plate with rubber feet	08700.00	1
He-Ne-laser, 5 mW with holder*	08701.00	1
Power supply for laser head 5 mW*	08702.93	1
Interferometer plate with precision drive	08715.00	1
Light barrier with counter	11207.30	1
Power supply 5 VDC/2.4 A	11076.99	1
Support	09906.00	1
Motor with gearing and cord pulley	08738.00	1
Perforated disk with driving belt	08738.01	1
Recorder, tY, 2 channel**	11415.95	1
Perforated disk with driving belt	08738.01	1
Connecting cord, l = 500 mm, red**	07361.01	2
Connecting cord, l = 500 mm, blue**	07361.04	2
Photoelement for optical base plate**	08734.00	1
Power supply 0-12 V DC/6 V,12 V AC	13505.93	1
Adjusting support 35×35 mm	08711.00	4
Surface mirror 30×30 mm	08711.01	4
Magnetic foot for optical base plate	08710.00	8
Support rod, stainless steel, 100 mm	02030.00	1
Holder for diaphragm/beam splitter	08719.00	1
Right angle clamp -PASS-	02040.55	1
Beam splitter 1/1, non polarizing	08741.00	1
Lens, mounted, f = +20 mm	08018.01	1
Lensholder for optical base plate	08723.00	1
Screen, white, 150×150 mm	09826.00	1
*Alternative to laser 5 mW, power supply and shutter:		
Laser, He-Ne 0.2/1.0 mW, 220 V AC	08180.93	1
**Alternative:		
Stop watch	03071.01	1

Complete Equipment Set, Manual on CD-ROM included
Doppler effect with the Michelson interferometer P2221000



Sample measurement with the y-t recorder.

Tasks:

1. Construction of a Michelson interferometer using separate components.
2. Measurement of the Doppler effect via uniform displacement of one of the mirrors.

2.2.11-00 Determination of the refraction index of air with the Mach-Zehnder interferometer

What you can learn about …

- ➔ Interference
- ➔ Wavelength
- ➔ Diffraction index
- ➔ Speed of light
- ➔ Phase
- ➔ Virtual light source

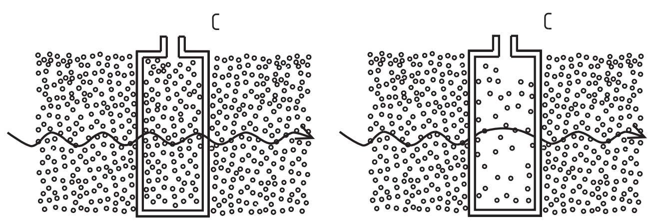
Principle:

Light is brought to interference by two mirrors and two beam splitters in the Mach-Zehnder arrangement. By changing the pressure in a measuring cell located in the beam path, one can deduce the refraction index of air.

What you need:

Optical base plate with rubber feet	08700.00	1
He-Ne-laser, 5 mW with holder*	08701.00	1
Power supply for laser head 5 mW*	08702.93	1
Magnetic foot for optical base plate	08710.00	10
Surface mirror 30×30 mm	08711.01	4
Adjusting support 35×35 mm	08711.00	4
Sliding device, horizontal	08713.00	1
xy shifting device	08714.00	2
Adapter ring device	08714.01	1
Pin hole 30 micron	08743.00	1
Achromatic objective 20× N.A. 0.45	62174.20	1
Holder for diaphragm/beam splitter	08719.00	2
Beam splitter 1/1, non polarizing	08741.00	2
Screen, white, 150×150 mm	09826.00	1
Glass cell, diameter 21.5 mm	08625.00	1
Manual vacuum pump with manometer	08745.00	1
Universal clamp with joint	37716.00	1
Tubing connector, T-shape, ID 8-9 mm	47519.03	1
Tubing adaptor, ID 3-6/7-11 mm	47517.01	1
Vacuum hose, d_i = 6 mm	39286.00	1
Silicone tubing, d_i = 3mm	39292.00	1
Glass cell holder on rod	08706.00	1
*Alternative to laser 5 mW, power supply and shutter:		
Laser, He-Ne 0.2/1.0 mW, 220 V AC	08180.93	1

Complete Equipment Set, Manual on CD-ROM included
Determination of the refraction index of air with the Mach-Zehnder interferometer P2221100



Schematic representation of the cell with normal pressure (a) and nearly absolute vacuum (b)

Tasks:

1. Construction of a Mach-Zehnder interferometer using individual optical components.
2. Measurement of the refraction index n of air by lowering the air pressure in a measuring cell.

Fabry-Perot interferometer – Determination of the laser light's wavelength 2.2.12-05

What you can learn about ...

- → Interference
- → Wavelength
- → Diffraction index
- → Speed of light
- → Phase
- → Virtual light source
- → Multibeam interferometer

Principle:

Two mirrors are assembled to form a Fabry-Perot interferometer. Using them, the multibeam interference of a laser's light beam is investigated. By moving one of the mirrors, the change in the interference pattern is studied and the wavelength of the laser's light determined.

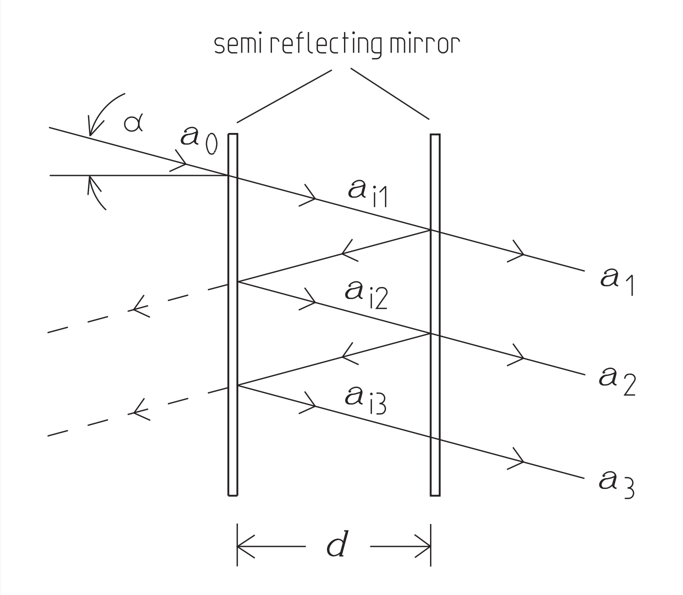
What you need:

Optical base plate with rubber feet	08700.00	1
He-Ne-laser, 5 mW with holder*	08701.00	1
Power supply for laser head 5 mW*	08702.93	1
Interferometer plate with precision drive	08715.00	1
Adjusting support 35×35 mm	08711.00	3
Surface mirror 30×30 mm	08711.01	3
Magnetic foot for optical base plate	08710.00	6
Holder for diaphragm/beam splitter	08719.00	2
Beam splitter 1/1, non polarizing	08741.00	1
Beam splitter T = 30, R = 70, with holder	08741.01	1
Lens, mounted, f = +20 mm	08018.01	1
Lensholder for optical base plate	08723.00	1
Screen, white, 150×150 mm	09826.00	1

*Alternative to laser 5 mW, power supply and shutter:

Laser, He-Ne 0.2/1.0 mW, 220 V AC	08180.93	1

Complete Equipment Set, Manual on CD-ROM included
Fabry-Perot interferometer – Determination of the laser lights's wavelength P2221205



Multibeam interferometer after Fabry and Perot. Illustration of the principle for deriving the individual amplitudes.

Tasks:

1. Construction of a Fabry-Perot interferometer using separate optical components.
2. The interferometer is used to determine the wavelength of the laser light.

2.2.12-06 Fabry-Perot interferometer – Optical resonator modes

What you can learn about …

- ➔ Interference
- ➔ Wavelength
- ➔ Diffraction index
- ➔ Speed of light
- ➔ Phase
- ➔ Virtual light source
- ➔ Two-beam interferometer

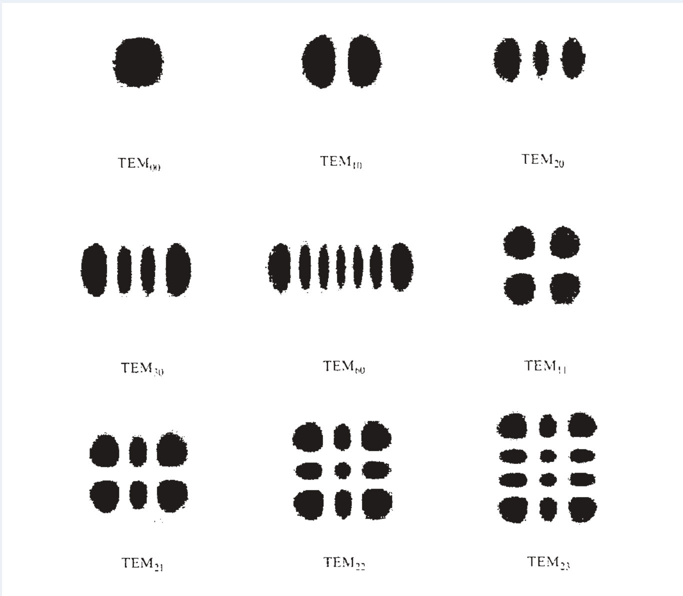
Principle:

Two mirrors are assembled to form a Fabry-Perot Interferometer. Using them, the multibeam interference of a laser's light beam is investigated. On moving one of the mirrors, the change in the intensity distribution of the interference pattern is studied. This is a qualitative experiment, to study the shape of different laser modes and compare it with some photos given in this description.

What you need:

Optical base plate with rubber feet	08700.00	1
Interferometer plate with precision drive	08715.00	1
He-Ne-laser, 5 mW with holder*	08701.00	1
Power supply for laser head 5 mW*	08702.93	1
Adjusting support 35×35 mm	08711.00	4
Surface mirror 30×30 mm	08711.01	2
Concave mirror OC; r = 1.4 m, T = 1.7%, mounted	08711.03	1
Plane mirror HR >99%, mounted	08711.02	1
Magnetic foot for optical base plate	08710.00	5
Lens, mounted, f = +20 mm	08018.01	1
Lensholder for optical base plate	08723.00	1
Screen, white, 150×150 mm	09826.00	1

Complete Equipment Set, Manual on CD-ROM included
Fabry-Perot interferometer – Optical resonator modes P2221206



Intensity distribution of the Hermitian-Gaussian resonator modes.

Tasks:

1. Construction of a Fabry-Perot interferometer using separate optical components.
2. The interferometer is used to observe different resonator modes within the interferometer.

Diffraction at a slit and Heisenberg's uncertainty principle 2.3.01-00

What you can learn about …

- → Diffraction
- → Diffraction uncertainty
- → Kirchhoff's diffraction formula
- → Measurement accuracy
- → Uncertainty of location
- → Uncertainty of momentum
- → Wave-particle dualism
- → De Broglie relationship

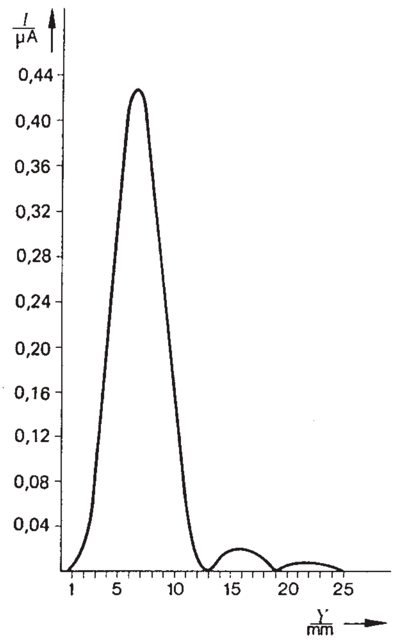
Principle:

The distribution of intensity in the Fraunhofer diffraction pattern of a slit is measured. The results are evaluated both from the wave pattern viewpoint, by comparison with Kirchhoff's diffraction formula, and from the quantum mechanics standpoint to confirm Heisenberg's uncertainty principle.

What you need:

Laser, He-Ne 1.0 mW, 230 VAC	08181.93	1
Diaphragm with 3 single slits	08522.00	1
Diaphragm holder for optical base plate	08040.00	1
Sliding device, horizontal	08713.00	1
Digital multimeter 2010	07128.00	1
Control Unit for Si-Photodetektor	08735.99	1
Adapter, BNC-plug/socket, 4 mm	07542.26	1
Optical profile bench, l = 1500 mm	08281.00	1
Base for optical profile bench, adjustable	08284.00	2
Slide mount for optical profil bench, h = 30 mm	08286.01	3
Connecting cable, 4 mm plug, 32 A, red, l = 50 cm	07361.01	1
Connecting cable, 4 mm plug, 32 A, blue, l = 50 cm	07361.04	1

Complete Equipment Set, Manual on CD-ROM included
Diffraction at a slit and Heisenberg's uncertainly principle P2230100



Intensity in the diffraction pattern of a 0.1 mm wide slit at a distance of 1140 mm. The photocurrent is plotted as a function of the position.

Tasks:

1. To measure the intensity distribution of the Fraunhofer diffraction pattern of a single slit (e.g. 0.1 mm).
   The heights of the maxima and the positions of the maxima and minima are calculated according to Kirchhoff's diffraction formula and compared with the measured values.
2. To calculate the uncertainty of momentum from the diffraction patterns of single slits of differing widths and to confirm Heisenberg's uncertainty principle.

2.3.02-00 Diffraction of light at a slit and an edge

What you can learn about …

- Intensity
- Fresnel integrals
- Fraunhofer diffraction

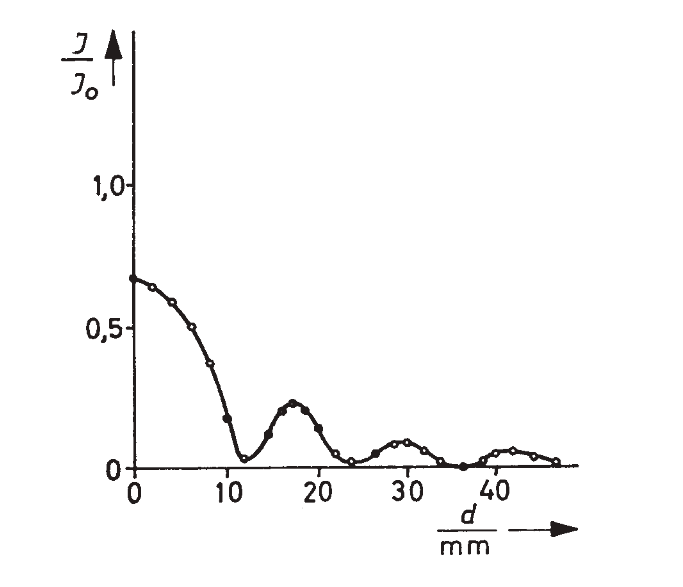
Principle:

Monochromatic light is incident on a slit or an edge. The intensity distribution of the diffraction pattern is determined.

What you need:

Laser, He-Ne 1.0 mW, 230 VAC	08181.93	1
Lens holder	08012.00	1
Lens, mounted, f = -50 mm	08026.01	1
Slit, adjustable	08049.00	1
Screen, metal, 300 mm x 300 mm	08062.00	1
Barrel base -PASS-	02006.55	4
Meter Scale, l = 1000 x 27 mm	03001.00	1
G-clamp	02014.00	1
Measuring tape, l = 2 m	09936.00	1
Si-Photodetector with amplifier	08735.00	1
Control unit for Si-Photodetector	08735.99	1
Digital multimeter 2010	07128.00	1
Connecting cord, l = 75 cm, red	07362.01	1
Connecting cord, l = 75 cm, blue	07362.04	1

Complete Equipment Set, Manual on CD-ROM included
Diffraction of light at a slit and an edge P2230200



Intensity distribution on diffraction at the slit, as a function of the position along a straight line parallel to the plane of the slit, standardised on the intensity without the slit.

Tasks:

1. Measurement of the width of a given slit.
2. Measurement of the intensity distribution of the diffraction pattern of the slit and
3. of the edge.

Intensity of diffractions due to pin hole diaphragms and circular obstacles 2.3.03-00

What you can learn about …

- Huygens principle
- Interference
- Fraunhofer and Fresnel diffraction
- Fresnel's zone construction
- Coherence
- Laser
- Airy disk
- Airy ring
- Poisson's spot
- Babinet's theorem
- Bessel function
- Resolution of optical instruments

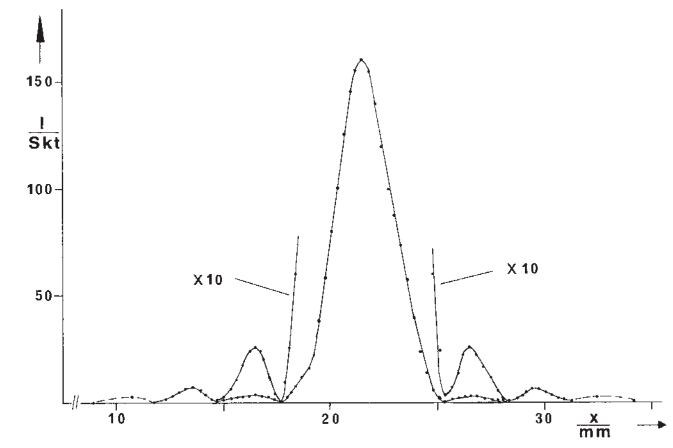
Principle:

Pin hole diaphragms and circular obstacles are illuminated with laser light. The resulting intensity distributions due to diffraction are measured by means of a photo diode.

What you need:

Laser, He-Ne 1.0 mW, 230 VAC	08181.93	1
Si-Photodetector with amplifier	08735.00	1
Control unit for Si-Photodetector	08735.99	1
Optical profile bench, l = 1500 mm	08281.00	1
Base for optical profile bench, adjustable	08284.00	2
Slide mount for optical profil bench, h = 30 mm	08286.01	4
Sliding device, horizontal	08713.00	1
Object holder 50 mm x 50 mm	08041.00	1
Screen, metal, 300 mm x 300 mm	08062.00	1
Screen with diffracting elements	08577.02	1
Digital multimeter 2010	07128.00	1
Connecting cable, 4 mm plug, 32 A, red, l = 75 cm	07362.01	1
Connecting cable, 4 mm plug, 32 A, blue, l = 75 cm	07362.04	1

Complete Equipment Set, Manual on CD-ROM included
Intensity of diffractions due to pin hole diaphragms and circular obstacles P2230300



Diffracted intensity I vs position x of the photodiode, using a diaphragm with D_1 = 0.25 mm.

Tasks:

1. The complete intensity distribution of the diffraction pattern of a pin hole diaphragm (D_1 = 0.25 mm) is determined by means of a sliding photo diode. The diffraction peak intensities are compared with the theoretical values. The diameter of the pin hole diaphragm is determined from the diffraction angles of peaks and minima.
2. The positions and intensities of minima and peaks of a second pin hole diaphragm (D_2 = 0.5 mm) are determined. The diffraction peak intensities are compared with the theoretical values. The diameter of the pin hole diaphragm is determined.
3. The positions of minima and peaks of the diffraction patterns of two complementary circular obstacles (D^*_1 = 0.25 mm and D^*_2 = 0.5 mm) are determined. Results are discussed in terms of Babinet's Theorem.

2.3.04-00 Diffraction intensity of multiple slits and grids

What you can learn about …

- ➔ Huygens principle
- ➔ Interference
- ➔ Fraunhofer und Fresnel diffraction
- ➔ Coherence
- ➔ Laser

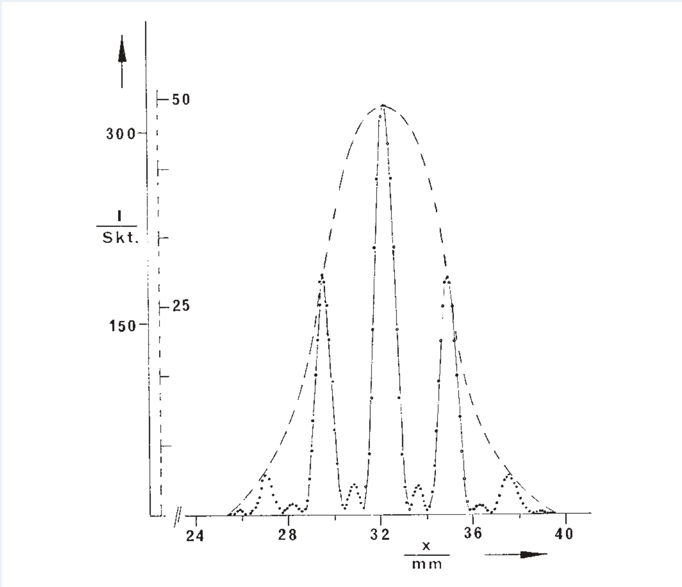
Principle:

Multiple slits which all have the same width and the same distance among each other, as well as transmission grids with different grid constants, are submitted to laser light. The corresponding diffraction patterns are measured according to their position and intensity, by means of a photo diode which can be shifted.

What you need:

Laser, He-Ne 1.0 mW, 230 VAC	08181.93	1
Si-Photodetector with amplifier	08735.00	1
Control unit for Si-Photodetector	08735.99	1
Optical profile bench, l = 1500 mm	08281.00	1
Base for optical profile bench, adjustable	08284.00	2
Slide mount for optical profil bench, h = 30 mm	08286.01	5
Sliding device, horizontal	08713.00	1
Lens holder	08012.00	2
Object holder 50 mm x 50 mm	08041.00	1
Lens, mounted, f = +20 mm	08018.01	1
Lens, mounted, f = +100 mm	08021.01	1
Diaphragm with 3 single slits	08522.00	1
Diaphragm with 4 multiple slits	08526.00	1
Diffraction grating, 4 lines/mm	08532.00	1
Diffraction grating, 8 lines/mm	08534.00	1
Diffraction grating,10 lines/mm	08540.00	1
Diffraction grating, 50 lines/mm	08543.00	1
Digital multimeter 2010	07128.00	1
Connecting cable, 4 mm plug, 32 A, red, l = 75 cm	07362.01	1
Connecting cable, 4 mm plug, 32 A, blue, l = 75 cm	07362.04	1

Complete Equipment Set, Manual on CD-ROM included
Diffraction intensity of multiple slits and grids P2230400



Diffraction intensity I as a function of the position x for a threefold slit, b_1 = 0.1 mm and g = 0.25 mm. Distance between threefold slit and photocell: L = 107 cm. For comparison, the intensity distribution of a single slit, b = 0.1 mm, is entered as a dotted line.

Tasks:

1. The position of the first intensity minimum due to a single slit is determined, and the value is used to calculate the width of the slit.
2. The intensity distribution of the diffraction patterns of a threefold, fourfold and even a fivefold slit, where the slits all have the same widths and the same distance among each other, is to be determined. The intensity relations of the central peaks are to be assessed.
3. For transmission grids with different lattice constants, the position of the peaks of several orders of diffraction is to be determined, and the found value used to calculate the wavelength of the laser light.

Diffraction of light through a double slit or by a grid with optical base plate 2.3.04-05

What you can learn about …

- → Fraunhofer diffraction
- → Huygens' principle
- → Interference
- → Coherence

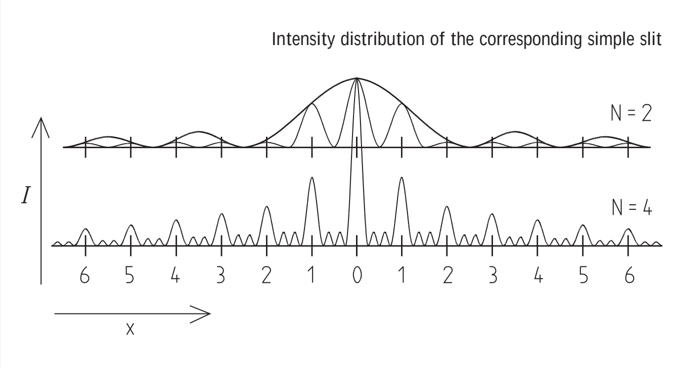
Principle:

The coherent monochromatic light of a laser is directed to a diaphragm with a varying number of slits. The resulting interference patterns are studied using a photoelement.

What you need:

Optical base plate with rubber feet	08700.00	1
He-Ne-laser, 5 mW with holder*	08701.00	1
Power supply for laser head 5 mW*	08702.93	1
Adjusting support 35×35 mm	08711.00	1
Surface mirror 30×30 mm	08711.01	1
Magnetic foot for optical base plate	08710.00	3
Diaphragm holder for optical base plate	08724.00	1
Diaphragm, 4 double slits	08523.00	1
Diaphragm, 4 multiple slits	08526.00	1
Photoelement for optical base plate**	08734.00	1
Sliding device, horizontal	08713.00	1
Universal measuring amplifier**	13626.93	1
Voltmeter, 0.3-300 VDC, 10-300 VAC	07035.00	1
Connecting cord, l = 500 mm, red**	07361.01	2
*Alternative to laser 5 mW, power supply and shutter:		
Laser, He-Ne 0.2/1.0 mW, 220 V AC	08180.93	1
or		
Diodelaser 0.2/1 mW; 635 nm	08760.99	1
**Alternative:		
Si-Photodetector with amplifier	08735.00	1
Control Unit for Si-Photodetector	08735.99	1
Screened cable, BNC, l = 750 mm	07542.11	1
Adapter, BNC-socket/4mm plug pair	07542.27	1

Complete Equipment Set, Manual on CD-ROM included
Diffraction of light through a double slit or by a grid with optical base plate P2230405



Qualitative intensity distribution of diffraction through 2 and 4 slits, the distance x being normalised to λ/s. The intensity distribution of the simple slit has been represented with exaggerated height to give a clearer view.

Tasks:

The intensity distribution of diffraction patterns formed by multiple slits is measured using a photoelement. The dependence of this distribution from the slit widths the number of slits and the grid constant is investigated. The obtained curves are compared to the theoretical values.

2.3.05-00 Determination of the diffraction intensity at slit and double slit systems

What you can learn about …

- → Huygens principle
- → Interference
- → Fraunhofer and Fresnel diffraction
- → Coherence
- → Laser

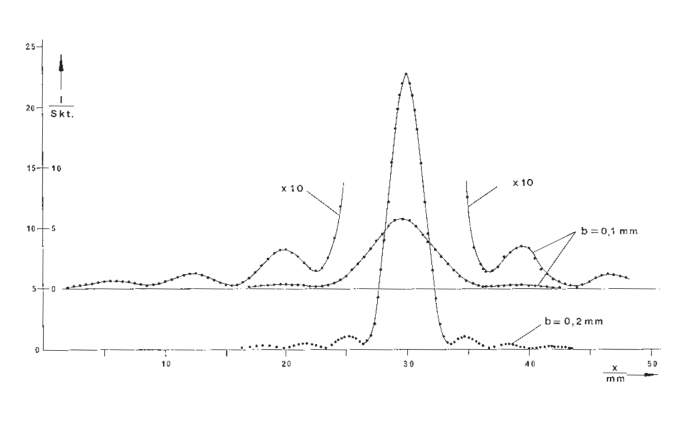
Principle:

Slit and double slit systems are illuminated with laser light. The corresponding diffraction patterns are measured by means of a photodiode which can be shifted, as a function of location and intensity.

What you need:

Laser, He-Ne 1.0 mW, 230 VAC	08181.93	1
Si-Photodetector with amplifier	08735.00	1
Control unit for Si-Photodetector	08735.99	1
Optical profile bench, l = 1500 mm	08281.00	1
Base for optical profile bench, adjustable	08284.00	2
Slide mount for optical profil bench, h = 30 mm	08286.01	5
Sliding device, horizontal	08713.00	1
Lens holder	08012.00	2
Object holder 50 mm x 50 mm	08041.00	1
Lens, mounted, f = +20 mm	08018.01	1
Lens, mounted, f = +100 mm	08021.01	1
Diaphragm with 3 single slits	08522.00	1
Diaphragm with 4 double slits	08523.00	1
Digital multimeter 2010	07128.00	1
Connecting cable, 4 mm plug, 32 A, red, l = 75 cm	07362.01	1
Connecting cable, 4 mm plug, 32 A, blue, l = 75 cm	07362.04	1

Complete Equipment Set, Manual on CD-ROM included
Determination of diffraction intensity at slit and double slit systems — P2230500



Diffraction intensity I as a function of location x for the single slit b_1 = 0.1 mm and b_2 = 0.2 mm.
The x axis of the graph for b_1 = 0.1 mm is shifted upwards. The intensity of the areas next to the central peak is represented enlarged by a factor of 10. (Distance between slit and photodiode L = 107 cm; λ = 632.8 nm).

Tasks:

1. Determination of the intensity distribution of the diffraction patterns due to two slits of different widths.
   The corresponding width of the slit is determined by means of the relative positions of intensity values of the extremes. Furthermore, intensity relations of the peaks are evaluated.
2. Determination of location and intensity of the extreme values of the diffraction patterns due to two double slits with the same widths, but different distances between the slits. Widths of slits and distances between the slits must be determined as well as the intensity relations of the peaks.

Diffraction intensity through a slit and a wire – Babinet's theorem 2.3.06-00

What you can learn about ...

- ➔ Huygens' principle
- ➔ Interference
- ➔ Fraunhofer und Fresnel diffraction
- ➔ Babinet's theorem
- ➔ Poissons' spot
- ➔ Coherence
- ➔ Laser

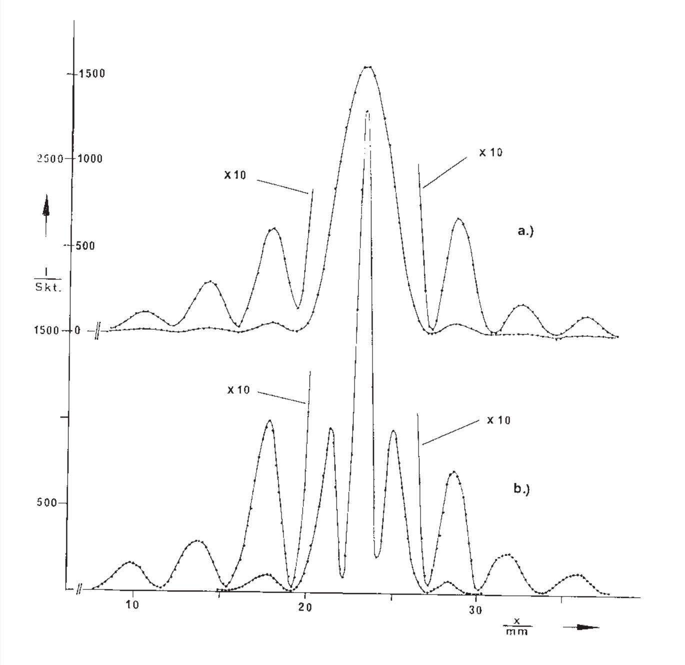
Principle:

An aperture consisting of a single slit and a complementary strip (wire) is illuminated with a laser beam. The corresponding diffraction patterns are measured according to position and intensity with a photocell which can be shifted.

What you need:

Laser, He-Ne 1.0 mW, 220 V AC	08181.93	1
Si-Photodetector with amplifier	08735.00	1
Control unit for Si-Photodetector	08735.99	1
Optical profile bench l = 150 cm	08281.00	1
Base f. opt. profile-bench, adjust.	08284.00	2
Slide mount f. opt. pr.-bench, h = 30 mm	08286.01	3
Slide device, horizontal	08713.00	1
Object holder, 5 x 5 cm	08041.00	1
Screen, with diffracting elements	08577.02	1
Digital multimeter 2010	07128.00	1
Connecting cable, l = 750 mm, red	07362.01	1
Connecting cable, l = 750 mm, blue	07362.04	1

Complete Equipment Set, Manual on CD-ROM included
Diffraction intensity through a slit and a wire – Babinet's theorem P2230600



Diffraction intensity I as a function of the position x for single slit a) and strip b). Width of the diffracting object b = 0.2 mm.
The intensities in the areas next to the central peak are represented extended by a factor of 10. (Distance between diffracting object and photocell L = 120 cm; Wavelength of the laser light λ = 632.8 nm)

Tasks:

1. Determination of the intensity distribution of the diffraction patterns due to a slit and complementary strip (wire).
2. Determination of the intensity relations of the diffraction pattern peaks for the single slit.
3. Babinet's theorem is discussed using the diffraction patterns of the slit and the complimentary strip.

2.3.06-05 Diffraction of light through a slit and stripes, Babinet's theorem

with optical base plate

What you can learn about …

- ➔ Fraunhofer interference
- ➔ Huygens' principle
- ➔ Multiple beam interference
- ➔ Babinet's theorem
- ➔ Coherence

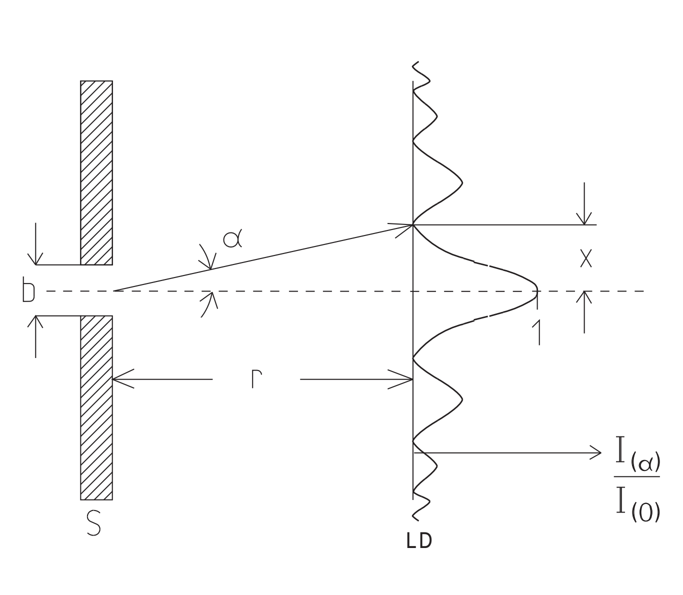
Principle:

Babinet's Principle states that the diffraction pattern for an aperture is the same as the pattern for an opaque object of the same shape illuminated in the same manner. That is the pattern produced by a diffracting opening of arbitrary shape is the same as a conjugate of the opening would produce.

What you need:

Optical base plate with rubber feet	08700.00	1
He-Ne-laser, 5 mW with holder*	08701.00	1
Power supply for laser head 5 mW*	08702.93	1
Adjusting support 35×35 mm	08711.00	1
Surface mirror 30×mm	08711.01	1
Magnetic foot for optical base plate	08710.00	3
Diaphragm holder for optical base plate	08724.00	1
Screen, with diffracting elements	08577.02	1
Sliding device, horizontal	08713.00	1
Photoelement for optical base plate**	08734.00	1
Universal measuring amplifier**	13626.93	1
Voltmeter, 0.3-300 VDC, 10-300 VAC	07035.00	1
Connecting cord, l = 500 mm, red**	07361.01	2
*Alternative to laser 5 mW, power supply and shutter:		
Laser, He-Ne 0.2/1.0 mW, 220 V AC	08180.93	1
or		
Diodelaser 0.2/1 mW; 635 nm	08760.99	1
**Alternative:		
Si-Photodetector with amplifier	08735.00	1
Control Unit for Si-Photodetector	08735.99	1
Screened cable, BNC, l = 750 mm	07542.11	1
Adapter, BNC-socket/4mm plug pair	07542.27	1

Complete Equipment Set, Manual on CD-ROM included
Diffraction of light through a slit and stripes, Babinet's theorem with optical base plate P2230605



Principle of set up for diffraction through a slit and qualitative distribution on intensities $I(\alpha)\ I_0$ in the detector plane LD.

Tasks:

Babinet's theorem is verified by the diffraction pattern of monochromatic light directed through a slit and an opaque stripe complementary to the latter. The experiment is also performed with a circular aperture and an opaque obstacle conjugate to this opening.

Photometric law of distance 2.4.02-01

What you can learn about ...

- → Luminous flux
- → Quantity of light
- → Luminous intensity
- → Illuminance
- → Luminance

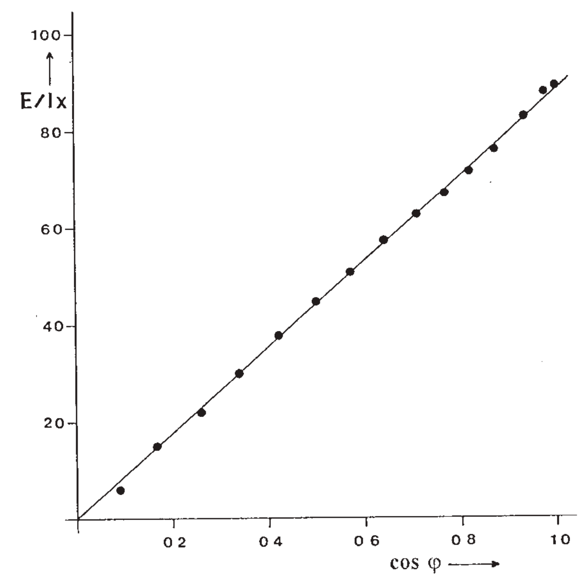
Principle:

The luminous intensity emitted by a punctual source is determined as a function of distance.

What you need:

Hand held measuring instrument Lux, RS 232	07137.00	1
Luxmeter probe	12107.01	1
Optical profile bench, l = 600 mm	08283.00	1
Base for optical profile bench, adjustable	08284.00	2
Slide mount for optical profil bench, h = 30 mm	08286.01	1
Slide mount for optical profil bench, h = 80 mm	08286.02	1
Lamp socket E 14, on stem	06175.00	1
Filament lamps, 6 V/5 A, E14	06158.00	1
Power supply 0-12 V DC/ 6 V, 12 V AC	13505.93	1
Universal clamp	37718.00	1

Complete Equipment Set, Manual on CD-ROM included
Photometric law of distance P2240201



Illuminance as a function of the reciprocal values of the square of the distances.

Tasks:

1. The luminous intensity emitted by a punctual source is determined as a function of distance from the source.
2. The photometric law of distance is verified by plotting illuminance as a function of the reciprocal value of the square of the distance.

2.4.02-11 Photometric law of distance with Cobra3

What you can learn about …

- ➔ Luminous flux
- ➔ Quantity of light
- ➔ Luminous intensity
- ➔ Illuminance
- ➔ Luminance

Principle:

The luminous intensity emitted by a punctual source is determined as a function of distance.

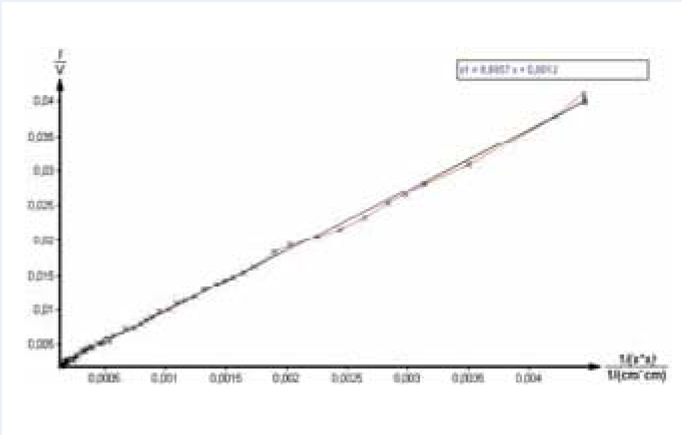
Experimental objective:

The luminous intensity is a function of the distance of the light sensor from the light source. The law for point light sources on which this is based should be determined.

What you need:

Cobra3 Basic-Unit, USB	12150.50	1
Power supply 12V/2A	12151.99	1
Software Cobra3 Force/Tesla	14515.61	1
Lamp socket E 14, on stem	06175.00	1
Filament lamps, 6 V/5 A	06158.00	1
Power supply 0-12 V DC/ 6 V, 12 V AC	13505.93	1
Stand tube	02060.00	2
Distributor	06024.00	1
Barrel base -PASS-	02006.55	2
Bench clamp -PASS-	02010.00	1
Meter Scale, l = 1000 x 27 mm	03001.00	1
Photo diode, G1	39119.01	1
Connecting cable, 4 mm plug, 32 A, red, l = 75 cm	07362.01	1
Connecting cable, 4 mm plug, 32 A, blue, l = 75 cm	07362.04	1
Carbon resistor 470 Ω, 1W, G1	39104.15	1
Movement sensor with cable	12004.10	1
Adapter BNC socket/4 mm plug pair	07542.27	1
Adapter, BNC socket - 4 mm plug	07542.20	1
Right angle clamp -PASS-	02040.55	1
Plate holder, opening width 0...10 mm	02062.00	1
Weight holder, 1g, silver bronzing	02407.00	1
Silk thread on spool, l = 200 mm	02412.00	1
PC, Windows® XP or higher		

Complete Equipment Set, Manual on CD-ROM included
Photometric law of distance with Cobra3 P2240211



Luminous intensity as a function of the square of the reciprocal of the distance (lamp – diode)

Tasks:

1. The luminous intensity emitted by a punctual source is determined as a function of distance from the source.
2. The photometric law of distance is verified by plotting illuminance as a function of the reciprocal value of the square of the distance.

Lambert's law 2.4.04-00

What you can learn about ...

- → Luminous flux
- → Light quantity
- → Light intensity
- → Illuminance
- → Luminance

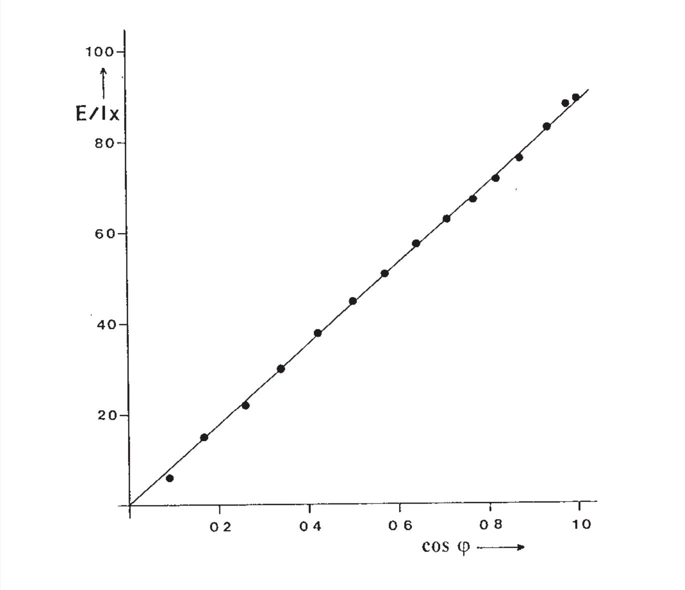
Principle:

Visible light impinges on a diffusely reflecting surface. The luminance of this surface is determined as a function of the angle of observation.

What you need:

Housing for experiment lamp	08129.01	1
Halogen lamp, 12 V/50 W	08129.06	1
Holder G 6.35 for 50/100 W halogen lamp	08129.04	1
Double condenser, f = 60 mm	08137.00	1
Lens holder	08012.00	1
Lens, mounted, f = +200 mm	08024.01	1
Zinc sulphide screen, 90 mm x 120 mm	08450.00	1
Right angle clamp -PASS-	02040.55	4
Tripod base -PASS-	02002.55	1
Barrel base -PASS-	02006.55	1
Stand tube	02060.00	1
Support rod, stainless steel 18/8, l = 100 mm	02030.00	1
Support rod -PASS-, square, l = 250 mm	02025.55	1
Support rod -PASS-, square, l = 1000 mm	02028.55	1
Articulated radial holder	02053.01	1
Graduated disk, for demonstration	02053.02	1
Universal clamp with joint	37716.00	1
Power supply 0-12 V DC/ 6 V, 12 V AC	13505.93	1
Luxmeter probe	12107.01	1
Hand held measuring instrument Lux, RS 232	07137.00	1

Complete Equipment Set, Manual on CD-ROM included
Lambert's law P2240400



Illuminance as a function of cos φ.

Tasks:

1. The luminous flux emitted reflected by a diffusely reflecting surface is to be determined as a function of the angle of observation.
2. Lambert's law (cos-law) is to be verified using the graph of the measurement values.

2.5.01-00 Polarisation by quarterwave plates

What you can learn about …

- Plane
- Circularly and elliptically polarised light
- Polariser
- Analyzer
- Plane of polarisation
- Double refraction
- Optic axis
- Ordinary and extraordinary ray

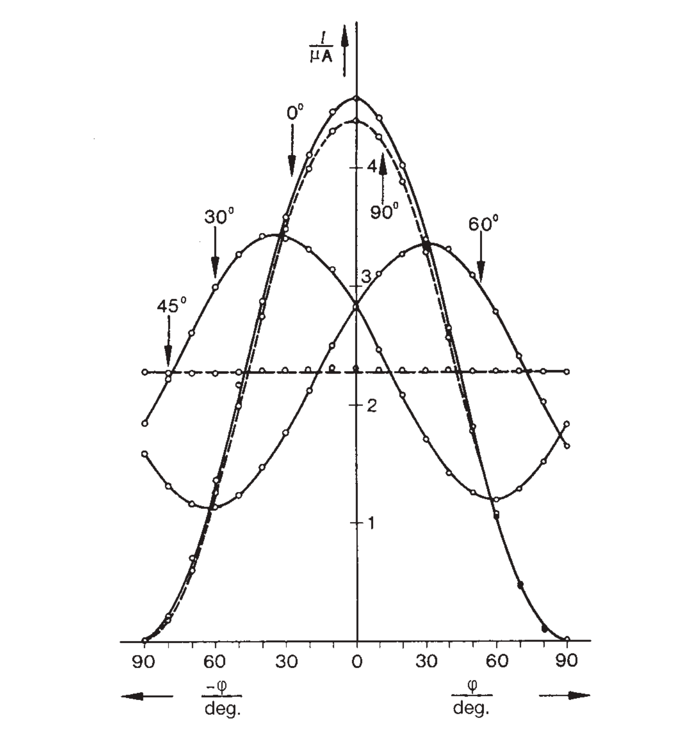
Principle:

Monochromatic light falls on a mica plate perpendicular to its optic axis. At the appropriate plate thickness ($\lambda/4$, or quarter-wave plate) there is a 90° phase shift between the ordinary and the extraordinary ray when the light emerges from the crystal. The polarisation of the emergent light is investigated at different angles between the optic axis of the $\lambda/4$ plate and the direction of polarisation of the incident light.

What you need:

Lens holder	08012.00	3
Lens, mounted, f = +100 mm	08021.01	1
Diaphragm holder for optical base plate	08040.00	2
Iris diaphragm	08045.00	1
Double condenser, f = 60 mm	08137.00	1
Condenser holder	08015.00	1
Mercury vapour high pressure lamp, 50 W	08144.00	1
Power supply 230V/50 Hz for 50 W Hg-lamp	13661.97	1
Interference filter yellow, 578 nm	08461.01	1
Polarisation filter on stem	08610.00	2
Optical profile bench, l = 1000 mm	08282.00	1
Base for optical profile bench, adjustable	08284.00	2
Slide mount for optical profil bench, h = 30 mm	08286.01	8
Slide mount for optical profil bench, h = 80 mm	08286.02	1
Polarisation specimen, mica	08664.00	2
Digital multimeter 2010	07128.00	1
Si-Photodetector with amplifier	08735.00	1
Control unit for Si-Photodetector	08735.99	1
Connecting cable, 4 mm plug, 32 A, red, l = 75 cm	07362.01	1
Connecting cable, 4 mm plug, 32 A, blue, l = 75 cm	07362.04	1

Complete Equipment Set, Manual on CD-ROM included
Polarisation by quarterwave plates P2250100



Intensity distribution of polarised light as a function of the direction of transmission of the analyser: with $\lambda/4$ plate at various angular settings.

Tasks:

1. To measure the intensity of plane-polarised light as a function of the position of the analyser.
2. To measure the light intensity behind the analyser as a function of the angle between the optic axis of the $\lambda/4$ plate and that of the analyser.
3. To perform experiment 2. with two $\lambda/4$ plates one behind the other.

Polarisation through λ/4 plates 2.5.01-05

What you can learn about …

- Linearly, circularly and elliptically polarised light
- Polarizer
- Analyser
- Plane of polarisation
- Malus' law
- Double refraction
- Optical axis
- Ordinary and extraordinary beam

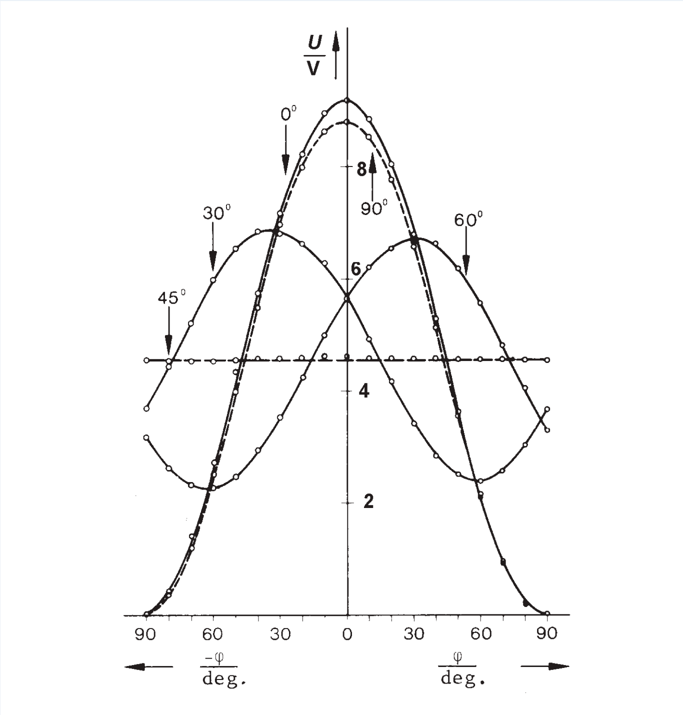
Principle:

Monochromatic light impinges on a mica plate, perpendicularly to its optical axis. If the thickness of the plate is adequate (λ/4 plate), a phase shift of 90° occurs between the ordinary and the extraordinary beam when the latter leaves the crystal. The polarisation of exiting light is examined for different angles between the optical axis of the λ/4 plate and the direction of polarisation of incident light.

What you need:

Optical base plate with rubber feet	08700.00	1
He-Ne-laser, 5 mW with holder*	08701.00	1
Power supply for laser head 5 mW*	08702.93	1
Adjusting support 35×35 mm	08711.00	1
Surface mirror 30×30 mm	08711.01	1
Magnetic foot for optical base plate	08710.00	7
Lensholder for optical base plate	08723.00	1
Lens, mounted, f = +20 mm	08018.01	1
Diaphragm holder for optical base plate	08724.00	2
Polarizing filter for optical base plate	08730.00	2
Polarization specimen, mica	08664.00	2
Photoelement for optical base plate**	08734.00	1
Universal measuring amplifier**	13626.93	1
Voltmeter, 0.3-300 VDC, 10-300 VAC	07035.00	1
Connecting cord, l = 500 mm, red**	07361.01	2
*Alternative to laser 5 mW, power supply and shutter:		
Laser, He-Ne 0.2/1.0 mW, 220 V AC	08180.93	1
or		
Diodelaser 0.2/1 mW; 635 nm	08760.99	1
**Alternative:		
Si-Photodetector with amplifier	08735.00	1
Control Unit for Si-Photodetector	08735.99	1
Screened cable, BNC, l = 750 mm	07542.11	1
Adapter, BNC-socket/4mm plug pair	07542.27	1

Complete Equipment Set, Manual on CD-ROM included
Polarisation through λ/4 plates P2250105



Intensity distribution of polarised light for different angles of the λ/4 plate, as a function of the analyser position.

Tasks:

1. Measurement of the intensity of linearly polarised light as a function of the analyser's position (Malus' law)
2. Measurement of the light intensity behind the analyser as a function of the angle between the optical axis of the λ/4 plate and the analyser.
3. Carrying out experiment (2) with two successive λ/4 plates.

2.5.02-00 Polarimetry

What you can learn about …

- ➔ Half-shade principle
- ➔ Optical rotatory power
- ➔ Optical activity
- ➔ Saccharimetry
- ➔ Specific rotation
- ➔ Reaction rate
- ➔ Weber-Fechner law

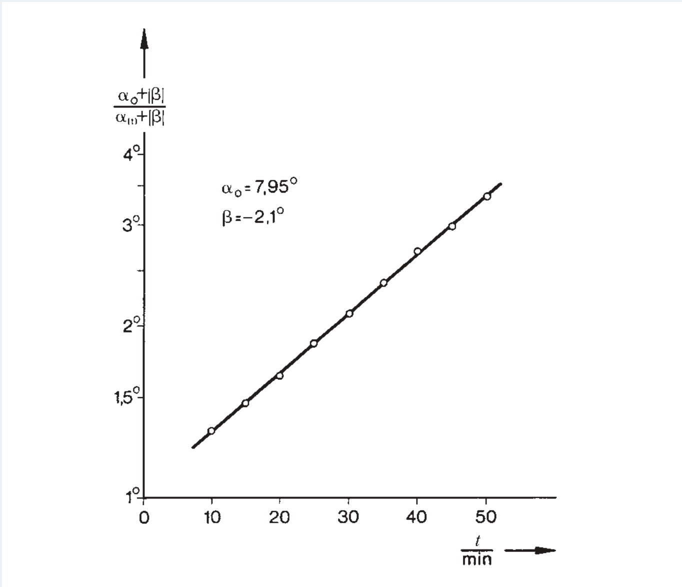
Principle:

The rotation of the plane of polarisation through a sugar solution measured with a half-shade penumbra polarimeter and the reaction rate constant for the inversion of cane sugar determined.

What you need:

Half-shade polarimeter, 230 V AC	35906.93	1
Immersion thermostat TC10	08492.93	1
Accessory set for TC10	08492.01	1
Bath for thermostat, Makrolon	08487.02	1
Stopwatch, digital, 1/100 s	03071.01	1
Crucible tongs, l = 200 mm, stainless steel	33600.00	1
Beaker, 250 ml, low form, plastic	36013.01	2
Graduated cylinder, 100 ml, plastic	36629.01	2
Graduated vessel, 1 l, with handle	36640.00	1
Funnel, plastic, d = 100 mm	36891.00	1
Spoon with spatula end, l = 180 mm, PA, wide	38833.00	1
Stirring rods, BORO 3.3, l = 300 mm, d = 8 mm	40485.06	1
Pipette, with rubber bulb, long	64821.00	1
D (+)-Sucrose, 100 g	30210.10	1
Hydrochloric acid 37 %, 1000 ml	30214.70	1
Water, distilled 5 l	31246.81	1
D(+)-Lactose, powder 100 g	31577.10	1
Balance LG 311, 4 beams	44007.31	1

Complete Equipment Set, Manual on CD-ROM included
Polarimetry P2250200



Semi-logarithmic plot of the measured values from cane sugar inversion.

Tasks:

1. To determine the specific rotation of cane sugar (sucrose) and lactose by measuring the rotation of various solutions of known concentration.
2. To determine the reaction rate constant when cane sugar is transformed into invert sugar.

Fresnel's equations – theory of reflection 2.5.03-00

What you can learn about …

- ➔ Electromagnetic theory of light
- ➔ Reflection coefficient
- ➔ Reflection factor
- ➔ Brewster's law
- ➔ Law of refraction
- ➔ Polarization
- ➔ Polarization level

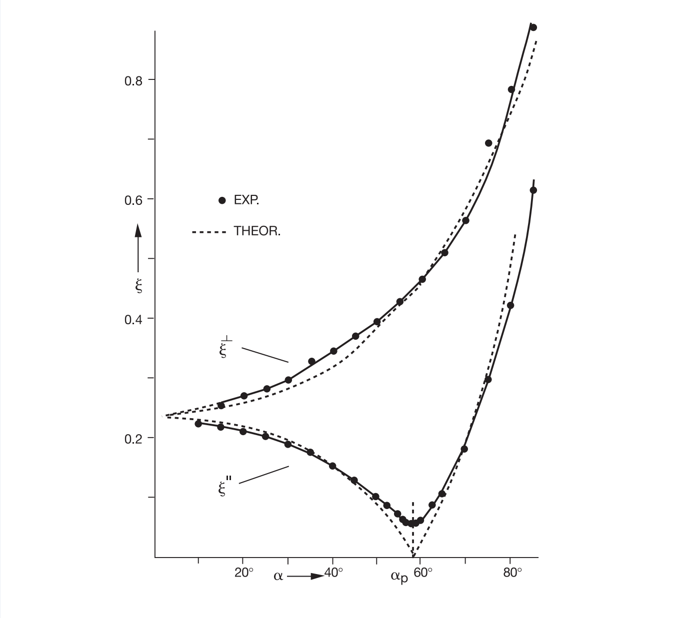
Principle:

Plane-polarized light is reflected at a glas surface. Both the rotation of the plane of polarization and the intensity of the reflected light are to be determined and compared with Frewsnel's formulae for reflection.

What you need:

Laser, He-Ne 1.0 mW, 230 VAC	08181.93	1
Polarisation filter on stem	08610.00	2
Prism, 60 degrees, h = 36 mm, flint	08237.00	1
Prism table with holder	08254.00	1
Si-Photodetector with amplifier	08735.00	1
Control unit for Si-Photodetector	08735.99	1
Digital multimeter 2010	07128.00	1
Connecting cord, 32 A, l = 750 mm, red	07362.01	1
Connecting cord, 32 A, l = 750 mm, blue	07362.04	1
Protractor scale with pointer	08218.00	1
Articulated radial holder	02053.01	1
Stand tube	02060.00	1
Tripod base -PASS-	02002.55	1
H-base -PASS-	02009.55	2
Right angle clamp -PASS-	02040.55	4
Support rod -PASS-, square, l = 250 mm	02025.55	1
Support rod -PASS-, square, l = 630 mm	02027.55	2

Complete Equipment Set, Manual on CD-ROM included
Fresnel's equations – theory of reflection P2250300



Measured and calculated curves forζ_r'' and $\zeta_r^{\perp}$ as a function of the angle of incidence.

Tasks:

1. The reflection coefficients for light polarized perpendicular and parallel to the plane of incidence are to be determined as a function of the angle of incidence and poltted graphically.
2. The refractive index of the flint glass prism is to be found.
3. The reflection coefficients are to be calculated using Fresnel's formulae and compared with the measured curves.
4. The reflection factor for the flint glass prism is to be calculated.
5. The rotation of the polarization plane for plane polarized light when reflected is to be determined as a function of the angle of incidence and presented graphically. It is then to be compared with values calculated using Fresnel's formulae.

2.5.04-00 Malus' law

What you can learn about …

- ➔ Electric theory of light
- ➔ Polarization
- ➔ Polarizer
- ➔ Analyzer
- ➔ Brewster's law
- ➔ Malus' law

Principle:

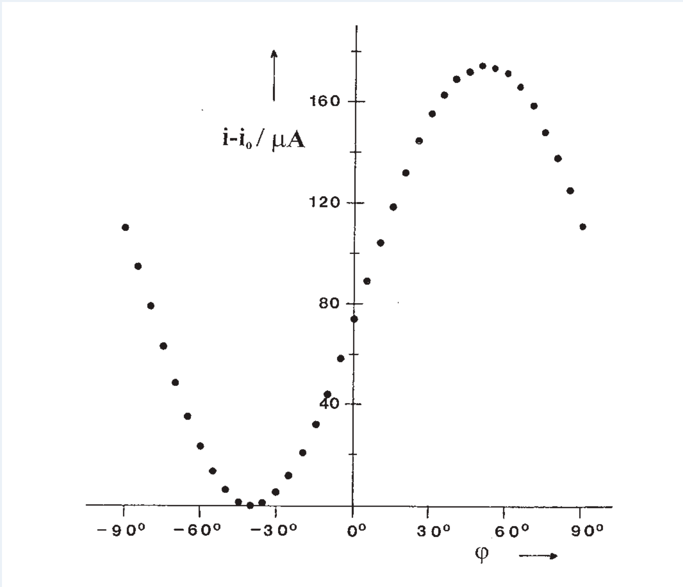
Linear polarized light passes through a polarization filter.

Transmitted light intensity is determined as a function of the angular position of the polarization filter.

What you need:

Laser, He-Ne 1.0 mW, 230 VAC	08181.93	1
Optical profile bench, l = 600 mm	08283.00	1
Base for optical profile bench, adjustable	08284.00	2
Slide mount for optical profil bench, h = 30 mm	08286.01	3
Polarisation filter on stem	08610.00	1
Photoelement for optical base plate	08734.00	1
Digital multimeter 2010	07128.00	1

Complete Equipment Set, Manual on CD-ROM included
Malu's law P2250400



Corrected photo cell current as a function of the angular position φ of the polarization plane of the analyzer.

Tasks:

1. The plane of polarization of a linear polarized laser beam is to be determined.
2. The intensity of the light transmitted by the polarization filter is to be determined as a function of the angular position of the filter.
3. Malus' law must be verified.

Faraday effect 2.6.01-00

What you can learn about ...

- ➔ Electromagnetic field interaction
- ➔ Electron oscillation
- ➔ Electromagnetism
- ➔ Polarization
- ➔ Verdet's constant
- ➔ Hall effect

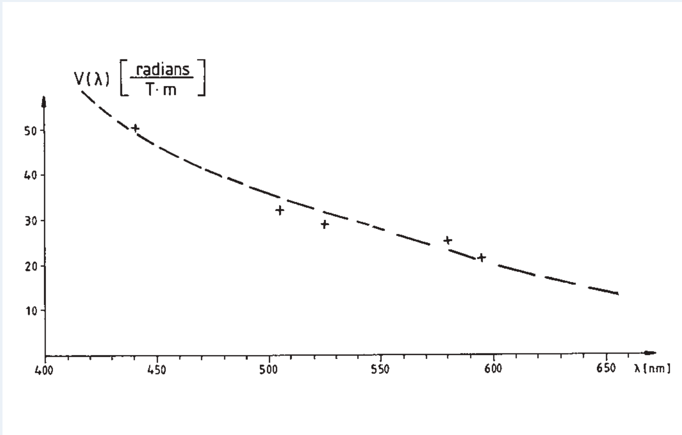
Principle:

The angle of rotation of the polarisation-plane of plane polarized light through a flint glass rod is found to be a linear function of the product of the mean flux-densitiy and the length of the optical medium. The factor of proportionally, called Verdet's constant, is investigated as a function of the wavelength and the optical medium.

What you need:

Glass rod for Faraday effect	06496.00	1
Coil, 600 turns	06514.01	2
Pole pieces, drilled	06495.00	1
Iron core, U-shaped, laminated	06501.00	1
Housing for experiment lamp	08129.01	1
Halogen lamp, 12 V/50 W	08129.06	1
Holder G 6.35 for 50/100 W halogen lamp	08129.04	1
Double condenser, f = 60 mm	08137.00	1
Variable transformer 25 V~/20 V-, 12 A	13531.93	1
Ampermeter, 1 mA...3 A DC/AC	07036.00	1
Commutator switch	06034.03	1
Teslameter, digital	13610.93	1
Hall probe, axial	13610.01	1
Lens, mounted, f = +150 mm	08022.01	1
Lens holder	08012.00	1
Table top on rod	08060.00	1
Object holder 50 mm x 50 mm	08041.00	1
Colour filter, 440 nm	08411.00	1
Colour filter, 505 nm	08413.00	1
Colour filter, 525 nm	08414.00	1
Colour filter, 580 nm	08415.00	1
Colour filter, 595 nm	08416.00	1
Polarisation filter with vernier	08611.00	2
Screen, translucent, 250 mm x 250 mm	08064.00	1
Optical profile bench, l = 1000 mm	08282.00	1
Base for optical profile bench, adjustable	08284.00	2
Slide mount for optical profil bench, h = 30 mm	08286.01	2
Slide mount for optical profil bench, h = 80 mm	08286.02	5
Universal clamp	37718.00	1
Connecting cable, 4 mm plug, 32 A, red, l = 75 cm	07362.01	3
Connecting cable, 4 mm plug, 32 A, blue, l = 75 cm	07362.04	3

Complete Equipment Set, Manual on CD-ROM included
Faraday effect P2260100



Verdet's constant as a function of the wavelength
+ measured values --- theoretical values.

Tasks:

1. To determine the magnetic flux-densitiy between the pole pieces using the axial Hall probe of the teslameter for different coil currents. The mean flux-density is calculated by numerical integration and the ratio maximum flux-density over mean flux-density established.
2. To measure the maximum flux-density as a function of the coil current and to establish the relationship between mean flux-density and coil current anticipating that the ratio found under 1. remains constant.
3. To determine the angle of rotation as a function of the mean flux-density using different colour filters. To calculate the corresponding Verdet's constant in each case.
4. To evaluate Verdet's constant as a function of the wavelength.

2.6.01-05 Faraday effect with optical base plate

What you can learn about …

- ➔ Interaction of electromagnetic fields
- ➔ Electronic oscillation
- ➔ Electromagnetism
- ➔ Polarisation
- ➔ Verdet's constant
- ➔ Malus' law

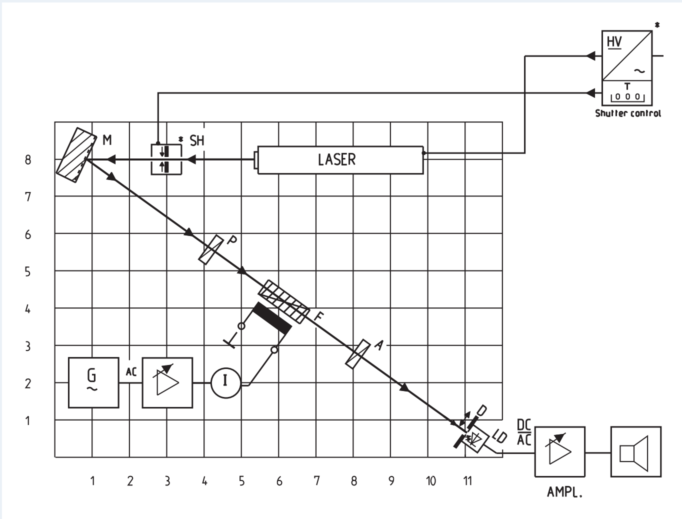
Principle:

The angle of rotation of the plane of polarisation of a linearly polarised light wave in a rod of flint glass appears to be a linear function of the average magnetic flow density and of the length of optical medium travelled through by the wave. The factor of proportionality is a medium specific constant and is called Verdet's constant.

What you need:

Optical base plate with rubber feet	08700.00	1
He-Ne-laser, 5 mW with holder*	08701.00	1
Power supply for laser head 5 mW*	08702.93	1
Adjusting support 35×35 mm	08711.00	1
Surface mirror 30×30 mm	08711.01	1
Magnetic foot for optical base plate	08710.00	5
Polarizing filter for optical base plate	08730.00	2
Faraday modulator for optical base plate	08733.00	1
Power frequency generator 1 MHz**	13650.93	1
Ammeter, 1 mA - 3 A DC/AC	07036.00	1
Photoelement for optical base plate***	08734.00	1
Universal measuring amplifier***	13626.93	1
Loudspeaker, 8 Ω/5 kΩ	13765.00	1
Screen, transparent with holder for optical base plate	08732.00	1
Connecting cord, l = 500 mm, red	07361.01	3
Connecting cord, l = 500 mm, blue	07361.04	2
*Alternative to laser 5 mW, power supply and shutter:		
Laser, He-Ne 0.2/1.0 mW, 220 V AC	08180.93	1
or		
Diodelaser 0.2/1 mW; 635 nm	08760.99	1
**Alternative:		
Radio and adapter plug		1
or		
Low frequency amplifier	13625.93	1
Function generator	13652.93	1
Connecting cord, l = 500 mm, red	07361.01	1
Connecting cord, l = 500 mm, blue	07361.04	1
*** Alternative:		
Si-Photodetector with amplifier	08735.00	1
Control Unit for Si-Photodetector	08735.99	1
Screened cable, BNC, l = 750 mm	07542.11	1
Adapter, BNC-socket/4mm plug pair	07542.27	1

Complete Equipment Set, Manual on CD-ROM included
Faraday effect with optical base plate P2260105



Experimental set up (* only required for 5 mW laser)

Tasks:

Qualitative investigation of the Faraday effect through observation of the electro optical modulation of the polarised laser light with frequencies in the acoustic range.

Recording and reconstruction of holograms 2.6.03-00

What you can learn about …

- ➔ Object beam
- ➔ Reference beam
- ➔ Real and virtual image
- ➔ Phase holograms
- ➔ Amplitude holograms
- ➔ Interference
- ➔ Diffraction
- ➔ Coherence
- ➔ Developing of film

Principle:

In contrast to normal photography a hologram can store information about the three-dimensionality of an object. To capture the three-dimensionality of an object, the film stores not only the amplitude but also the phase of the light rays. To achieve this, a coherent light beam (laser light) is split into an object and a reference beam by being passed through a beam splitter. These beams interfere in the plane of the holographic film. The hologram is reconstructed with the reference beam which was also used to record the hologram.

What you need:

Base plate in experimental case	08700.01	1
He/Ne Laser, 5mW with holder	08701.00	1
Power supply for laser head 5 mW	08702.93	1
Magnetic foot for optical base plate	08710.00	6
Holder for diaphragm/ beam plitter	08719.00	2
Sliding device, horizontal	08713.00	1
XY-shifting device	08714.00	2
Adapter ring device	08714.01	1
Achromatic objective 20 x N.A.0.4	62174.20	1
Pin hole 30 micron	08743.00	1
Adjusting support 35 x 35 mm	08711.00	2
Surface mirror 30 x 30 mm	08711.01	2
Surface mirror,large, d = 80 mm	08712.00	1
Beam plitter 1/1, non polarizing	08741.00	1
Object for holography	08749.00	1
Holographic plates, 20 pcs.*	08746.00	1
Darkroom equipment for holography	08747.88	1

consisting of:

Plastic trays, 4 pcs. • Laboratory gloves, medium, 100 pcs. • Tray thermometer, offset, +40°C • Roller squeegee • Clamps, 2 pcs. • Film tongs, 2 pcs. • Darkroom lamp with green filter • Light bulb 230 V/15 W • Funnel • Narrow-necked bottles, 4 pcs.

Set of photographic chemicals	08746.88	1

Consisting of: Holographic developer • Stop bath • Wetting agent • Laminate; Paint

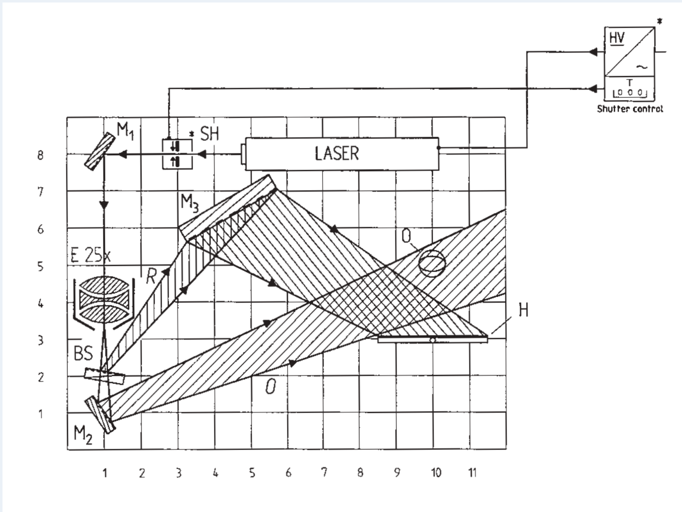
Bleaching chemicals:

Potassium dichromate, 250 g	30102.25	1
Sulphuric acid, 95-98%, 500 ml	30219.50	1

*Alternative:

Holographic sheet film	08746.01	1
Glass plate, 120 x 120 x 2 mm	64819.00	2

Complete Equipment Set, Manual on CD-ROM included
Recording and reconstruction of holograms P2260300



Setup for recording and reconstruction of a transmission hologram.

Tasks:

1. Capture the holographic image of an object.
2. Perform the development and bleaching of this phase hologram.
3. Reconstruct the transmission hologram (reconstruction beam is the reference beam during image capture).

2.6.03-05 Transfer hologram from a master hologram

What you can learn about ...

- ➔ Coherence of light
- ➔ Object/Reference beam
- ➔ Real and virtual image
- ➔ Phase conjugation
- ➔ Phase/Amplitude holograms
- ➔ Interference diffraction
- ➔ Developing of film

Principle:

After preparing a transmission hologram (master hologram) of an object, the reconstructed real image is used to illuminate a second holographic plate. Thereby a transfer hologram is prepared.

What you need:

Optical base plate in experiment case	08700.01	1
He-Ne-laser, 5 mW with holder	08701.00	1
Power supply for laser head 5 mW	08702.93	1
Magnetic foot for optical base plate	08710.00	6
Holder for diaphragm/beam splitter	08719.00	2
Sliding device, horizontal	08713.00	1
xy shifting device	08714.00	2
Achromatic objective 20× N.A. 0.45	62174.20	1
Pin hole 30 micron	08743.00	1
Adapter ring device	08714.01	1
Adjusting support 35×35 mm	08711.00	2
Surface mirror 30×30 mm	08711.01	2
Surface mirror, large, d = 80 mm	08712.00	1
Beam splitter 1/1, non polarizing	08741.00	1
Object for holography	08749.00	1
Holographic plates, 20 pieces*	08746.00	1
Darkroom equipment for holography	08747.88	1

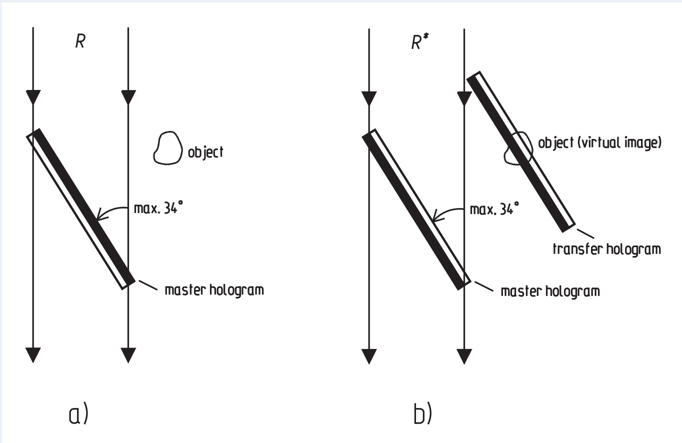
consisting of:
Plastic trays, 4 pcs. • Laboratory gloves, medium, 100 pcs. • Tray thermometer, offset, +40°C • Roller squeegee • Clamps, 2 pcs. • Film tongs, 2 pcs. • Darkroom lamp with green filter • Light bulb 230 V/15 W • Funnel • Narrow-necked bottles, 4 pcs.

Set of photographic chemicals	08746.88	1

consisting of: Holographic developer • Stop bath • Wetting agent • Laminate • Paint

Bleaching chemicals:

Potassium dichromate, 250 g	30102.25	1
Sulphuric acid, 95-98%, 500 ml	30219.50	1



Correct selection of the object position so that the image-capture of a transfer hologram is possible.

Tasks:

Image-capture and reconstruction of a transmission hologram, which is also termed the master hologram. Reconstruction of the master hologram with the phase conjugated reference wave R^* and image-capture of the transfer hologram, whereby an image-plane hologram should be generated.

*Alternative:

Holographic sheet film	08746.01	1
Glass plate, 120×120×2 mm	64819.00	4

Complete Equipment Set, Manual on CD-ROM included
Transfer hologram from a master hologram P2260305

Real time procedure I (bending of a plate) 2.6.03-06

What you can learn about …

- ➔ Interference
- ➔ Optical path length
- ➔ Refraction index
- ➔ Phase difference

Principle:

– In real time procedures, alterations of an object are directly observed. A hologram is recorded under the initial object conditions and remains in exactly the same position (at exactly the same place) where it was located during the image-capture procedure while it is being developed.

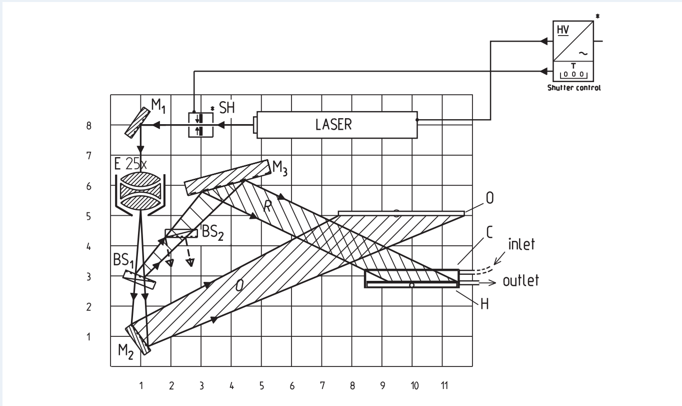
– The hologram is reconstructed with the reference beam and the object is illuminated with the object beam (both waves are unchanged with respect to the captured image). The light scattered by the object interferes with the reconstructed light wave of the hologram.

– During the occurrence of minor alterations (e.g. bending) of the object, interference fringes become visible on observing the hologram.

What you need:

Optical base plate in experiment case	08700.01	1
He-Ne-laser, 5 mW with holder	08701.00	1
Power supply for laser head 5 mW	08702.93	1
Magnetic foot for optical base plate	08710.00	7
Holder for diaphragm/beam splitter	08719.00	2
Sliding device, horizontal	08713.00	1
xy shifting device	08714.00	2
Adapter ring device	08714.01	1
Achromatic objective 20× N.A. 0.45	62174.20	1
Pin hole 30 micron	08743.00	1
Adjusting support 35×35 mm	08711.00	2
Surface mirror 30×30 mm	08711.01	2
Surface mirror, large, d = 80 mm	08712.00	1
Beam splitter 1/1, non polarizing	08741.00	2
Screen, white, 150×150 mm	09826.00	1
Slotted weight, 50 g, black	02206.01	2
Right angle clamp -PASS-	02040.55	4
Cell with magnetic base	08748.00	1
Hose clip, diam. 8-12mm	40996.01	2
Filter funnel, PP, d = 75 mm	46895.00	1
Retort stand, h = 500 mm	37692.00	1
Pinchcock, width 15 mm	43631.15	1
Ballon flask, HDPE, 10 l	47477.00	1
Universal clamp	37715.00	4
Holographic sheet film*	08746.01	1
Insert for cell 08748.00 for films*	08748.02	1
Rubber tubing, vacuum i. d. 6 mm	39286.00	2
Gas wash bottle, w/o frit, 250 ml	35834.05	1
Manual vacuum pump with manometer*	08745.00	1
Silicone grease, 50 g	31863.00	1
Silicone tubing, d_i = 8 mm	47531.00	1
Darkroom equipment for holography consisting of:	08747.88	1

Plastic trays, 4 pcs. • Laboratory gloves, medium, 100 pcs. • Tray thermometer, offset, +40°C • Roller squeegee • Clamps, 2 pcs. • Film tongs, 2 pcs. • Darkroom lamp with green filter • Light bulb 230 V/15 W • Funnel • Narrow-necked bottles, 4 pcs.



Experimental set-up for real-time procedures as a holographic interferometer for a bending plate.

Tasks:

Image-capture and reconstruction of a hologram of a plate which is covered with different masses during the reconstruction.

Set of photographic chemicals consisting of: Holographic developer • Stop bath • Wetting agent • Laminate • Paint	08746.88	1
Bleaching chemicals:		
Potassium dichromate, 250 g	30102.25	1
Sulphuric acid, 95-98%, 500 ml	30219.50	1
*Alternative:		
Holographic plates, 20 pieces	08746.00	1
Insert for cell 08748.00 for plates	08748.01	1

Complete Equipment Set, Manual on CD-ROM included
Real time procedure I (bending of a plate) P2260306

2.6.04-00 CO_2-laser

What you can learn about …

- ➔ Molecular vibration
- ➔ Exitation of molecular vibration
- ➔ Electric discharge
- ➔ Spontaneous emission
- ➔ Vibration niveau
- ➔ Rotation niveau
- ➔ Inversion
- ➔ Induced emission
- ➔ Spectrum of emission
- ➔ Polarization
- ➔ Brewster angle
- ➔ Optical resonator

Principle:

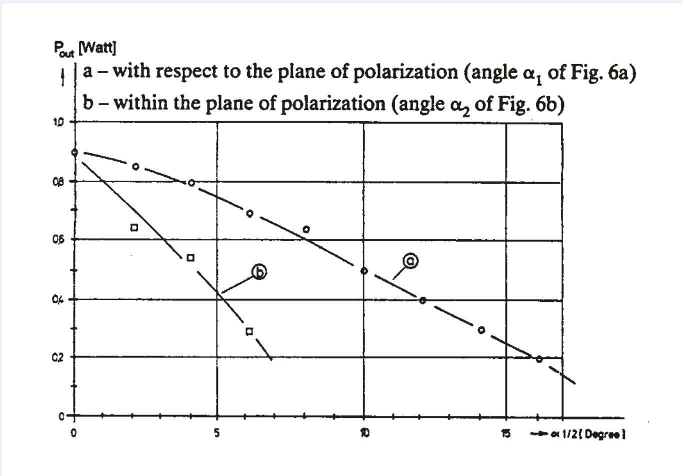
Among molecular laser, the CO_2-laser is of greatest practical importance. The high level of efficiency with which laser radiation can be generated in continuous wave (cw) and pulse operation is its most fascinating feature.

The experimental equipment set is an open CO_2-didactic laser system of typ. 5 W power output. Since it is an "open" system, all components of the system can be handled individually and the influence of each procedure on the output power can be studied. One very primary and essential target in learning is the alignment of the CO_2-laser by means of a He-Ne-laser.

What you need:

CO_2-laser tube, detachable, typically 5 W	08596.00	1
Module box for CO_2-laser tube	08597.00	1
Set of laser mirrors, ZnSe and Si	08598.00	1
Optical bench on steel rail, l = 1,3 m	08599.00	1
HV-power supply 5 kV/50 mA DC	08600.93	1
Ballast resistor unit incl. 3 HV cables	08601.00	1
Cooling water unit, portable	08602.93	1
Rotatory vane vacuum pump, two stages	02751.93	1
Gas filter/buffer unit	08605.00	1
He/Ne-laser/adjusting device	08607.93	1
Diaphragm for adjusting CO_2 Laser	08608.00	2
Screen, translucent, 250 mm x 250 mm	08064.00	1
Right angle clamp -PASS-	02040.55	1
Powermeter 30 mW/10 Watt	08579.93	1
Support for power probe	08580.00	1
Protection glasses, 10.6 micro-m	08581.00	1
Cleaning set for laser	08582.00	1
ZnSe biconvex lens, d = 24 mm, f = 150 mm	08609.00	1
Digital Thermometer, 2 x NiCr-Ni	07050.01	1
HV-isolated temperature probe	08584.00	1
Control panel with support, 1 gas*	08606.00	1
Pressure control valve 200/3 bar, CO_2/He*	08604.01	1
Laser gas in bottle, 50 l/200 bar*	08603.00	1
**Alternative to:*		
Laser gas mixing unit, 3 gases	08606.88	1
Option:		
Experiment set for laser beam analysis	08610.10	1
1. Estimation of wavelength by diffraction grating and		
2. Distribution of power by diaphragm		
IR conversion plate for observation of CO_2-laser infrared radiation	08611.00	1

Complete Equipment Set, Manual on CD-ROM included
CO_2-laser P2260400



Laser power as a function of the angle of inclination of the brewster window normal N.

Tasks:

1. Align the CO_2-laser and optimize its power output.
2. Check the influence of the Brewster windows position on the power output.
3. Determine the power output as a function of the electric power input and gasflow.
4. Evaluate the efficiency as a function of the electric power input and gasflow.
5. If the gas-mixing unit is supplied the influence of the different components of the laser gas (CO_2, He, N_2) to the output efficiency of the CO_2-laser are analyzed.
6. Measurement of temperatures differences for the laser gas (imput / output) for study of conversion efficiency.

LDA – Laser Doppler Anemometry with Cobra3 2.6.05-11

What you can learn about ...

- Interference
- Doppler effect
- Scattering of light by small particles (Mie scattering)
- High- and low-pass filters
- Sampling theorem
- Spectral power density
- Turbulence

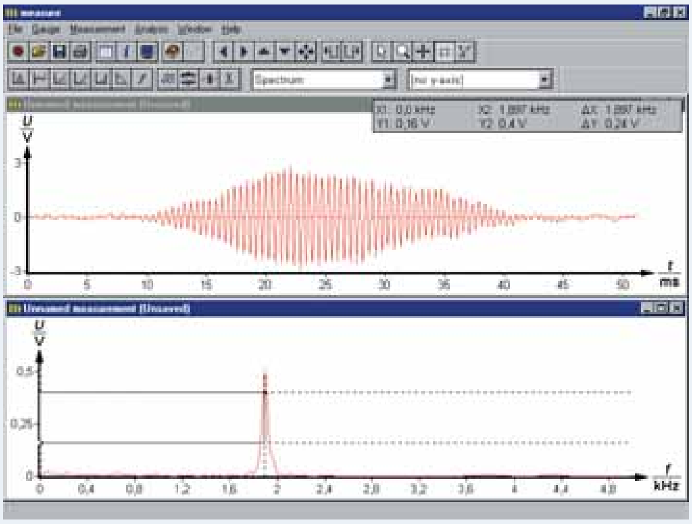
Principle:

Small particles in a current pass through the LDA measuring volume and scatter the light whose frequency is shifted by the Doppler effect due to the particle movement.

The frequency change of the scattered light is detected and converted into a particle or flow velocity.

What you need:

Optical base plate with rubberfeet	08700.00	1
He/Ne Laser, 5 mW with holder	08701.00	1
Power supply for laser head 5 mW	08702.93	1
Adjusting support 35 x 35 mm	08711.00	2
Surface mirror 30 x 30 mm	08711.01	2
Magnetic foot for optical base plate	08710.00	8
Holder for diaphragm/ beam plitter	08719.00	1
Lens, mounted, f = +100 mm	08021.01	1
Lens, mounted, f = +50 mm	08020.01	1
Lens, mounted, f = +20 mm	08018.01	1
Iris diaphragm	08045.00	1
Beam plitter 1/1, non polarizing	08741.00	1
Si-Photodetector with Amplifier	08735.00	1
Control Unit for Si-Photodetector	08735.99	1
Adapter BNC socket/4 mm plug pair	07542.27	1
Screened cable, BNC, l = 750 mm	07542.11	1
Prism table with holder for optical base plate	08725.00	1
Lens holder for optical base plate	08723.00	3
Screen, white, 150 x 150 mm	09826.00	1
XY-shifting device	08714.00	1
Pin hole 30 micron	08743.00	1
LDA-Accessory-Set	08740.00	1
Support rod -PASS-, square, l = 630 mm	02027.55	2
Right angle clamp -PASS-	02040.55	2
Universal clamp	37718.00	2
Support base -PASS-	02005.55	1
Aspirator bottle, clear glass, 1000 ml	34175.00	2
Silicone tubing, d = 7 mm	39296.00	1
Pinchcock, width 10 mm	43631.10	3
Glass tube, AR-glass, straight, d = 8 mm, l = 80 mm, 10 pcs.	36701.65	1
Rubber stopper, d = 32/26 mm, 1 hole	39258.01	2
Rubber stopper, d = 22/17 mm, 1 hole	39255.01	2
Measuring tape, l = 2 m	09936.00	1
Spatulas, double bladed, l = 150 mm, wide	33460.00	1
Beaker, DURAN®, short form, 150 ml	36012.00	1
Cobra3 Basic-Unit, USB	12150.50	1
Power supply 12V/2A	12151.99	1
Software Cobra3 Fourier Analysis	14514.61	1
Sliding device, horizontal	08713.00	1
PC, Windows® XP or higher		



Measurement of the signal spectrum with a signal peak

Tasks:

1. Measurement of the light-frequency change of individual light beams which are reflected by moving particles.
2. Determination of the flow velocities.

Complete Equipment Set, Manual on CD-ROM included
LDA – Laser Doppler Anemometry with Cobra3 P2260511

2.6.07-01/05 Helium Neon Laser

What you can learn about …

- → Spontaneous and stimulated light emission
- → Inversion
- → Collision of second type
- → Gas discharge tube
- → Resonator cavity
- → Transverse and longitudinal resonator modes
- → Birefringence
- → Brewster angle
- → Littrow prism
- → Fabry Perot Etalon

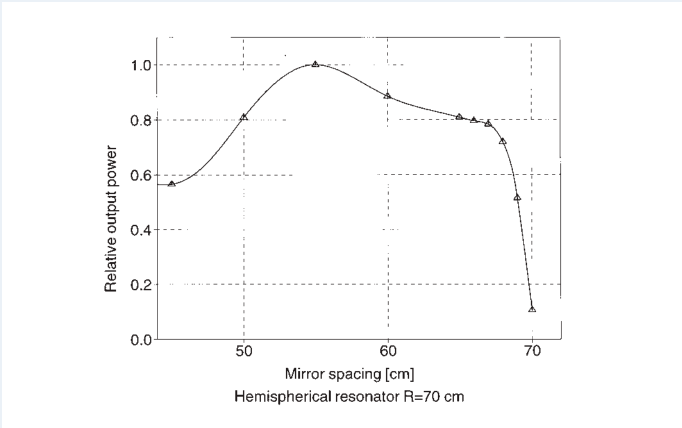
Principle:

The difference between spontaneous and stimulated emission of light is demonstrated. The beam propagation within the resonator cavity of a He-Ne laser and its divergence are determined, its stability criterion is checked and the relative output power of the laser is measured as a function of the tube's position inside the resonator and of the tube current.

What you need:

		Helium Neon Laser P2260701	Helium Neon Laser, advanced set P2260705
Exp. Set-Helium-Neon Laser	08656.93	1	1
Photoelement for optical base plate	08734.00	1	1
DMM, auto range, NiCr-Ni thermocouple	07123.00	1	1
Scale, l = 750 mm, on rod	02200.00	1	1
Screen, white, 150x150mm	09826.00		1
Diffraction grating, 600 lines/mm	08546.00	1	1
Plate holder	02062.00	1	1
Slide mount for optical profile-bench	08286.00	1	1
Danger sign -Laser-	06542.00	1	1
Barrel base -PASS-	02006.55	1	1
Vernier caliper	03010.00	1	1
Sliding device, horizontal	08713.00	1	1
Connection box	06030.23	1	1
Resistor 10 Ohm 2%, 2 W, G1	06056.10	1	1
Resistor 100 Ohm 2%, 1 W, G1	06057.10	1	1
Resistor 1 kOhm, 1 W, G1	39104.19	1	1
Resistor 10 kOhm, 1 W, G1	39104.30	1	1
Resistor 100 kOhm, 1 W, G1	39104.41	1	1
Connecting cord, 32 A, l = 750 mm, red	07362.01	1	1
Connecting cord, 32 A, l = 750 mm, blue	07362.04	1	1
Measuring tape, l = 2 m	09936.00		1
Protection glasses HeNe-laser	08581.10	1	1
Lyot-plate with holder and rider	08656.10		1
Littrow-prism with x/y-holder	08656.20		1
Fabry-Perot etalon in x/y-holder	08656.30		1
Cleaning set for laser	08582.00	1	1

Complete Equipment Set, Manual on CD-ROM included
Helium Neon Laser P22607 01/05



Relative output power as a function of mirror spacing.

The following items can be realized with advanced set 08656.02.

By means of a birefringent tuner and a Littrow prism different wavelengths can be selected and quantitatively determined if a monochromator is available.

Finally you can demonstrate the existence of longitudinal modes and the gain profile of the He-Ne laser provided an analysing Fabry Perot system is at your disposal.

Tasks:

1. Set up the He-Ne laser. Adjust the resonator mirrors by use of the pilot laser. (left mirror: VIS, HR, plane ; right mirror: VIS, HR, R = 700 mm)
2. Check on the stability condition of a hemispherical resonator.
3. Measure the integral relative output power as a function of the laser tube's position within the hemispherical resonator.
4. Measure the beam diameter within the hemispherical resonator right and left of the laser tube.
5. Determine the divergence of the laser beam.
6. Measure the integral relative output power as a function of the tube current.

The He-Ne laser can be tuned using a BFT or a LTP. Longitudinal modes can be observed by use of a Fabry Perot Etalon of low finesse. Remark: These points can only be covered quantitatively if a monochromator and an analysing Fabry Perot system are available.

Optical pumping 2.6.08-00

What you can learn about …

- → Spontaneous emission
- → Induced emission
- → Mean lifetime of a metastable state
- → Relaxation
- → Inversion
- → Diode laser

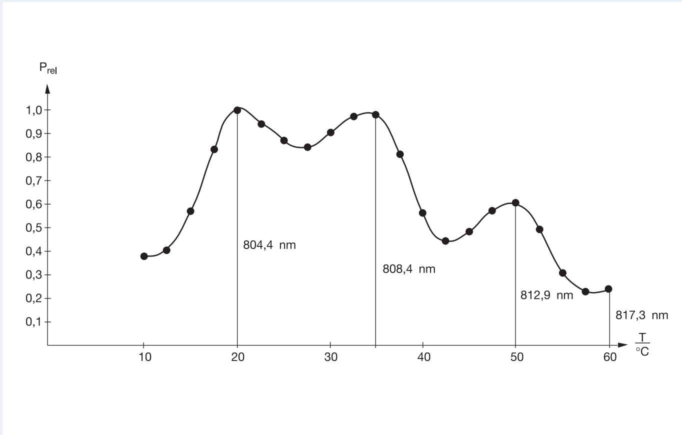
Principle:

The visible light of a semiconductor diode laser is used to excite the neodymium atoms within a Nd-YAG (Neodymium-Yttrium Aluminium Garnet) rod. The power output of the semiconductor diode laser is first recorded as a function of the injection current. The fluorescent spectrum of the Nd-YAG rod is then determined and the maon absorption lines of the Nd-atoms are verified. Conclusively, the mean life-time of the $^4F_{3/2}$-level of the Nd-atoms is measured in appoximation.

What you need:

Basic set optical pumping	08590.93	1
Sensor for measurement of beam power	08595.00	1
Digital multimeter 2010	07128.00	1
Oscilloscope 30 MHz, 2 channels	11459.95	1
Screened cable, BNC, l = 750 mm	07542.11	3
Protection glasses for Nd-YAG laser	08581.20	1
Optical base plate in exp. case	08700.01	1

Complete Equipment Set, Manual on CD-ROM included
Optical pumping P2260800



Relative fluorescent power of the Nd-YAG rod as a function of the diode temperature (wavelength) for I = 450 mA.

Tasks:

1. To determine the power output of the semiconductor diode laser as a function of the injection current.
2. To trace the fluorescent spectrum of the Nd-YAG rod pumped by the diode laser and to verify the main absorption lines of neodymium.
3. To measure the mean life-time of the $^4F_{3/2}$-level of the Nd-atoms.
4. For further applications see experiment 2.6.09 “Nd-YAG laser”.

2.6.09-00 Nd-YAG laser

What you can learn about ...

- ➔ Optical pumping
- ➔ Spontaneous emission
- ➔ Induced emission
- ➔ Inversion
- ➔ Relaxation
- ➔ Optical resonator
- ➔ Resonator modes
- ➔ Polarization
- ➔ Frequency doubling

Principle:

The rate equation model for an optically pumped four-level laser system is determined. As lasing medium, a Nd-YAG (Neodymium-Yttrium Aluminium Garnet) rod has been selected which is pumped by means of a semiconductor diode laser.

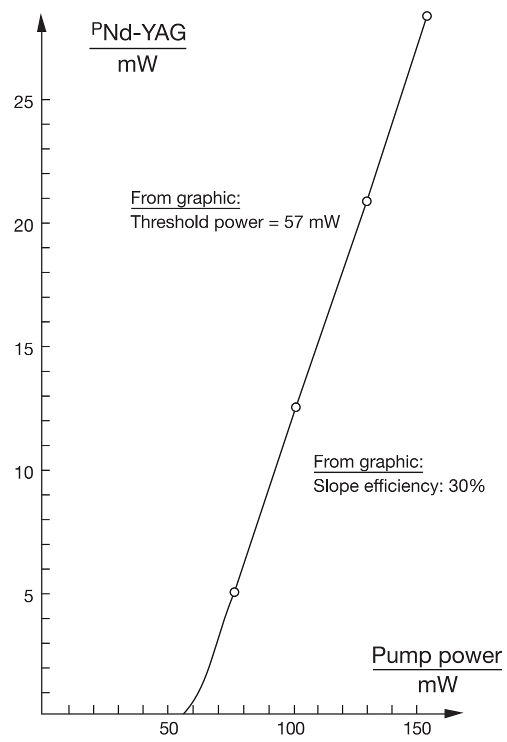
The IR-power output of the Nd-YAG laser is measured as a function of the optical power input and the slope efficiency as well as the threshold power are determined.

Finally, a KTP-crystal is inserted into the laser cavity and frequency doubling is demonstrated. The quadratic relationship between the power of the fundamental wave and the beam power for the second harmonic is then evident.

What you need:

Basic set optical pumping	08590.93	1
Sensor for measurement of beam power	08595.00	1
Nd-YAG laser cavity mirror/holder	08591.01	1
Laser cavity mirror frequency doubling	08591.02	1
Frequency doubling crystal in holder	08593.00	1
Filter plate, short pass type	08594.00	1
Digital multimeter 2010	07128.00	1
Oscilloscope 30 MHz, 2 channels	11459.95	1
Screened cable, BNC, l = 750 mm	07542.11	3
Protection glasses for Nd-YAG laser	08581.20	1
Cleaning set for laser	08582.00	1
Optical base plate in exp. case	08700.01	1

Complete Equipment Set, Manual on CD-ROM included
Nd-YAG laser P2260900



Nd-YAG laser power output as a function of the pump power λ = 808.4 nm.

Tasks:

1. Set up the Nd-YAG laser and optimize its power output.
2. The IR-power output of the Nd-YAG laser is to be measured as a function of the pump power. The slope efficiency and the threshold power are to be determined.
3. Verify the quadratic relationship betweenthe power of the fundamental wave, with λ = 1064 nm, and the beam power of the second harmonic with λ = 532 nm.

Fibre optics 2.6.10-00

What you can learn about …

- → Total reflection
- → Diode laser
- → Gaussian beam
- → Monomode and multimode fibre
- → Numerical aperture
- → Transverse and longitudinal modes
- → Transit time
- → Threshold energy
- → Slope efficiency
- → Velocity of light

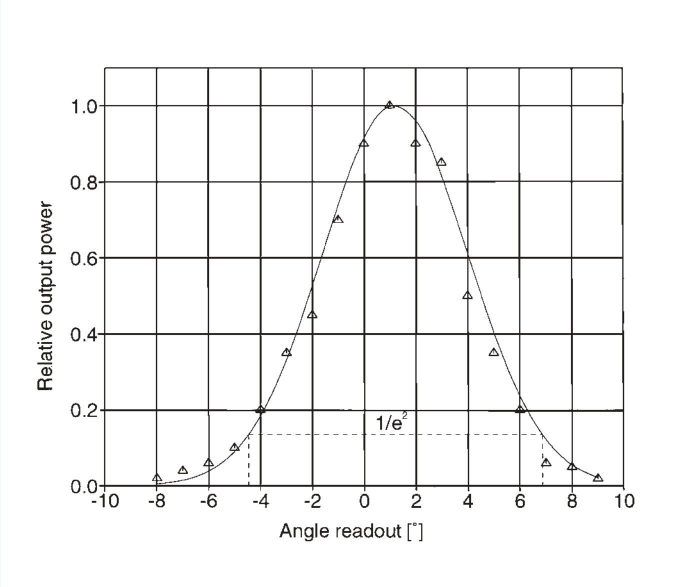
Principle:

The beam of a laser diode is treated in a way that it can be coupled into a monomode fibre. The problems related to coupling the beam into the fibre are evaluated and verified. In consequence a low frequency signal is transmitted through the fibre. The numerical aperture of the fibre is recorded. The transit time of light through the fibre is measured and the velocity of light within the fibre is determined. Finally the measurement of the relative output power of the diodelaser as a function of the supply current leads to the characteristics of the diodelaser such as "threshold energy" and "slope efficiency".

What you need:

Experimentation Set Fibre Optics	08662.93	1
Screened cable, BNC, l = 750 mm	07542.11	2
Oscilloscope 150 MHz, 2-channel	11452.99	1

Complete Equipment Set, Manual on CD-ROM included
Fibre optics P2261000



Relative output power at the fibre end versus angle readout.

Tasks:

1. Couple the laser beam into the fibre and adjust the setting-up in a way that a maximum of output power is achieved at the exit of the fibre.
2. Demonstrate the transmission of a LF – signal through the fibre.
3. Measure the numerical aperture of the fibre.
4. Measure the transit time of light through the fibre and determine the velocity of light within the fibre.
5. Determine the relative output power of the diodelaser as a function of the supply current.

2.6.11-00 Fourier optics – 2f Arrangement

What you can learn about …

- ➔ Fourier transform
- ➔ Lenses
- ➔ Fraunhofer diffraction
- ➔ Index of refraction
- ➔ Huygens' principle

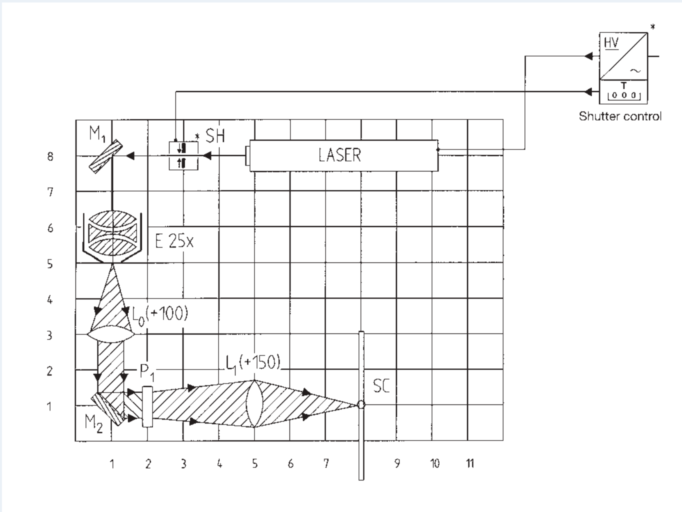
Principle:

The electric field distribution of light in a specific plane (object plane) is Fourier transformed into the 2f configuration.

What you need:

Optical base plate with rubberfeet	08700.00	1
He/Ne Laser, 5mW with holder	08701.00	1
Power supply for laser head 5 mW	08702.93	1
Adjusting support 35 x 35 mm	08711.00	2
Surface mirror 30 x 30 mm	08711.01	2
Magnetic foot for optical base plate	08710.00	7
Holder for diaphragm/ beam plitter	08719.00	1
Lens, mounted, f = +150 mm	08022.01	1
Lens, mounted, f = +100 mm	08021.01	1
Lens holder for optical base plate	08723.00	2
Screen, white, 150 x 150 mm	09826.00	1
Diffraction grating, 50 lines/mm	08543.00	1
Screen with diffracting elements	08577.02	1
Achromatic objective 20 x N.A.0.4	62174.20	1
Sliding device, horizontal	08713.00	1
XY-shifting device	08714.00	2
Adapter ring device	08714.01	1
Pin hole 30 micron	08743.00	1
Rule, plastic, 200 mm	09937.01	1

Complete Equipment Set, Manual on CD-ROM included
Fourier optics– 2f Arrangement P2261100



Experimental set-up for the fundamental principles of Fourier optic (2f set-up). *only required for the 5 mW laser!

Tasks:

Investigation of the Fourier transform by a convex lens for different diffraction objects in a 2f set-up.

Fourier optics – 4f Arrangement – Filtering and reconstruction 2.6.12-00

What you can learn about …

- ➔ Fourier transform
- ➔ Lenses
- ➔ Fraunhofer diffraction
- ➔ Index of refraction
- ➔ Huygens' principle
- ➔ Debye-Sears-effect

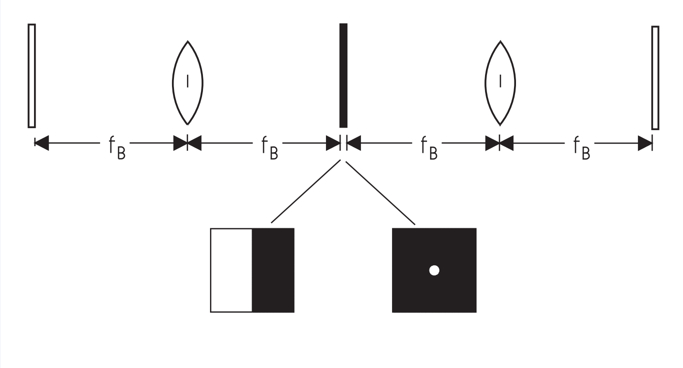
Principle:

The electric field distribution of light in a specific plane (object plane) is Fourier transformed into the 4f configuration by 2 lenses and optically filtered with appropriate diaphragms.

What you need:

Optical base plate with rubberfeet	08700.00	1
He/Ne Laser, 5mW with holder	08701.00	1
Power supply for laser head 5 mW	08702.93	1
Adjusting support 35 x 35 mm	08711.00	2
Surface mirror 30 x 30 mm	08711.01	2
Magnetic foot for optical base plate	08710.00	9
Holder for diaphragm/beam plitter	08719.00	2
Lens, mounted, f = +100 mm	08021.01	3
Lens holder for optical base plate	08723.00	3
Screen, white, 150 x 150 mm	09826.00	1
Slide -Emperor Maximilian-	82140.00	1
Screen with arrow slit	08133.01	1
Diffraction grating, 4 lines/mm	08532.00	1
Diffraction grating, 50 lines/mm	08543.00	1
Diaphragms, d = 1, 2, 3 and 5 mm	09815.00	1
Screen with diffracting elements	08577.02	1
Sliding device, horizontal	08713.00	1
XY-shifting device	08714.00	2
Achromatic objective 20 x N.A.0.4	62174.20	1
Adapter ring device	08714.01	1
Pin hole 30 micron	08743.00	1
Rule, plastic, 200 mm	09937.01	1
Ultrasonic generator	13920.99	1
Glass cell, 150 x 55 x 100 mm	03504.00	1
Table with stem	09824.00	2
Support rod, stainless steel 18/8, l = 250 mm, d = 10 mm	02031.00	1
Bosshead	02043.00	1
Universal clamp	37718.00	1

Complete Equipment Set, Manual on CD-ROM included
Fourier optics – 4f Arrangement – Filtering and reconstruction P2261200



Principle of the set-up for coherent optical filtration.

Tasks:

1. Optical filtration of diffraction objects in 4f set-up.
2. Reconstruction of a filtered image.

2.6.13-00 Magnetostriction with the Michelson interferometer

What you can learn about ...

- Interference
- Wavelength
- Diffraction index
- Speed of light
- Phase
- Virtual light source
- Ferromagnetic material
- Weiss molecular magnetic fields
- Spin-orbit coupling

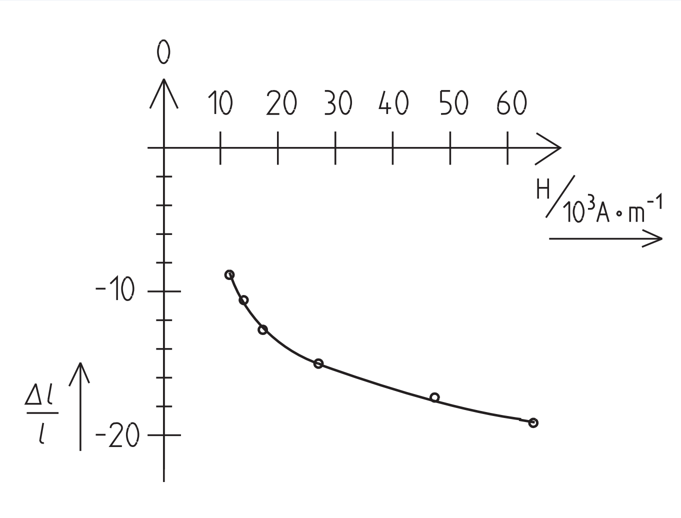
Principle:

With the aid of two mirrors in a Michelson arrangement, light is brought to interference. Due to the magnetostrictive effect, one of the mirrors is shifted by variation in the magnetic field applied to a sample, and the change in the interference pattern is observed.

What you need:

Optical base plate with rubber feet	08700.00	1
He-Ne-laser, 5 mW with holder*	08701.00	1
Power supply for laser head 5 mW*	08702.93	1
Adjusting support 35×35 mm	08711.00	3
Surface mirror 30×30 mm	08711.01	4
Magnetic foot for optical base plate	08710.00	7
Holder for diaphragm/beam splitter	08719.00	1
Beam splitter 1/1, non polarizing	08741.00	1
Lens, mounted, f = +20 mm	08018.01	1
Lensholder for optical base plate	08723.00	1
Screen, white, 150×150mm	09826.00	1
Faraday modulator for optical base plate	08733.00	1
Rods for magnetostriction, set	08733.01	1
Power supply, universal	13500.93	1
Digital multimeter	07134.00	1
Connecting cord, l = 500 mm, blue	07361.04	1
Flat cell battery, 9 V	07496.10	1
*Alternative to laser 5 mW, power supply and shutter:		
Laser, He-Ne 0.2/1.0 mW, 220 V AC	08180.93	1

Complete Equipment Set, Manual on CD-ROM included
Magnetostriction with the Michelson interferometer P2261300

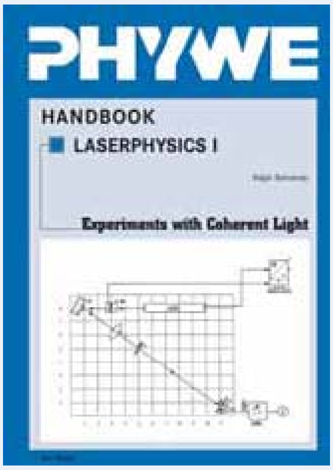


Measuring results of the magnetostriction of nickel with the relative change in length $\Delta l/l$ plotted against applied field strength H

Tasks:

1. Construction of a Michelson interferometer using separate optical components.
2. Testing various ferromagnetic materials (iron and nickel) as well as a non-ferromagnetic material, copper, with regard to their magnetostrictive properties.

Laser Physics



Laser Physics I – Experiments with coherent light 01179.02

16 described Experiments

Please ask for a complete equipment list Ref. No. 22702

1 Diffraction of light

LP 1.1 (12166)
Diffraction of light through a slit and at an edge.

LP 1.2 (12167)
Diffraction through a slit and Heisenberg's uncertainty principle.

LP 1.3 (12168)
Diffraction of light through a double slit or by a grid.

LP 1.4 (12169)
Diffraction of light through a slit and stripes, Babinet's theorem

2 Interference of light

LP 2.1 (12170)
Fresnel mirror and biprism

LP 2.2 (12171)
Michelson interferometer

LP 2.3 (12172)
Newton's rings

3 Polarisation of light

LP 3.1 (12173)
Fresnel's law, theory of reflection

LP 3.2 (12174)
Polarisation through $\lambda/4$ plates

LP 3.3 (12175)
Half shadow polarimeter, rotation of polarisation through an optically active medium

LP 3.3 (12176)
Kerr effect

LP 3.5 (12177)
Faraday effect

4 Refraction of light

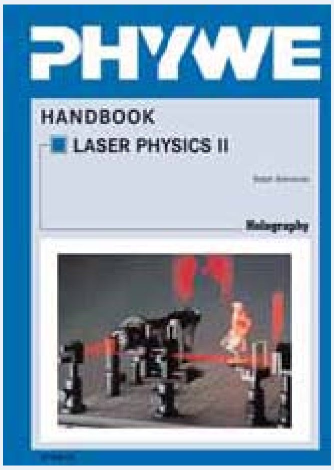
LP 4.1 (12178)
Index of refraction n of a flint glass prism

LP 4.2 (12179)
Determination of the index of refraction of air with Michelson's interferometer

LP 4.3 (12180)
Determination of the index of refraction of CO_2 with Michelson's interferometer

5 Law of radiation

LP 5.1 (12181)
Lambert's law of radiation



Laser Physics II Holography 01400.02

11 described Experiments

Please ask for a complete equipment list Ref. No. 22703

LH 1 (12900)
Fresnel zone plate

LH 2 (12901)
White light hologram

LH 3 (12902)
White light hologram with expansion system

LH 4 (12903)
Transmission hologram

LH 5 (12904)
Transmission hologram with expansion system

LH 6 (12905)
Transfer hologram from a master hologram.

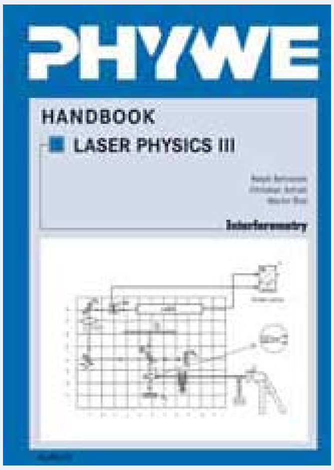
LH 7 (12906)
Double exposure procedure

LH 8 12907)
Time-averaging procedure I (with tuning fork).

LH 9 (12908)
Time-averaging procedure II (with loudspeaker).

LH 10 12909)
Real time procedure I (bending of a plate).

LH 11 (12910)
Real time procedure II (oscillating plate).



Laser Physics III Interferometry 01401.02

18 described Experiments

Please ask for a complete equipment list Ref. No. 22704

LI 1 (13066)
Michelson interferometer

LI 2 (13067)
Michelson interferometer – high resolution

LI 3 (13068)
Mach - Zehnder interferometer

LI 4 (13069)
Sagnac interferometer

LI 5 (13070)
Doppler-Effect with Michelson interferom.

LI 6 (13071)
Magnetostriction with Michelson interferometer

LI 7 (13072)
Thermal expansion of solids with Michelson interferometer

LI 8 (13073)
Refraction index of CO_2-gas with Michelson interferometer

LI 9 (13074)
Refraction index of air with Michelson interferometer

LI 10 (13075)
Refraction index of air with Mach-Zehnder interferometer

LI 11 (13076)
Refraction index of of CO_2-gas with Mach-Zehnder interferometer

LI 12 (13077)
Fabry - Perot interferometer – determination of the wavelength of laserlight

LI 13 (13078)
Fabry - Perot interferometer – optical resonator modes

LI 14 (22611)
Fourier optics –2 f arrangement

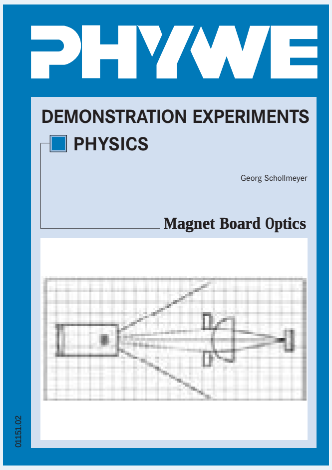
LI 15 (22612)
Fourier optics – 4 f arrangement, filtering and reconstruction

LI 16 (13079)
Optical determination of the velocity of ultrasound in liquids – phasemodulation of laserlight by ultrasonic waves

LI 17 (13080)
LDA – Laser Doppler Anemometry

LI 18 (13081)
Twyman-Green interferometer

Physics Demonstration Experiments – Magnet Board Optics



Geometrical optics and theory of colours on the magnetic board

The demonstration system presents the following advantages:

- simple handling and minimum preparation time through components with magnets
- clear length of beams through 50 W halogen lamp with magnet and large model objects
- clear and dust proof storage of all components in the device shaped wooden tray
- detailed description of experiments with figures.
  60 experiments covering light propagation (7), mirror (16), diffraction (10), lenses (13), colours (6), eye (3), optical instruments (5)

Physics Demonstration Experiments – Magnet Board Optics • No. 01151.02 • 60 described Experiments

Please ask for a complete equipment list Ref. No. 22701

1 Propagation of light

OT 1.1 (11000)
Rectilinear propagation of light

OT 1.2 (11001)
Shadow formation by a point light source

OT 1.3 (11002)
Umbra and penumbra with two point light sources

OT 1.4 (11003)
Umbra and penumbra with an extensive light source

OT 1.5 (11004)
Length of shadows

OT 1.6 (11005)
Solar and lunar eclipses with a point light source

OT 1.7 (11006)
Solar and lunar eclipses with an extensive light source

2 Mirrors

OT 2.1 (11007)
Reflection of light

OT 2.2 (11008)
The law of reflection

OT 2.3 (11009)
Formation of an image point by a plane mirror

OT 2.4 (11010)
Image formation by a plane mirror

OT 2.5 (11011)
Applications of reflection by plane mirrors

OT 2.6 (11012)
Reflection of light by a concave mirror

OT 2.7 (11013)
Properties of a concave mirror

OT 2.8 (11014)
Real images with a concave mirror

OT 2.9 (11015)
Law of imagery and magnification of a concave mirror

OT 2.10 (11016)
Virtual images with a concave mirror

OT 2.11 (11017)
Aberrations with a concave mirror

OT 2.12 (11018)
Reflection of light by a convex mirror

OT 2.13 (11019)
Properties of a convex mirror

OT 2.14 (11020)
Image formation by a convex mirror

OT 2.15 (11021)
Law of imagery and magnification of a convex mirror

OT 2.16 (11022)
Reflection of light by a parabolic mirror

3 Refraction

OT 3.1 (11023)
Refraction at the air-glass boundary

OT 3.2 (11024)
Refraction at the air-water boundary

OT 3.3 (11025)
The law of refraction

OT 3.4 (11026)
Total reflection at the glass-air boundary

OT 3.5 (11027)
Total reflection at the water-air boundary

OT 3.6 (11028)
Passage of light through a planoparallel glass plate

OT 3.7 (11029)
Refraction by a prism

OT 3.8 (11030)
Light path through a reversing prism

OT 3.9 (11031)
Light path through a deflection prism

OT 3.10 (11032)
Light transmission by total reflection

4 Lenses

OT 4.1 (11033)
Refraction of light by a convergent lens

OT 4.2 (11034)
Properties of a convergent lens

OT 4.3 (11035)
Real images with a convergent lens

OT 4.4 (11036)
Law of imagery and magnification of a convergent lens

OT 4.5 (11037)
Virtual images with a convergent lens

OT 4.6 (11038)
Refraction of light at a divergent lens

OT 4.7 (11039)
Properties of a divergent lens

OT 4.8 (11040)
Image formation by a divergent lens

OT 4.9 (11041)
Law of imagery and magnification of a divergent lens

OT 4.10 (11042)
Lens combination consisting of two convergent lenses

OT 4.11 (11043)
Lens combination consisting of a convergent and a divergent lens

OT 4.12 (11044)
Spherical aberration

OT 4.13 (11045)
Chromatic aberration

5 Colours

OT 5.1 (11046)
Colour dispersion with a prism

OT 5.2 (11047)
Non-dispersivity of spectral colours

OT 5.3 (11048)
Reunification of spectral colours

OT 5.4 (11049)
Complementary colours

OT 5.5 (11050)
Additive colour mixing

OT 5.6 (11051)
Subtractive colour mixing

6 The human eye

OT 6.1 (11052)
Structure and function of the human eye

OT 6.2 (11053)
Short-sightedness and its correction

OT 6.3 (11054)
Long-sightedness and its correction

7 Optical equipment

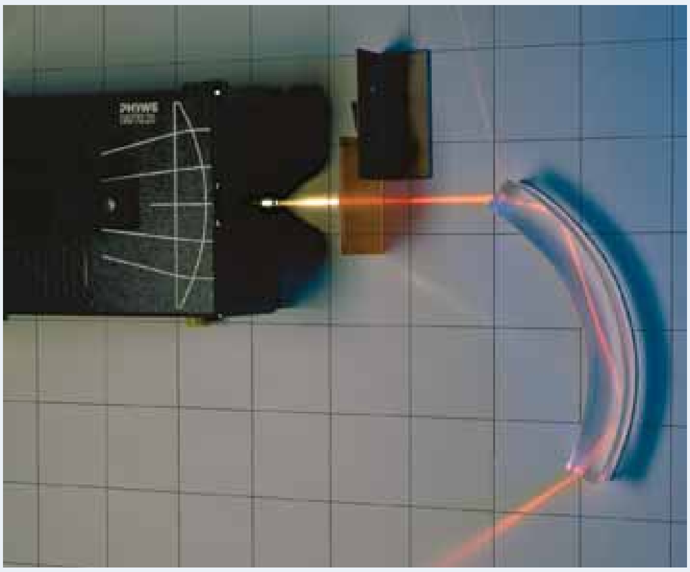
OT 7.1 (11055)
The magnifying glass

OT 7.1 (11056)
The camera

OT 7.3 (11057)
The astronomical telescope

OT 7.4 (11058)
The Newtonian reflecting telescope

OT 7.5 (11059)
Herschel's reflecting telescope



Light guide

Thermodynamics

3

3

Thermodynamics

Contents

Thermal expansion in solids and liquids 3.1.01-00

What you can learn about ...

- → Linear expansion
- → Volume expansion of liquids
- → Thermal capacity
- → Lattice potential
- → Equilibrium spacing
- → Grüneisen equation

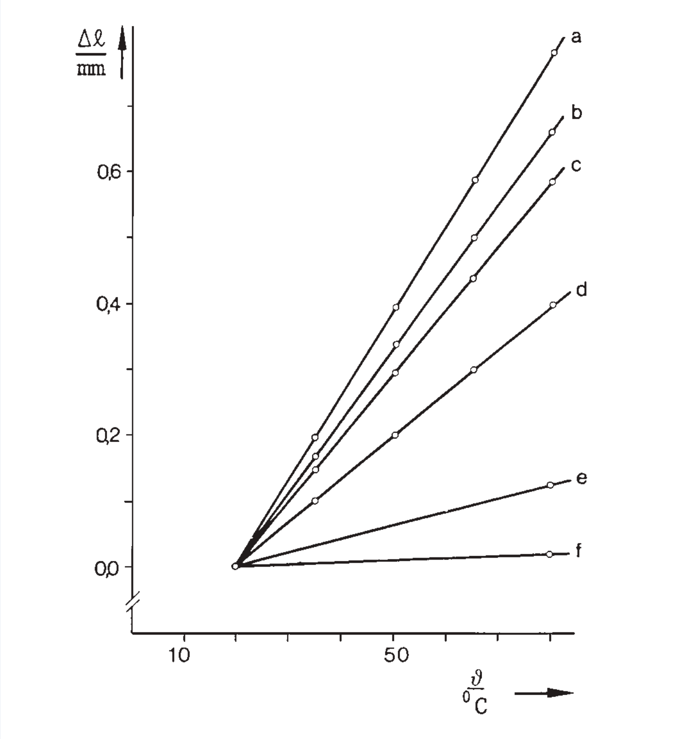
Principle:

The volume expansion of liquids and the linear expansion of various materials is determined as a function of temperature.

What you need:

Dilatometer with clock gauge for practical class experiments	04233.00	1
Tube for dilatometer, copper	04231.05	1
Tube for dilatometer, aluminium	04231.06	1
Tube for dilatometer, quarz glass	04231.07	1
Immersion thermostat TC10	08492.93	1
Accessory set for TC10	08492.01	1
Bath for thermostat, Makrolon	08487.02	1
Laboratory thermometers, -10...+100°C	38056.00	1
Rubber tubing, d_i = 6 mm, l = 1 m	39282.00	2
Syringe 1 ml, Luer, pack of 10	02593.03	1
Cannula, LUER, d = 0.60 mm, 20 pcs.	02599.04	1
Measuring tube, l = 300 mm, IGJ 19/26	03024.00	2
Wash bottle, plastic, 250 ml	33930.00	1
Flat bottom flasks, DURAN®, 100 ml, IGJ 19/26	35811.01	2
Beaker, DURAN®, tall form, 100 ml	36002.00	1
Ethyl acetate, 250 ml	30075.25	1
Glycerol, 250 ml	30084.25	1
Olive oil, pure, 100 ml	30177.10	1
Set of Analytical Balance	49223.88	1

Complete Equipment Set, Manual on CD-ROM included
Thermal expansion in solids and liquids P2310100

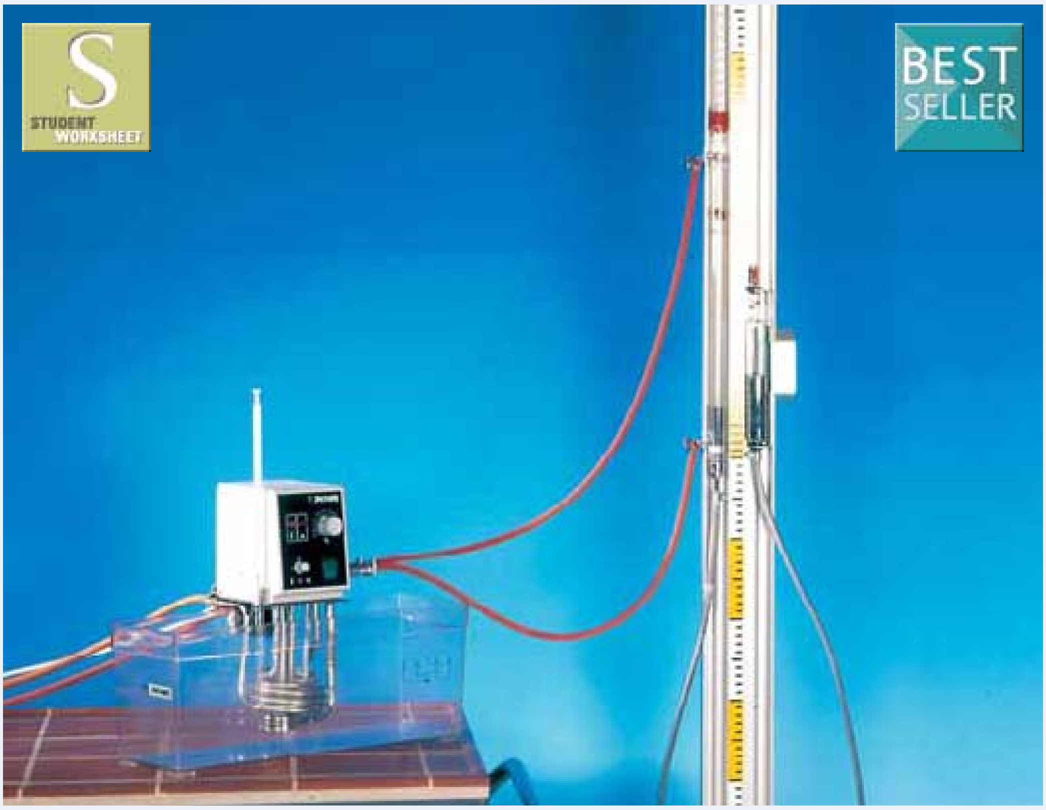


Relationship between length l and temperature ϑ, for a) aluminium, b) brass, c) copper, d) steel, e) duran glass, f) quartz glass (l_0 = 600 mm)

Tasks:

1. To determine the volume expansion of ethyl acetate ($C_4H_8O_2$), methylated spirit, olive oil, glycerol and water as a function of temperature, using the pycnometer.
2. To determine the linear expansion of brass, iron, copper, aluminium, duran glass and quartz glass as a function of temperature using a dilatometer.
3. To investigate the relationship between change in length and overall length in the case of aluminium.

3.2.01-01 Equation of state of ideal gases



What you can learn about …

- ➔ Pressure and temperature
- ➔ Volume
- ➔ Coefficient of thermal expansion
- ➔ Coefficient of thermal tension
- ➔ Coefficient of cubic compressibility
- ➔ General equation of state for ideal gases
- ➔ Universal gas constant
- ➔ Boyle and Mariotte's law
- ➔ Gay-Lussac's law
- ➔ Charles' (Amontons') law

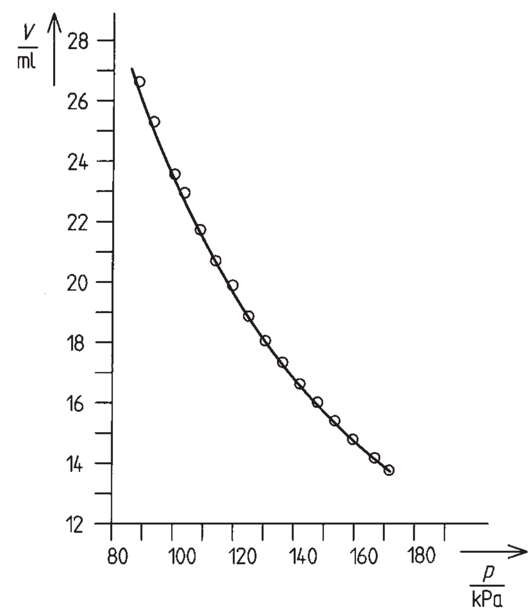
Principle:

The state of a gas is determined by its temperature, its pressure and the amount of substance. For the limiting case of an ideal gas these state variables are linked by the general equation of state, from which special correlations can be derived for specific changes of state.

What you need:

Gas law apparatus	04362.00	1
Immersion thermostat TC10	08492.93	1
Accessory set for TC10	08492.01	1
Bath for thermostat, Makrolon	08487.02	1
Weather monitor, 6 lines LCD	87997.10	1
Laboratory thermometers, -10...+100°C	38056.00	1
Mercury tray	02085.00	1
Support base -PASS-	02005.55	1
Support rod, stainless steel 18/8, l = 1000 mm	02034.00	1
Right angle clamp	37697.00	2
Universal clamp	37715.00	2
Pinchcock, width 15 mm	43631.15	1
Hose clip, d = 8-12 mm	40996.01	6
Rubber tubing, d_i = 6 mm, l = 1 m	39282.00	3
Mercury, filtered, 1000 g	31776.70	1
Water, distilled 5 l	31246.81	1

Complete Equipment Set, Manual on CD-ROM included
Equation of state of ideal gases P2320101



Correlation between pressure p and volume V for a constant quantity of air (n = 0.9536 mmol) during an isothermic change of state (T = 298.15 K).

Tasks:

For a constant amount of gas (air) investigate the correlation of

1. Volume and pressure at constant temperature (Boyle and Mariotte's law)
2. Volume and temperature at constant pressure (Gay-Lussac's law)
3. Pressue and temperature at constant volume (Charles' (Amontons' law))

From the relationships obtained calculate the universal gas constant as well as the coefficient of thermal expansion, the coefficient of thermal tension, and the coefficient of cubic compressibility.

Equation of state of ideal gases with Cobra3 3.2.01-15

What you can learn about …

- ➔ Thermal tension coefficient
- ➔ General equation of state for ideal gases
- ➔ Universal gas constant
- ➔ Amontons' law

Principle:

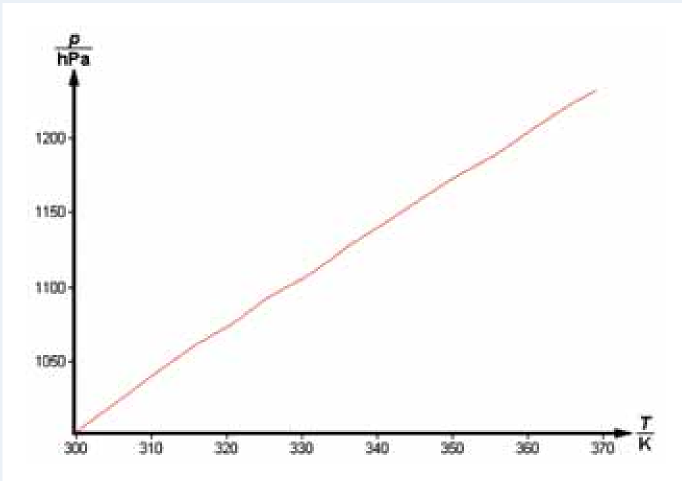
The state of a gas is determined by temperature, pressure and amount of substance. For the limiting case of ideal gases, these state variables are linked via the general equation of state. For a change of state under isochoric conditions this equation becomes Amontons' law.

In this experiment it is investigated whether Amontons' law is valid for a constant amount of gas (air).

What you need:

Cobra3 Basic-Unit, USB	12150.50	1
Power supply 12V/2A	12151.99	1
Data cable 2 x SUB-D, plug/socket, 9 pole	14602.00	1
Measuring module pressure	12103.00	1
Measuring module temperature NiCr-Ni, 330°C	12104.00	1
Thermocouple NiCr-Ni, sheathed	13615.01	1
Cobra3 measuring module converter	12150.04	1
Temperature sensor, semiconductor type	12120.00	1
Software Cobra3 Gas Laws	14516.61	1
Glass jacket	02615.00	1
Gas syringes, without cock, 100 ml	02614.00	1
Heating apparatus	32246.93	1
Power regulator	32288.93	1
H-base -PASS-	02009.55	1
Support rod, stainless steel 18/8, l = 250 mm, d = 10 mm	02031.00	2
Right angle clamp	37697.00	3
Universal clamp	37715.00	2
Universal clamp with joint	37716.00	1
Magnet rod, l = 200 mm, d = 10 mm	06311.00	1
Magnetic stirring rod, cylindrical, l = 30 mm	46299.02	1
Beaker, DURAN®, tall form, 250 ml	36004.00	1
Funnel, glass, d = 50 mm	34457.00	1
Hose connector, reducing, d = 3-5/6-10 mm	47517.01	1
Silicone tubing, d = 2 mm	39298.00	1
Silicone tubing, d = 7 mm	39296.00	1
Rubber caps	02615.03	1
Hose clip, d = 8-12 mm	40996.01	2
PC, Windows® XP or higher		

Complete Equipment Set, Manual on CD-ROM included
Equation of state of ideal gases with Cobra3 P2320115



Dependence of the pressure on the temperature under isochoric conditions.

Tasks:

For a constant amount of gas (air) investigate the correlation of

1. Volume and pressure at constant temperature (Boyle and Mariotte's law)
2. Volume and temperature at constant pressure (Gay-Lussac's law)
3. Pressue and temperature at constant volume (Charles' (Amontons' law))

From the relationships obtained calculate the universal gas constant as well as the coefficient of thermal expansion, the coefficient of thermal tension, and the coefficient of cubic compressibility.

3.2.02-01 Heat capacity of gases

What you can learn about ...

- ➔ Equation of state for ideal gases
- ➔ 1st law of thermodynamics
- ➔ Universal gas constant
- ➔ Degree of freedom
- ➔ Mole volumes
- ➔ Isobars
- ➔ Isotherms
- ➔ Isochors and adiabatic changes of slate

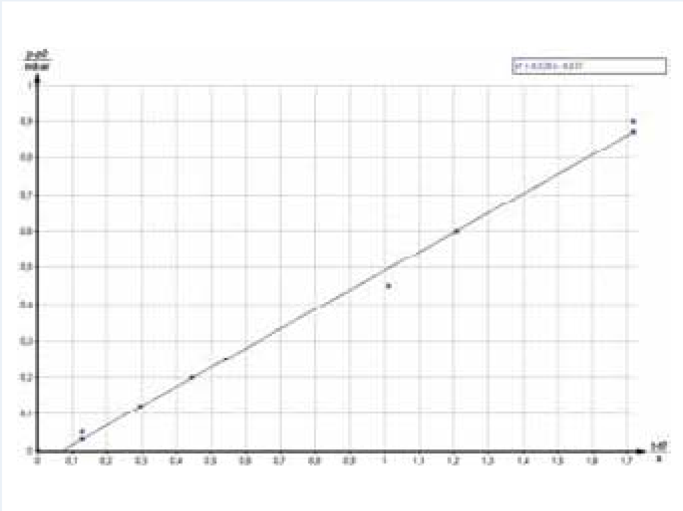
Principle:

Heat is added to a gas in a glass vessel by an electric heater which is switched on briefly. The temperature increase results in a pressure increase, which is measured with a manometer. Under isobaric conditions a temperature increase results in a volume dilatation, which can be read from a gas syringe. The molar heat capacities C_V and C_p are calculated from the pressure or volume change.

What you need:

Precision manometer	03091.00	1
Universal counter	13601.99	1
Digital multimeter 2010	07128.00	2
Mariotte flask, 10 l	02629.00	1
Gas syringes, without cock, 100 ml	02614.00	2
Glass stopcocks, 1 way, straight	36705.00	1
Three-way cock	36732.00	1
Rubber stopper, d = 32/2 6mm, 3 holes	39258.14	1
Rubber stopper, d = 59.5/50.5 mm, 1 hole	39268.01	1
Rubber tubing, d_i = 6 mm, l = 1 m	39282.00	2
Nickel electrode with socket, d = 3	45231.00	2
Nickel electrode	45218.00	1
Chrome-nickel wire, d = 0.1 mm, l = 100 m	06109.00	1
Scissors, stainless, l = 140 mm, round	64625.00	1
Two way switch, single pole	06030.00	1
Connecting cable, 4 mm plug, 32 A, red, l = 50 cm	07361.01	1
Connecting cable, 4 mm plug, 32 A, yellow, l = 50 cm	07361.02	3
Connecting cable, 4 mm plug, 32 A, red, l = 75 cm	07362.01	1
Connecting cable, 4 mm plug, 32 A, blue, l = 50 cm	07361.04	4
Tripod base -PASS-	02002.55	1
Retort stand, h = 750 mm	37694.00	2
Universal clamp	37718.00	2
Right angle clamp	37697.00	2

Complete Equipment Set, Manual on CD-ROM included
Heat capacity of gases P2320201



Pressure change Δp as a function of the heat-up time Δt. U = 4.59 V, I = 0.43 A

Tasks:

Determine the molar heat capacities of air at constant volume C_V and at constant pressure C_p.

Heat capacity of gases with Cobra3 3.2.02-11

What you can learn about ...

- Equation of state for ideal gases
- 1st law of thermodynamics
- Universal gas constant Degree of freedom
- Mole volumes
- Isobars
- Isotherms
- Isochors and adiabatic changes of slate

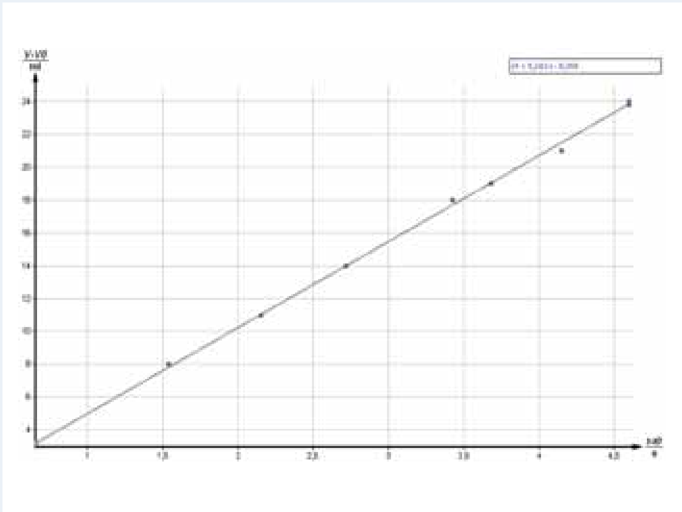
Principle:

Heat is added to a gas in a glass vessel by an electric heater which is switched on briefly. The temperature increase results in a pressure increase, which is measured with a manometer. Under isobaric conditions a temperature increase results in a volume dilatation, which can be read from a gas syringe. The molar heat capacities C_V and C_p are calculated from the pressure or volume change.

What you need:

Cobra3 Basic-Unit, USB	12150.50	1
Power supply 12V/2A	12151.99	1
Software Cobra3 Universal recorder	14504.61	1
Precision manometer	03091.00	1
Hand held measuring instrument Pressure, RS 232	07136.00	1
Cobra3 current probe 6 A	12126.00	1
Mariotte flask, 10 l	02629.00	1
Gas syringes, without cock, 100 ml	02614.00	2
Glass stopcocks, 1 way, straight	36705.00	1
Three-way cock	36732.00	1
Rubber stopper, d = 32/26 mm, 3 holes	39258.14	1
Rubber stopper, d = 59.5/50.5 mm, 1 hole	39268.01	1
Rubber tubing, d_i = 6 mm, l = 1 m	39282.00	2
Nickel electrode with socket, d = 3	45231.00	2
Nickel electrode	45218.00	1
Chrome-nickel wire, d = 0.1 mm, l = 100 m	06109.00	1
Scissors, stainless, l = 140 mm, round	64625.00	1
Push button switch, circuit closing	06039.00	1
Connecting cable, 4 mm plug, 32 A, red, l = 50 cm	07361.01	1
Connecting cable, 4 mm plug, 32 A, red, l = 75 cm	07362.01	1
Connecting cable, 4 mm plug, 32 A, blue, l = 50 cm	07361.04	4
Tripod base -PASS-	02002.55	1
Retort stand, h = 750 mm	37694.00	2
Universal clamp	37718.00	2
Right angle clamp	37697.00	2

Complete Equipment Set, Manual on CD-ROM included
Heat capacity of gases with Cobra3 P2320211



Volume change Δ_V as a function of the heat-up time Δ_t. U = 4.59 V, I = 0.43 A.

Tasks:

Determine the molar heat capacities of air at constant volume C_V and at constant pressure C_p.

3.2.03-00 Maxwellian velocity distribution

What you can learn about ...

- ➔ Kinetic theory of gases
- ➔ Temperature
- ➔ Gas
- ➔ Molecules
- ➔ Model kinetic energy
- ➔ Average velocity
- ➔ Velocity distribution

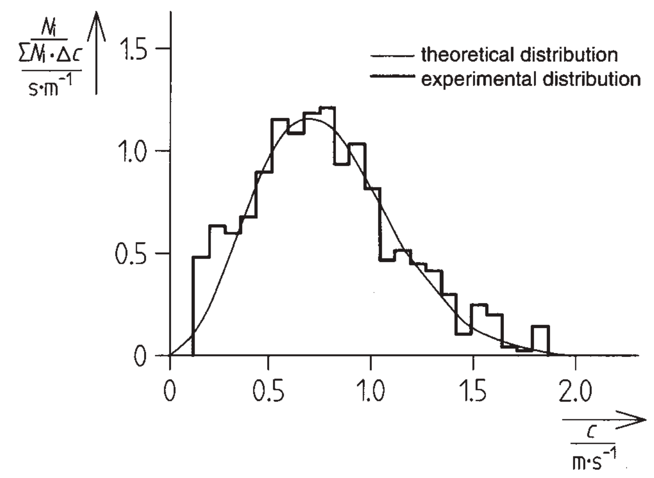
Principle:

By means of the model apparatus for kinetic theory of gases the motion of gas molecules is simulated and the velocity is determined by registration of the throw distance of the glass balls. This velocity distribution is compared to the theoretical MAXWELL-BOLTZMANN equation.

What you need:

Kinetic gas theory apparatus	09060.00	1
Receiver with recording chamber	09061.00	1
Power supply 0-12 V DC/ 6 V, 12 V AC	13505.93	1
Digital stroboscopes	21809.93	1
Stopwatch, digital, 1/100 s	03071.01	1
Tripod base -PASS-	02002.55	2
Connecting cable, 4 mm plug, 32 A, red, l = 75 cm	07362.01	1
Connecting cable, 4 mm plug, 32 A, blue, l = 75 cm	07362.04	1
Test tube, AR-glass, d = 16 mm	37656.10	1
Test tube rack for 12 tubes, wood	37686.10	1

Complete Equipment Set, Manual on CD-ROM included
Maxwellian velocity distribution P2320300



Experimental and theoretical velocity distribution in the model experiment.

Tasks:

1. Measure the velocity distribution of the “model gas”.
2. Compare the result to theoretical behaviour as described by the MAXWELL-BOLTZMANN distribution.
3. Discuss the results.

Thermal equation of state and critical point 3.2.04-00

What you can learn about …

- Ideal gas
- Real gas
- Equation of state
- Van der WAALS equation
- BOYLE temperature
- Critical point
- Interaction potential
- Molecule radius

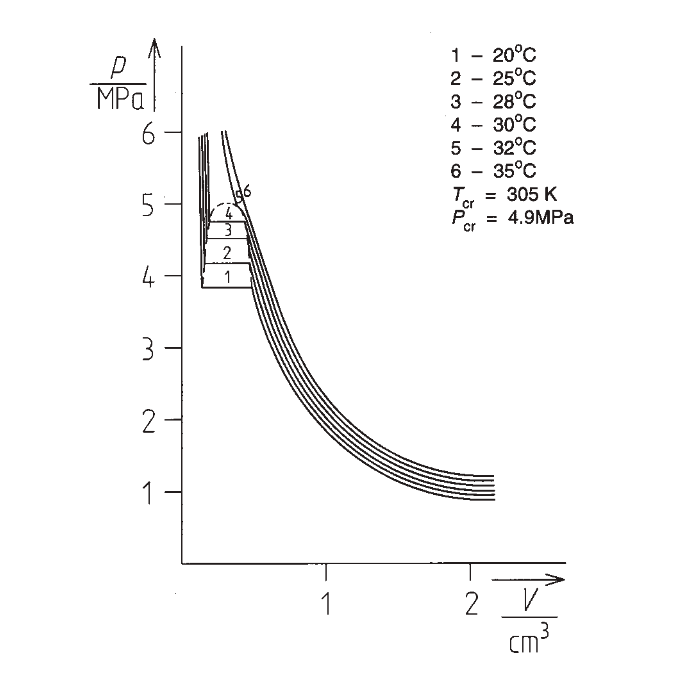
Principle:

A substance which is gaseous under normal conditions is enclosed in a variable volume and the variation of pressure with the volume is recorded at different temperatures. The critical point is determined graphically from a plot of the isotherms.

What you need:

Critical point apparatus	04364.10	1
Immersion thermostat TC10	08492.93	1
Accessory set for TC10	08492.01	1
Bath for thermostat, Makrolon	08487.02	1
Gasket for GL18, hole d = 8 mm, 10 pcs	41240.03	1
Vacuum pump, rotary sliding-vane, one-stage	02750.93	1
Adapter	02657.00	1
Safety bottle, 500 ml	34170.01	1
Spring manometer, 0...1000 mbar	34170.02	1
Glass tube, right-angled	36701.07	1
Glass tubes, right-angled	36701.57	1
Stopcock, 3-way, f-shaped, glass	36731.00	1
Tripod base -PASS-	02002.55	1
Support rod, stainless steel 18/8, l = 500 mm	02032.00	1
Laboratory thermometers, -10...+100°C	38056.00	1
Universal clamp	37718.00	1
Right angle clamp	37697.00	1
Rubber tubing, d = 8 mm	39283.00	4
Rubber tubing, vacuum, i.d. = 8 mm	39288.00	1
Rubber tubing/vacuum, d = 6 mm	39286.00	1
Pinchcock, width 15 mm	43631.15	1
Hose clip, d = 8-12 mm	40996.01	4
Hose clip for 12-20 diameter tube	40995.00	2
Mercury tray	02085.00	1
Compressed gas, ethane, 14 g	41772.09	1

Complete Equipment Set, Manual on CD-ROM included
Thermal equation of state and critical point P2320400



p-V-isotherms of ethane.

Tasks:

1. Measure a number of p-V-isotherms of ethane.
2. Determine the critical point and the critical quantities of ethane.
3. Calculate the constants of the Van der WAALS equation, the BOYLE-temperature, the radius of the molecules and the parameters of the interaction potential.

3.2.05-00 Adiabatic coefficient of gases – Flammersfeld oscillator

What you can learn about …

- ➔ Equation of adiabatic change of slate
- ➔ Polytropic equation
- ➔ Rüchardt's experiment
- ➔ Thermal capacity of gases

Principle:

A mass oscillates on a volume of gas in a precision glass tube. The oscillation is maintained by leading escaping gas back into the system. The adiabatic coefficient of various gases is determined from the periodic time of the oscillation.

What you need:

Gas oscillator, Flammersfeld	04368.00	1
Graduated cylinder, BORO 3.3, 1000 ml	36632.00	1
Aspirator bottle, clear glass, 1000 ml	34175.00	1
Air control valve	37003.00	1
Light barrier with counter	11207.30	1
Power supply 5 V DC/2.4 A with 4 mm plugs	11076.99	1
Micrometer	03012.00	1
Glass tube, AR-glass, right-angled, l = 85 + 60 mm, 10 pcs.	36701.52	1
Rubber stopper, d = 22/17 mm, 1 hole	39255.01	1
Rubber stopper, d = 32/26 mm, 1 hole	39258.01	1
Rubber tubing, d_i = 6 mm, l = 1 m	39282.00	2
Sliding weight balance, 101 g	44012.01	1
Aquarium pump, 230 V AC	64565.93	1
Aneroid barometer	03097.00	1
Stopwatch, 15 minutes	03076.01	1
Tripod base -PASS-	02002.55	1
Support rod -PASS-, square, l = 400 mm	02026.55	1
Right angle clamp -PASS-	02040.55	2
Universal clamp	37715.00	1
Pressure-reducing valves, CO_2 / He	33481.00	1
Pressure-reducing valves, nitrogen	33483.00	1
Steel cylinders, carbon dioxide, 10 l	41761.00	1
Steel cylinders, nitrogen, 10 l	41763.00	1

Complete Equipment Set, Manual on CD-ROM included
Adiabatic coefficient of gases – Flammersfeld oscillator P2320500

Ten measurements, each of about n = 300 oscillations, gave for the adiabatic coefficients

Argon	χ = 1.62 ± 0.09
Nitrogen	χ = 1.39 ± 0.07
Carbon dioxide	χ = 1.28 ± 0.08
Air	χ = 1.38 ± 0.08

Tasks:

Determine the adiabatic coefficient χ of air nitrogen and carbon dioxide (and also of argon, if available) from the periodic time of the oscillation T of the mass m on the volume V of gas

Joule-Thomson effect 3.2.06.00

What you can learn about …

- ➔ Real gas
- ➔ Intrinsic energy
- ➔ Gay-Lussac theory
- ➔ Throttling
- ➔ Van der Waals equation
- ➔ Van der Waals force
- ➔ Inverse Joule-Thomson effect
- ➔ Inversion temperature

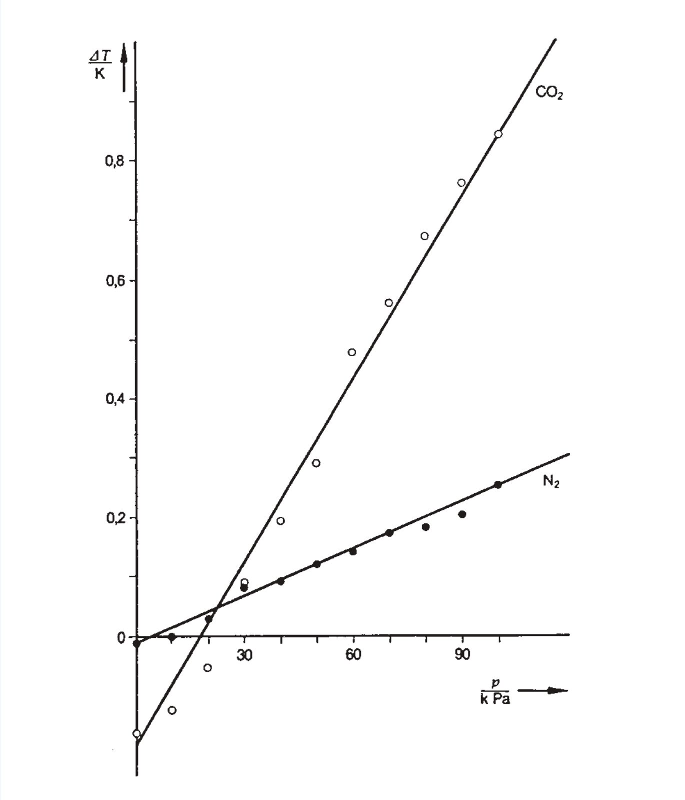
Principle:

A stream of gas is fed to a throttling point, where the gas (CO_2 or N_2) undergoes adiabatic expansion. The differences in temperature established between the two sides of the throttle point are measured at various pressures and the Joule-Thomson coefficients of the gases in question are calculated.

What you need:

Joule-Thomson apparatus	04361.00	1
Temperature meter digital, 4-2	13617.93	1
Temperature probe, Pt100	11759.01	2
Pressure-reducing valves, CO_2 / He	33481.00	1
Pressure-reducing valves, nitrogen	33483.00	1
Wrench for steel cylinders	40322.00	1
Steel cylinder, nitrogen, 10 l	41763.00	1
Steel cylinder, CO_2, 10 l	41761.00	1
Gas-cylinder Trolley for 2 Cylinder	41790.20	1
Hose clip for 12-20 diameter tube	40995.00	2
Rubber tubing, vacuum, i.d. = 8 mm	39288.00	2

Complete Equipment Set, Manual on CD-ROM included
Joule-Thomson effect P2320600



Temperature differences measured at various ram pressures.

Tasks:

1. Determination of the Joule-Thomson coefficient of CO_2.
2. Determination of the Joule-Thomson coefficient of N_2.

3.3.01-01 Heat capacity of metals

What you can learn about ...

- → Mixture temperature
- → Boiling point
- → Dulong Petit's law
- → Lattice vibration
- → Internal energy
- → Debye temperature

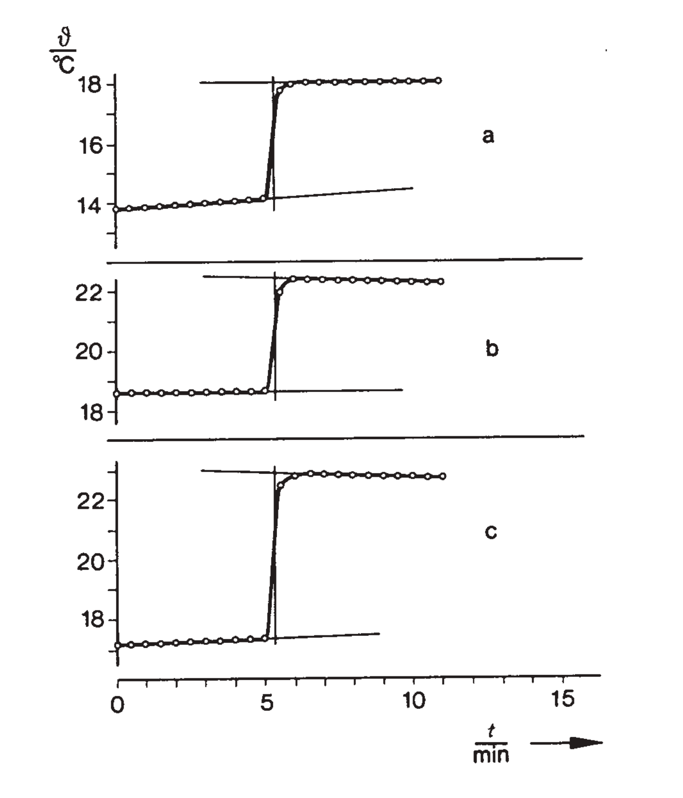
Principle:

Heated specimens are placed in a calorimeter filled with water at low temperature. The heat capacity of the specimen is determined from the rise in the temperature of the water.

What you need:

Calorimeter, 500 ml	04401.00	1
Metal bodies, set of 3	04406.00	4
Steel pot, 1 l	05933.00	1
Butane burner Labogaz 206	32178.00	1
Butane cartridge C 206 without valve	47535.00	1
Aneroid barometer	03097.00	1
Precision mercury thermometers, -10...+ 50°C	38033.00	1
Stopwatch, digital, 1/100 s	03071.01	1
Portable Balance, OHAUS CS 200	48916.93	1
Fishing line on spool, d = 0,5 mm, l = 100 mm	02090.00	1
Wire triangle (clay triangle), l = 60 mm	33278.00	1
Tripod, ring d = 140 mm, h = 240 mm	33302.00	1
Beaker, DURAN®, short form, 250 ml	36013.00	1
Beaker, DURAN®, short form, 600 ml	36015.00	1
Glass beads, 850 pieces, d = 6 mm	36756.25	1

Complete Equipment Set, Manual on CD-ROM included
Heat capacity of metals P2330101



Temperature as a function of time in the method of mixtures experiment a) steel, b) brass, c) aluminium.

Tasks:

1. To determine the heat capacity of the calorimeter by filling it with hot water and determining the rise in temperature.
2. To determine the specific heat capacity of aluminium, iron and brass.
3. To verify Dulong Petit's law with the results of these experiments.

Heat capacity of metals with Cobra3 3.3.01-11

What you can learn about …

- → Mixture temperature
- → Boiling point
- → Dulong Petit's law
- → Lattice vibration
- → Internal energy
- → Debye temperature

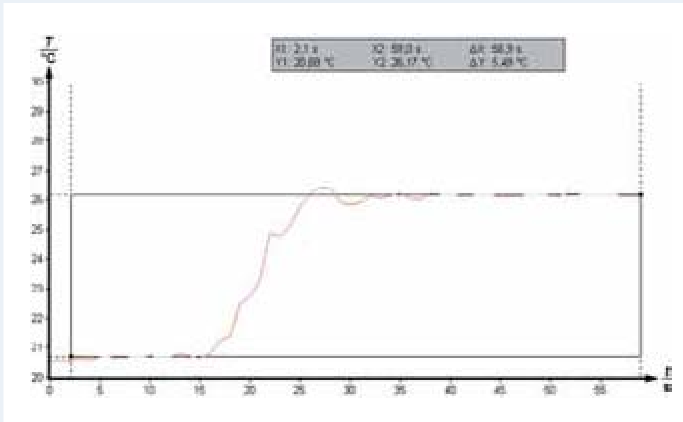
Principle:

Heated specimens are placed in a calorimeter filled with water at low temperature. The heat capacity of the specimen is determined from the rise in the temperature of the water.

What you need:

Cobra3 Basic-Unit, USB	12150.50	1
Power supply 12V/2A	12151.99	1
Software Cobra3 Temperature	14503.61	1
Measuring module temperature NiCr-Ni, 330°C	12104.00	1
Immersion probe NiCr-Ni,-50/1000°C	13615.03	1
H-base -PASS-	02009.55	1
Support rod, stainless steel 18/8, l = 600 mm	02037.00	2
Bosshead	02043.00	2
Universal clamp	37718.00	2
Ring with Bosshead, i.d. = 10 cm	37701.01	1
Wire nets, 160 x 160 mm	33287.01	1
Metal bodies, set of 3	04406.00	3
Butane burner Labogaz 206	32178.00	1
Butane cartridge C 206 without valve	47535.00	1
Stopwatch, digital, 1/100 s	03071.01	1
Portable Balance, OHAUS CS 200	48916.93	1
Fishing line on spool, d = 0,5 mm, l = 100 mm	02090.00	1
Calorimeter vessel, 500 ml	04401.10	1
Beaker, DURAN®, short form, 400 ml	36014.00	1
Beaker, DURAN®, short form, 600 ml	36015.00	1
Stirring rod	04404.10	1
Pipette, with rubber bulb	64701.00	1
Beads, 200 g	36937.20	1
PC, Windows® XP or higher		
Paper tissues		

Complete Equipment Set, Manual on CD-ROM included
Heat capacity of metals with Cobra3 P2330111



Course of temperature in the calorimeter.
For 180 g Iron (100 °C) and 200 g water (room-temperature).

Tasks:

1. To determine the specific heat capacity of aluminium, iron and brass.
2. To verify Dulong Petit's law with the results of these experiments.

3.3.02-00 Mechanical equivalent of heat

What you can learn about ...

- → Mechanical equivalent of heat
- → Mechanical work
- → Thermal energy
- → Thermal capacity
- → First law of thermodynamics
- → Specific thermal capacity

Principle:

In this experiment, a metal test body is rotated and heated by the friction due to a tensed band of synthetic material. The mechanical equivalent of heat for problem 1 is determined from the defined mechanical work and from the thermal energy increase deduced from the increase of temperature. Assuming the equivalence of mechanical work and heat, the specific thermal capacity of aluminum and brass is determined.

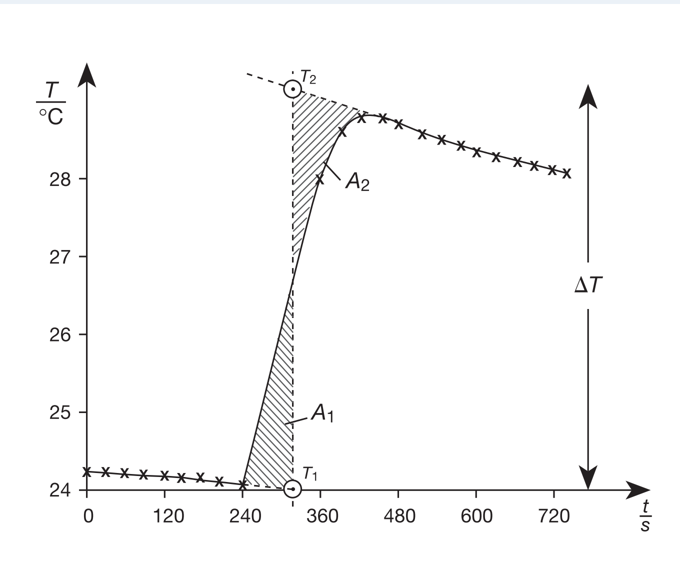
Tasks:

1. Determination of the mechanical equivalent of heat.
2. Determination of the specific thermal capacity of aluminum and brass.

What you need:

Mechanical equivalence of heat apparatus	04440.00	1
Friction cylinder CuZn, 1.28 kg	04441.02	1
Friction cylinder Al, 0.39 kg	04441.03	1
Support rod -PASS-, square, l = 250 mm	02025.55	1
Right angle clamp -PASS-	02040.55	1
Precision spring balances, 10.0 N	03060.03	1
Precision spring balances, 100.0 N	03060.04	1
Stopwatch, digital, 1/100 s	03071.01	1
Bench clamp -PASS-	02010.00	1
Universal clamp with joint	37716.00	1
Commercial weight, 1000 g	44096.70	1
Commercial weight, 5000 g	44096.81	1

Complete Equipment Set, Manual on CD-ROM included
Mechanical equivalent of heat P2330200



Temperature-time diagram for a measurement example.

Vapour pressure of water at high temperature 3.4.01-00

What you can learn about …

- ➔ Boiling point
- ➔ Heat of vaporisation
- ➔ Clausius-Clapeyron equation
- ➔ Van't Hoff law
- ➔ Carnot cycle

Principle:

Water is heated in a closed pressure chamber; as much water vaporises as to make the pressure in the chamber correspond to the vapour pressure at the temperature at any time. The heat of vaporisation is determined at various temperatures from the measurement of vapour pressure as a function of temperature.

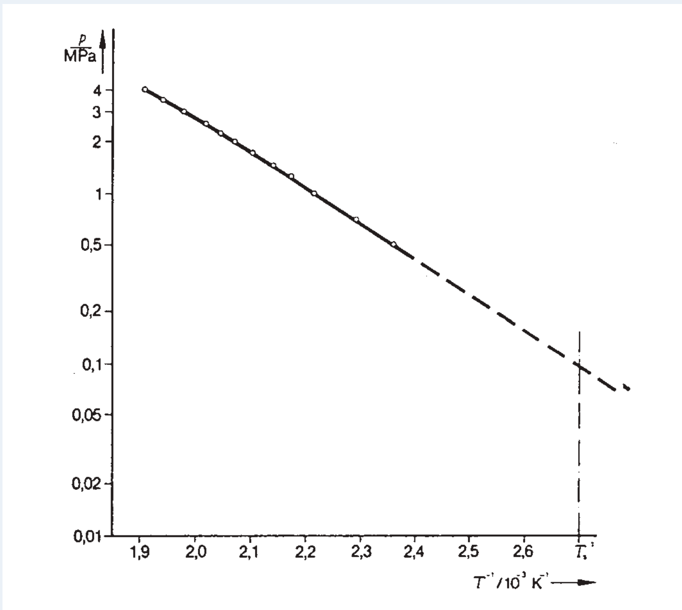
Tasks:

1. To measure the vapour pressure of water as a function of temperature.
2. To calculate the heat of vaporisation at various temperatures from the values measured.
3. To determine boiling point at normal pressure by extrapolation.

What you need:

High pressure vapour unit	02622.10	1
Heat conductive paste, 50 g	03747.00	1
Heating apparatus	32246.93	1
Pipette, with rubber bulb, long	64821.00	1
Tripod base -PASS-	02002.55	1
Bosshead	02043.00	1
Support rod, stainless steel 18/8, l = 250 mm, d = 10 mm	02031.00	1
Laboratory thermometer, -10...+250°C	38065.00	1

Complete Equipment Set, Manual on CD-ROM included
Vapour pressure of water at high temperature P2340100



Natural logarithm of vapour pressure p as a function of the reciprocal of the temperature ($1/T$): T_b = boiling point at normal pressure.

3.4.02-00 Vapour pressure of water below 100°C – Molar heat of vaporization

What you can learn about ...

- → Pressure
- → Temperature
- → Volume
- → Vaporization
- → Vapour pressure
- → Clausius-Clapeyron equation

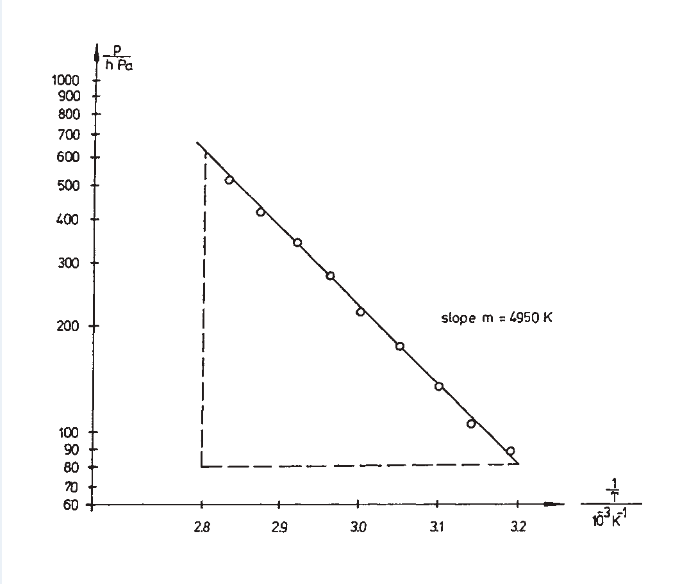
Principle:

The vapour pressure of water in the range of 40°C to 85°C is investigated. It is shown that the Clausius-Clapeyron equation describes the relation between temperature and pressure in an adequate manner. An average value for the heat of vaporization of water is determined.

What you need:

Manometer -1.0...0.6 bar	03105.00	1
Thermometer, -10...+110 °C	38005.02	2
Round flask, 100 ml, 3 necks, GL25, 2 x GL18	35677.15	1
Glass stopcocks, 1 way, right-angled	36705.01	1
Vacuum pump, rotary sliding-vane, one-stage	02750.93	1
Magnetic stirrer, Heating, Temperature-connection, 10 l	35731.93	1
Magnetic stirring rod, cylindrical, l = 30 mm	46299.02	2
Glass tube 200 mm ext. d = 8 mm	64807.00	1
Gasket for GL 18, 8 mm hole, 10 pcs	41242.03	1
Rubber tubing, vacuum, i.d. = 8 mm	39288.00	1
Rubber tubing, d = 12 mm	39285.00	1
Support base -PASS-	02005.55	1
Support rod -PASS-, square, l = 630 mm	02027.55	1
Support rod with hole, stainless steel, l = 50 cm, M10 thread	02022.20	1
Universal clamp with joint	37716.00	2
Right angle clamp -PASS-	02040.55	2
Beaker, DURAN®, short form, 400 ml	36014.00	1
Beaker, DURAN®, short form, 600 ml	36015.00	1
Water, distilled 5 l	31246.81	1

Complete Equipment Set, Manual on CD-ROM included
Vapour pressure of water below 100°C – Molar heat of vaporization P2340200



Semilogarithmic representation of vapour pressure p as a function of $^1/_T$.

Tasks:

1. About 250 ml of de-mineralized water are allowed to boil for about 10 minutes to eliminate all traces of dissolved gas. The water is then cooled down to room temperature.
2. The 3-neck round flask is filled about three-quarters full with gas-free water and heated. At 35°C the space above the water within the round flask is evacuated. Further heating causes an increase in pressure p and temperature t of water within the round flask. p and t are read in steps of 5 °C up to a maximum of t = 85°C.

Boiling point elevation 3.4.03-00

What you can learn about ...

- ➔ Raoult's law
- ➔ Henry's law
- ➔ Ebullioscopic constants
- ➔ Chemical potential
- ➔ Gibbs-Helmholtz equation
- ➔ Concentration ratio
- ➔ Degree of dissociation

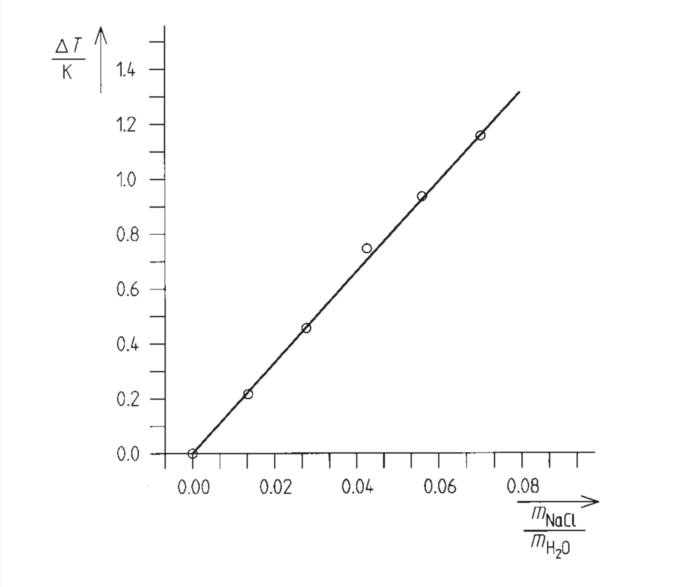
Principle:

The boiling point of a solution is always higher than that of the pure solvent. The dependence of the temperature difference (elevated boiling point) on the concentration of the solute can be determined using a suitable apparatus.

What you need:

Appartus for elevation of boiling point	36820.00	1
Heating mantle for roundbottom flask, 250 ml	49542.93	1
Clamp for heating mantle	49557.01	1
Power regulator	32288.93	1
Set of Precision Balance Sartorius CPA 623 S	49224.88	1
Weighing dishes, square shape, 84 x 84 x 24 mm, 25 pcs.	45019.25	1
Temperature meter digital, 4-2	13617.93	1
Temperature probe, Pt100	11759.01	1
Protective sleeves for temperature probe, 2 pcs.	11762.05	1
Retort stand, h = 750 mm	37694.00	1
Right angle clamp	37697.00	3
Universal clamp	37718.00	3
Flask, round, 1 neck, 250 ml, GL25/14	35812.15	1
Beaker, DURAN®, tall form, 250 ml	36004.00	1
Gasket for GL 18, 8 mm hole, 10 pcs	41242.03	1
Silicone tubing, d = 7 mm	39296.00	1
Mortar with pestle, 150 ml, porcelain	32604.00	3
Pinchcock, width 15 mm	43631.15	1
Spoon with spatula end, l = 150 mm, steel, micro	33393.00	1
Wash bottle, plastic, 500 ml	33931.00	1
Pellet press for calorimeter	04403.04	1
Funnel, glass, d = 80 mm	34459.00	1
Pasteur pipettes, l = 145 ml	36590.00	1
Rubber caps, 10 pcs	39275.03	1
Beads, 200 g	36937.20	1
Sodium chloride, 500 g	30155.50	1
Urea, 250 g	30086.25	1
Hydroquinone, 250 g	30089.25	1
Glycerol, 250 ml	30084.25	1
Water, distilled 5 l	31246.81	1

Complete Equipment Set, Manual on CD-ROM included
Boiling point elevation P2340300



Example of a measurement: boiling point increase as function of concentration of table salt in an aqueous solution.

Tasks:

1. Measure the increase in boiling point of water as a function of the concentration of table salt, urea and hydroquinone.
2. Investigate the relationship between the increase in boiling point and the number of particles.
3. Determine the molar mass of the solute from the relationship between the increase in boiling point and the concentration.

3.4.04-00 Freezing point depression

What you can learn about …

- ➔ Raoult's law
- ➔ Cryoscopic constants
- ➔ Chemical potential
- ➔ Gibbs-Helmholtz equation
- ➔ Concentration ratio
- ➔ Degree of dissociation
- ➔ Van't Hoff factor
- ➔ Cryoscopy

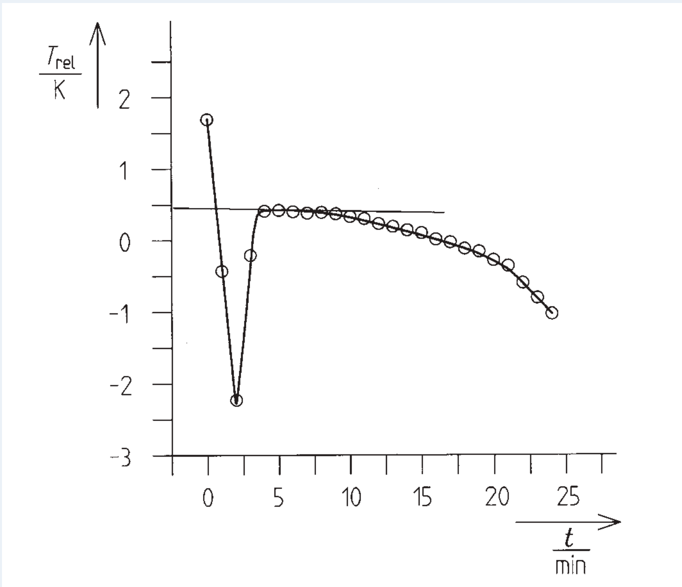
Principle:

The freezing point of a solution is lower than that of the pure solvent. The depression of the freezing point can be determined experimentally using a suitable apparatus (cryoscopy). If the cryoscopic constants of the solvent are known, the molecular mass of the dissolved substances can be determined.

What you need:

Apparatus for freezing point depression	36821.00	1
Gaskets for connecting caps, GL 25	41243.03	1
Temperature meter digital, 4-2	13617.93	1
Temperature probe, Pt100	11759.01	2
Protective sleeves for temperature probe, 2 pcs.	11762.05	1
Pellet press for calorimeter	04403.04	1
Magnetic stirrer mini, plastic (ABS)	47334.93	1
Right angle clamp	37697.00	2
Universal clamp	37718.00	2
Beaker, DURAN®, short form, 1000 ml	36017.00	1
Volumetric pipettes, 50 ml	36581.00	1
Safety pipettor Flip	36592.00	1
Retort stand, h = 1000 mm	37695.00	1
Wash bottle, plastic, 500 ml	33931.00	1
Magnetic stirring rod, cylindrical, l = 15 mm	46299.01	1
Precision Balance, Sartorius TE 153S	48832.93	1
Stopwatch, digital, 1/100 s	03071.01	1
Mortar with pestle, 70 ml, porcelain	32603.00	2
Spoon with spatula end, l = 150 mm, steel, micro	33393.00	1
Spoon with spatula end, l = 150 mm, steel, wide	33398.00	1
Funnel, plastic, d = 50 mm	36890.00	1
Weighing dishes, square shape, 84 x 84 x 24 mm, 25 pcs.	45019.25	1
Pasteur pipettes, l = 145 ml	36590.00	1
Rubber caps, 10 pcs	39275.03	1
Stirring rods, BORO 3.3, l = 300 mm, d = 8 mm	40485.06	1
Sodium chloride, 500 g	30155.50	1
Hydroquinone, 250 g	30089.25	1
Denatured alcohol (Spirit forburning), 1000 ml	31150.70	1

Complete Equipment Set, Manual on CD-ROM included
Freezing point depression P2340400



Cooling curve of water/table salt (NaCl) mixture.

Tasks:

1. Determine the size of freezing point depression after dissolving a strong electrolyte (NaCl) in water. By comparing the experimental value with the theoretical one predicted for this concentration, determine the number of ions into which the electrolyte dissociates.
2. Determine the apparent molar mass of a non-electrolyte (hydroquinone) from the value of freezing point depression.

Stefan-Boltzmann's law of radiation 3.5.01-01/15

Set-up of experiment P2350115 with Cobra3

What you can learn about …

- Black body radiation
- Thermoelectric e. m. f.
- Temperature dependence of resistances

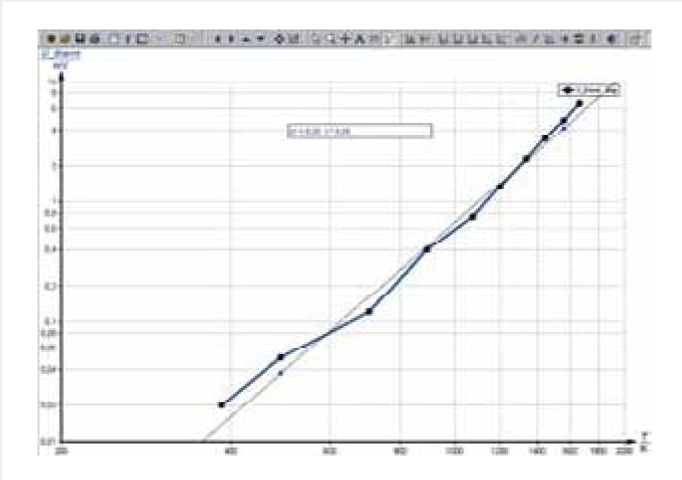
Principle:

According of Stefan-Boltzmann's law, the energy emitted by a black body per unit area and unit time is proportional to the power "four" of the absolute temperature of the body. Stefan-Boltzmann's law is also valid for a so-called "grey" body whose surface shows a wavelength-independent absorption-coefficient of less than one. In the experiment, the "grey" body is represented by the filament of an incandescent lamp whose energy emission is investigated as a function of the temperature.

What you need:

Item	Order No.	Experiment P2350101 with amplifier	Experiment P2350115 with Cobra3
Optical profile bench, l = 600 mm	08283.00	1	
Base for optical profile bench, adjustable	08284.00	2	
Slide mount for optical profil bench, h = 30 mm	08286.01	2	
Universal measuring amplifier	13626.93	1	
Thermopile, Moll type	08479.00	1	1
Shielding tube for thermopile	08479.01	1	1
Variable transformer with rectifier 15 V~/12 V- , 5 A	13530.93	1	1
Lamp socket E 14, on stem	06175.00	1	1
Filament lamps, 6 V/5 A	06158.00	3	3
Connection box	06030.23	1	1
Resistor 100 Ω 2%, 1W, G1	06057.10	1	1
Digital multimeter 2010	07128.00	3	1
Connecting cable, 4 mm plug, 32 A, blue, l = 50 cm	07361.04	4	3
Connecting cable, 4 mm plug, 32 A, red, l = 50 cm	07361.01	4	2
Barrel base -PASS-	02006.55		2
Meter Scale, l = 1000 x 27 mm	03001.00		1
Cobra3 Basic-Unit, USB	12150.50		1
Power supply 12V/2A	12151.99		1
Software Cobra3 Universal recorder	14504.61		1
PC, Windows® XP or higher			

Complete Equipment Set, Manual on CD-ROM included
Stefan-Boltzmann's law of radiation P23501 01/15



Thermoelectric e. m. f. of thermopile as a function of the filament's absolute temperature.

Tasks:

1. To measure the resistance of the filament of the incandescent lamp at room temperature and to ascertain the filament's resistance R_0 at zero degrees centigrade.
2. To measure the energy flux density of the lamp at different heating voltages. The corresponding heating currents read off for each heating voltage and the corresponding filament resistance calculated. Anticipating a temperature-dependency of the second order of the filament-resistance, the temperature can be calculated from the measured resistances.

3.5.02-00 Thermal and electrical conductivity of metals

What you can learn about …

- ➔ Electrical conductivity
- ➔ Wiedmann-Franz law
- ➔ Lorenz number
- ➔ Diffusion
- ➔ Temperature gradient
- ➔ Heat transport
- ➔ Specific heat
- ➔ Four-point measurement

Principle:

The thermal conductivity of copper and aluminium is determined in a constant temperature gradient from the calorimetrically measured heat flow.

The electrical conductivity of copper and aluminium is determined, and the Wiedmann-Franz law is tested.

Tasks:

1. Determine the heat capacity of the calorimeter in a mixture experiment as a preliminary test. Measure the calefaction of water at a temperature of 0 °C in a calorimeter due to the action of the ambient temperature as a function of time.
2. To begin with, establish a constant temperature gradient in a metal rod with the use of two heat reservoirs (boiling water and ice water) After removing the pieces of ice, measure the calefaction of the cold water as a function of time and determine the thermal conductivity of the metal rod.
3. Determine the electrical conductivity of copper and aluminium by recording a current-voltage characteristic line.
4. Test of the Wiedmann-Franz law.

What you need:

Calorimeter vessel, 500 ml	04401.10	1
Calorimeter vessel with heat conductivity connection	04518.10	1
Heat conductivity rod, Cu	04518.11	1
Heat conductivity rod, Al	04518.12	1
Magnetic stirrer mini, plastic (ABS)	47334.93	1
Heat conductive paste, 50 g	03747.00	1
Gauze bag	04408.00	1
Rheostats, 10 Ω, 5.7 A	06110.02	1
Immersion heater, 300 W, 220-250 VDC/AC	05947.93	1
Temperature meter digital, 4-2	13617.93	1
Temperature probe, Pt100	11759.01	1
Temperature surface probe Pt 100	11759.02	2
Stopwatch, digital, 1/100 s	03071.01	1
Tripod base -PASS-	02002.55	1
Bench clamp -PASS-	02010.00	1
Support rod -PASS-, square, l = 630 mm	02027.55	1
Support rod -PASS-, square, l = 1000 mm	02028.55	1
Universal clamp	37715.00	4
Right angle clamp -PASS-	02040.55	6
Supporting block 105 x 105 x 57 mm	02073.00	1
Beaker, DURAN®, short form, 400 ml	36014.00	1

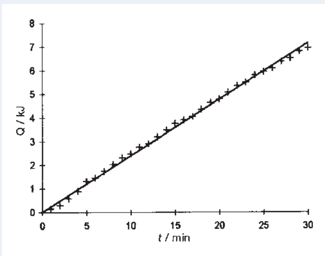


Diagram: Heat of surroundings over time.

For the electrical conductivity you need:

Multi-tap transformer with rectifier 14 VAC/12 VDC, 5 A	13533.93	1
Digital multimeter 2010	07128.00	2
Universal measuring amplifier	13626.93	1
Connecting cable, 4 mm plug, 32 A, red, l = 50 cm	07361.01	4
Connecting cable, 4 mm plug, 32 A, blue, l = 50 cm	07361.04	4

Complete Equipment Set, Manual on CD-ROM included
Thermal and electrical conductivity of metals P2350200

Solar ray Collector 3.6.01-00

What you can learn about ...

- ➔ Absorption
- ➔ Heat radiation
- ➔ Greenhouse effect
- ➔ Convection
- ➔ Conduction of heat
- ➔ Collector equations
- ➔ Efficiency
- ➔ Energy ceiling

Principle:

The solar ray collector is illuminated with a halogen lamp of known light intensity. The heat energy absorbed by the collector can be calculated from the volume flow and the difference in the water temperatures at the inlet and outlet of the absorber, if the inlet temperature stays almost constant by releasing energy to a reservoir. The efficiency of the collector is determined from this. The measurement is made with various collector arrangements and at various absorber temperatures.

What you need:

Solar collector	06753.00	1
Laboratory thermometers, -10...+100°C	38056.00	2
Laboratory thermometer -10...+110 °C	38060.00	1
Circulating pump w. flowmeter	06754.01	1
Power supply 0-12 V DC/ 6 V, 12 V AC	13505.93	1
Heat exchanger	06755.00	1
Stand for solar collector	06757.00	1
Immersion heater, 1000 W, 220-250 V	04020.93	1
Halogen lamp 1000 W	08125.93	1
Hot/cold air blower, 1700 W	04030.93	1
Tripod base -PASS-	02002.55	2
Support rod -PASS-, square, l = 250 mm	02025.55	2
Right angle clamp -PASS-	02040.55	2
Universal clamp	37718.00	1
Beaker, DURAN®, tall form, 2000 ml	36010.00	1
Beaker, DURAN®, short form, 5000 ml	36272.00	1
Safety gas tubing, DVGW, l = 1000 mm	39281.10	3
Measuring tape, l = 2 m	09936.00	1
Stopwatch, digital, 1/100 s	03071.01	1
Connecting cable, 4 mm plug, 32 A, red, l = 75 cm	07362.01	1
Connecting cable, 4 mm plug, 32 A, blue, l = 75 cm	07362.04	1

Complete Equipment Set, Manual on CD-ROM included
Solar ray Collector P2360100

No.	Glass plate	Light	Cold air	ϑ_e °C	$\vartheta_a - \vartheta_e$ K	η %
1.1	+*	–	–	≈ 5	2.5	15
1.2	–*	–	–	≈ 5	5.0	29
2.1	+	+	–	≈ 20	11.0	64
2.2	–	+	–	≈ 20	12.5	73
3.1	+	+	–	≈ 50	8.0	47
3.2	–	+	+	≈ 50	8.0	47
3.3	+	+	–	≈ 50	6.0	35
3.4	–	+	+	≈ 50	3.0	17

* This series of measurements without rear insulation

Water Temperatures and Collector Efficiency under Various Experimental Conditions, $\dot{m}$ = 100 cm3/min, q_i = 1 kW/m^2, A = 0 · 12 m^2.

Tasks:

To determine the efficiency of the solar ray collector under various experimental conditions.

1. Absorption of energy from the environment (20°C) without illumination by sun or halogen lamp, water temperature at the absorber inlet $\vartheta_e \approx$ 5°C.
   1.1 Absorber with insulation and glass plate (complete collector)
   1.2 Absorber alone (energy ceiling)
2. Illumination with halogen lamp. Water temperature qe≈ 20°C.
   2.1 Complete collector
   2.2 Collector without glass plate
3. Illumination with halogen lamp. Water temperature qe ≈ 50°C.
   3.1 Complete collector
   3.2 Complete collector, cold jet of air impinges
   3.3 Collector without glass plate
   3.4 Collector without glass plate, cold jet of air impinges.

3.6.02-00 Heat pump

What you can learn about …

- ➔ Refrigerator
- ➔ Compressor
- ➔ Restrictor valve
- ➔ Cycle
- ➔ Vaporization
- ➔ Condensation
- ➔ Vapour pressure
- ➔ Vaporisation enthalpy

Principle:

Pressures and temperatures in the circulation of the heat electrical compression heat pump are measured as a function of time when it is operated as a water-water heat pump.

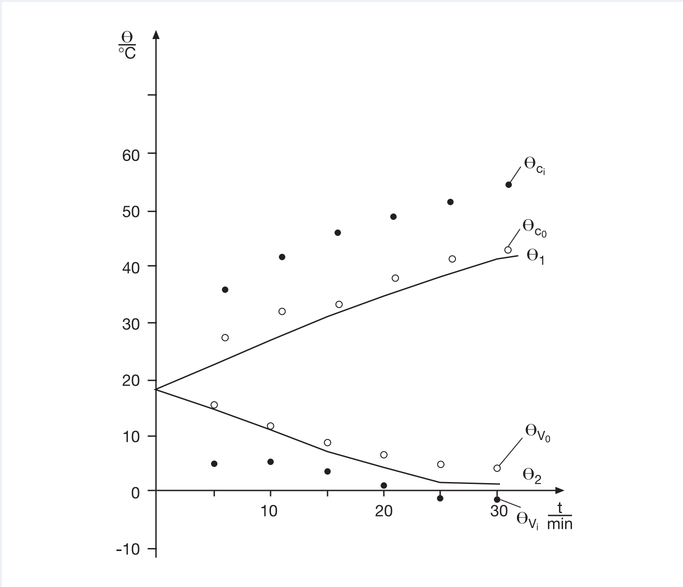
The energy taken up and released is calculated from the heating and cooling of the two water baths.

When it is operated as an air-water heat pump, the coefficient of performance at different vaporiser temperatures is determined.

What you need:

Heat pump, compressor principle	04370.88	1
Laboratory thermometers, -10...+100°C	38056.00	4
Laboratory thermometer -10...+110 °C	38060.00	2
Heat conductive paste, 50 g	03747.00	1
Hot/cold air blower, 1700 W	04030.93	1
Stopwatch, digital, 1/100 s	03071.01	1
Tripod base -PASS-	02002.55	1
Support rod -PASS-, square, l = 250 mm	02025.55	1
Universal clamp with joint	37716.00	1
Right angle clamp -PASS-	02040.55	1
Beaker, DURAN®, tall form, 2000 ml	36010.00	1
Stirring rods, BORO 3.3, l = 300 mm, d = 7 mm	40485.05	2
Work and power meter	13715.93	1

Complete Equipment Set, Manual on CD-ROM included
Heat pump P2360200



Temperatures at the inlet and outlet of the vaporiser Θ_{V_i} (●), Θ_{V_o} (○) and condenser Θ_{C_i} (●), Θ_{C_o} (○) as a function of the operating time; continuous curves: temperature in water reservoirs.

Tasks:

1. Water heat pump:
   To measure pressure and temperature in the circuit and in the water reservoirs on the condenser side and the vaporiser side alternately. To calculate energy taken up and released, also the volume concentration in the circuit and the volumetric efficiency of the compressor.
2. Air-water heat pump:
   To measure vaporiser temperature and water bath temperature on the condenser side under different operating conditions on the vaporiser side,
   - 2.1 with stream of cold air
   - 2.2 with stream of hot air
   - 2.3 without blower.

If a power meter is available, the electric power consumed by the compressor can be determined with it and the coefficient of performance calculated.

Heat insulation / Heat conduction 3.6.03-00

What you can learn about ...

- → Heat transition
- → Heat transfer
- → Heat conductivity
- → Thermal radiation
- → Hothouse effect
- → Thermal capacity
- → Temperature amplitude attenuation

Principle:

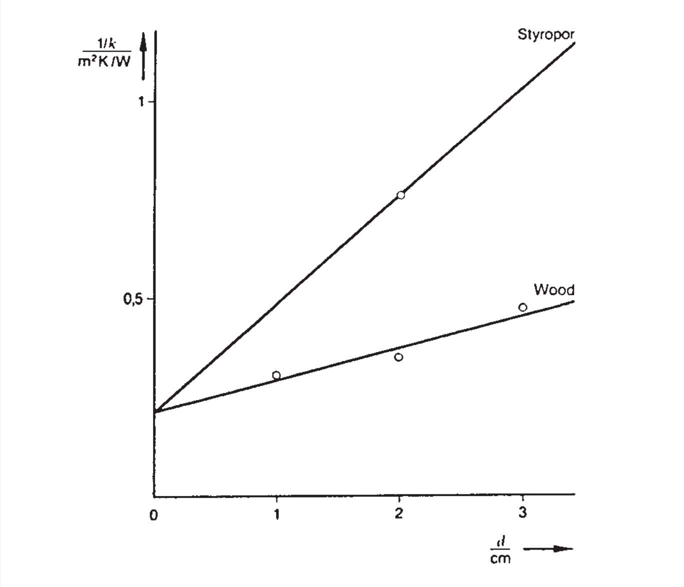
A model house with replaceable side walls is used for determining the heat transition coefficients (k values) of various walls and windows and for establishing the heat conductivities of different materials. For this purpose the temperatures on the inside and outside of the walls are measured at a constant interior and outer air temperature (in the steady state).

With a multilayer wall structure the temperature difference over a layer is proportional to the particular thermal transmission resistance. The thermal capacity of the wall material affects the wall temperatures during heating up and temporary exposure to solar radiation.

What you need:

High insulation house	04507.93	1
Thermal regulation for high insulation house	04506.93	1
Partitions, plastic foam, 5 off	44536.02	1
Ceramic lamp socket E27 with reflector, switch, safety plug	06751.01	1
Filament lamp with reflector, 230 V/120 W	06759.93	1
Cobra4 Mobile Link	12620.55	2
Cobra4 Sensor-Unit 2x Temp NiCr-Ni	12641.00	2
Thermocouple NiCr-Ni, max. 500°C, simple	13615.02	4
Tripod base -PASS-	02002.55	1
Stopwatch, digital, 1/100 s	03071.01	1
Right angle clamp -PASS-	02040.55	1
High performance charger for 4 Ni-MH accumulators	07929.99	1

Complete Equipment Set, Manual on CD-ROM included
Heat insulation / Heat conduction P2360300



Heat transition resistance $1/k$ as a function of the wall thickness d.

Tasks:

1. Measurement and interpretation of water temperatures during the heating up and during temporary external illumination of the walls.
2. Determination of the heat conductivities of wood and Styropor.
3. Determination of the k values of ordinary glass and insulating glass windows and of wooden walls of different thicknesses, and of walls with wood, Styropor or cavity layers.

3.6.04-01/15 Stirling engine

Set-up of experiment P2360415 with Cobra3

What you can learn about …

- First and second law of thermodynamics
- Reversible cycles
- Isochoric and isothermal changes
- Gas laws
- Efficiency
- Stirling engine
- Conversion of heat
- Thermal pump

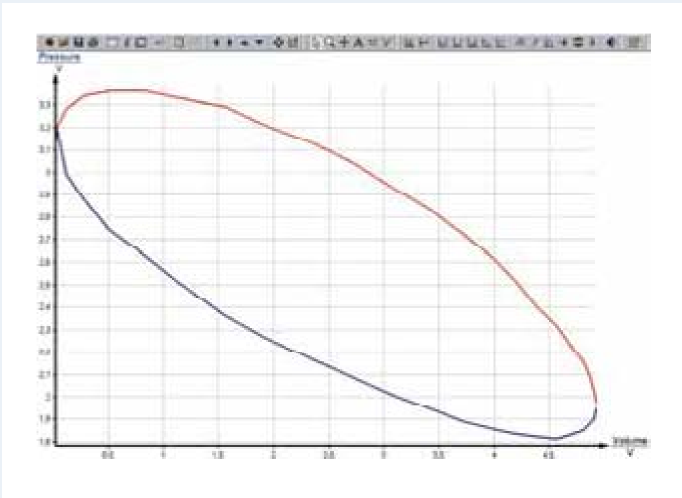
Principle:

The Stirling engine is submitted to a load by means of an adjustable torque meter, or by a coupled generator. Rotation frequency and temperature changes of the Stirling engine are observed. Effective mechanical energy and power, as well as effective electrical power, are assessed as a function of rotation frequency. The amount of energy converted to work per cycle can be determined with the assistance of the pV diagram. The efficiency of the Stirling engine can be estimated.

What you need:

		Experiment P2360401 with oscilloscope	Experiment P2360415 with Cobra3
Stirling motor, transparent	04372.00	1	1
Motor/Generator unit	04372.01	1	1
Torque meter	04372.02	1	1
Chimney for Stirling engine	04372.04	1	1
Meter for Stirling engine, pVnT	04371.97	1	1
Sensor unit pVn for Stirling engine	04371.00	1	1
Syringe 20 ml, Luer, 10 pcs	02591.03	1	
Rheostats, 330 Ω, 1.0 A	06116.02	1	
Digital multimeter 2010	07128.00	2	
Connecting cable, 4 mm plug, 32 A, red, l = 50 cm	07361.01	2	
Connecting cable, 4 mm plug, 32 A, blue, l = 50 cm	07361.04	3	
Oscilloscope 30 MHz, 2 channels	11459.95	1	
Screened cable, BNC, l = 750 mm	07542.11	2	2
Thermocouple NiCr-Ni, sheathed	13615.01	2	2
Cylinder, PP, 50 ml	36628.01	1	
Denatured alcohol (Spirit forburning), 1000 ml	31150.70	1	1
Adapter BNC socket/4 mm plug pair	07542.27		2
Cobra3 Basic-Unit, USB	12150.50		1
Power supply 12V/2A	12151.99		1
Software Cobra3 Universal recorder	14504.61		1
PC, Windows® XP or higher			
Optional accessories for solar motor work			
Accessories f. solar motor work	04372.03	1	
Support base -PASS-	02005.55	1	
Extension coupling, hinged	02045.00	1	
Support rod, stainl. steel, l = 500 mm	02032.00	1	
Optional accessories for heat pump work			
Power supply	13505.93	1	

Complete Equipment Set, Manual on CD-ROM included
Stirling engine P23604 01/15

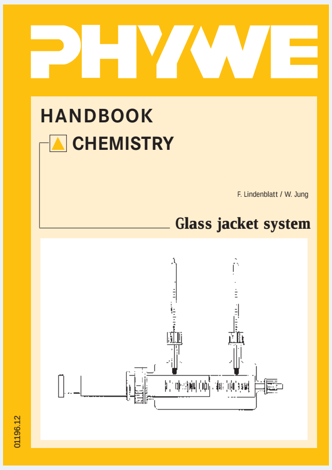


Pressure as a function of Volume for the Stirling process.

Tasks:

1. Determination of the burner's thermal efficiency
2. Calibration of the sensor unit
3. Calculation of the total energy produced by the engine through determination of the cycle area on the oscilloscope screen, using transparent paper and coordinate paper.
4. Assessment of the mechanical work per revolution, and calculation of the mechanical power output as a function of the rotation frequency, with the assistance of the torque meter.
5. Assessment of the electric power output as a function of the rotation frequency.
6. Efficiency assessment.

Glass jacket system



Glass jacket equipment system

This system consists of a glass jacket, special inserts and accessories. It was mainly developed for experiments with gases and can be used at school for teaching physics, chemistry and biology.

- Demonstrative and transparent
- Versatile and easily assembled
- Water bath for accurate measurements

Fields of application:

- Working out the laws of gases
- Determination of molar masses
- Determination of combustion enthalpies.

Glass jacket system • No. 01196.12 • 17 described Experiments

Please ask for a complete equipment list Ref. No. 23701

GL 1 (12229)
Gay-Lussac's law

GL 2 (12230)
Amonton's law

GL 3 (12231)
The Boyle-Mariotte law

GL 4 (12232)
The gas laws of Boyle-Marriotte, Gay-Lussac and Amontons

GL 5 (12233)
Determination of molar masses by means of vapour density method

GL6 (12234)
The law of integral volumes

GL 7 (12235)
Gay-Lussac's law of gaseous combustion

GL 8 (12236)
Avogadro's law

GL 9 (12237)
The chemical formula for methane, ethane and propane

GL 10 (12238)
Determination of the heat of formation of water

GL 11 (12239)
Determination of the heat of formation of CO_2 and CO and Hess's law

GL 12 (12240)
Determination of heating value (fuel value) of solid and gaseous fuels in a horizontal calorimeter

GL 13 (12241)
Determination of the calorific value of some foods

GL 14 (12242)
Determination of the heating value (fuel value) of liquids in the vertical calorimeter

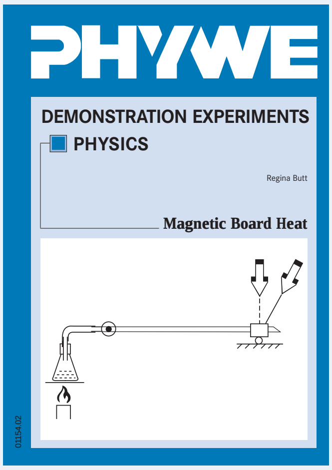
GL 15 (12243)
Determination of the fuel value of heating oil and diesel fuel and the calorific value of olive oil

GL 16 (12244)
Chromatographic separation techniques: gas chromatography

GL 17 (12245)
Distillation with steam

Amonton's law (GL 2)

Demonstration Experiments Physics– Magnetic Board Heat



The demonstration board with support stand finds application in all fields of physics. Experimentation on the board has the following advantages in the range of thermodynamics:

- Quantity of liquids and convection currents in liquids can easily be seen in glass vessels placed in front of the single-color background
- Observations are supported by use of colored marking arrows and points
- Description of the experiments and explanatory sketches and tables can be made directly on the board
- Individual positioning and simple movement of the holders
- Secure positioning through strong magnets

Special holders and equipment allow a secure, simple and clear method of experimentation on the demonstration board.
The distance of the experimental equipment to the board are correlative and optimised for the specified application.

Demonstration Experiments Physics – Magnetic Board Heat • No. 01154.02 • 15 described Experiments

Please ask for a complete equipment list Ref. No. 23703

1 Thermal expansion

1.1 (12913)
Volume expansion of water

1.2 (12914)
Preparing a thermometer scale

1.3 (12915)
Linear expansion of solid bodies

1.4 (12916)
Volume expansion of gases at constant pressure

1.5 (12917)
Pressure elevation on heating gases at constant volume

2 Heat transport

2.1 (12918)
Heat flux in liquids and gases

2.2 (12919)
Heat conduction in solid bodies

2.3 (12920)
Heat conduction in water

2.4 (12921)
Absorption of thermal radiation

2.5 (12922)
Utilisation of radiated energy with a solar collector

2.6 (12923)
Utilisation of radiated energy with a solar cell

3 Refraction

3.1 (12924)
Gay-Lussac's law

3.1 (12925)
Charles' law

3.3 (12926)
Boyle and Mariotte's law

3.4 (12927)
Molar volume and universal gas constant – Determination of the relative molar mass

Volume expansion of gases at constant pressure (1.4)

Linear expansion of solid bodies (1.3)

4

Electricity

4

Electricity

Contents

Measurement of small resistance 4.1.01-01

What you can learn about ...

- → Ohm's law
- → Resistivity
- → Contact resistance
- → Conductivity
- → Four-wire method of measurement

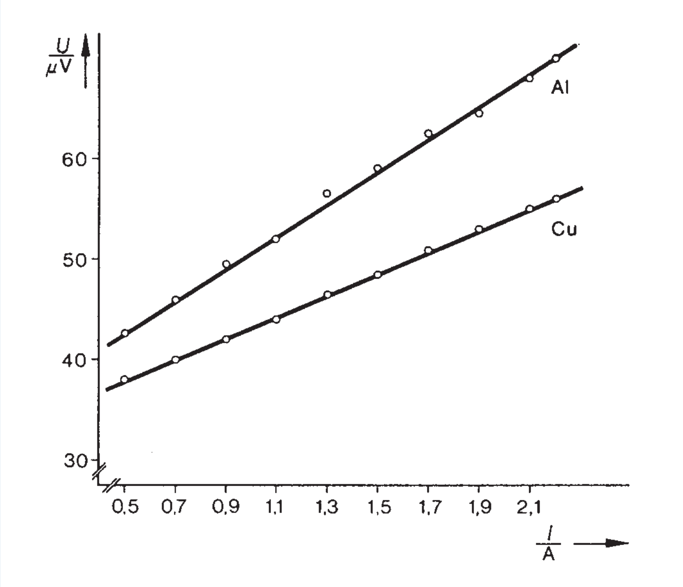
Principle:

The resistances of various DC conductors are determined by recording the current/voltage characteristic. The resistivity of metal rods and the contact resistance of connecting cords are calculated.

What you need:

Heat conductivity rod, Cu	04518.11	1
Heat conductivity rod, Al	04518.12	1
Universal measuring amplifier	13626.93	1
Digital multimeter 2010	07128.00	2
Power supply 0-12 V DC/ 6 V, 12 V AC	13505.93	1
Connection box	06030.23	1
Connecting cable, 4 mm plug, 32 A, yellow, l = 10 cm	07359.02	2
Connecting cable, 4 mm plug, 32 A, red, l = 25 cm	07360.01	1
Connecting cable, 4 mm plug, 32 A, blue, l = 25 cm	07360.04	1
Connecting cable, 4 mm plug, 32 A, red, l = 50 cm	07361.01	2
Connecting cable, 4 mm plug, 32 A, blue, l = 50 cm	07361.04	1
Connecting cable, 4 mm plug, 32 A, yellow, l = 75 cm	07362.02	2
Connecting cable, 4 mm plug, 32 A, blue, l = 75 cm	07362.04	1
Connecting cable, 4 mm plug, 32 A, yellow, l = 200 cm	07365.02	2

Complete Equipment Set, Manual on CD-ROM included
Measurement of small resistance P2410101



Current/voltage characteristics of a copper rod and an aluminium rod.

Tasks:

1. To plot the current/voltage characteristics of metal rods (copper and aluminium) and to calculate their resistivity.
2. To determine the resistance of various connecting cords by plotting their current/voltage characteristics and calculating the contact resistances.

4.1.01-15 Ohm's Law with FG-Module

What you can learn about …
- → Ohm's law
- → Resistivity
- → Contact resistance
- → Conductivity
- → Power and Work

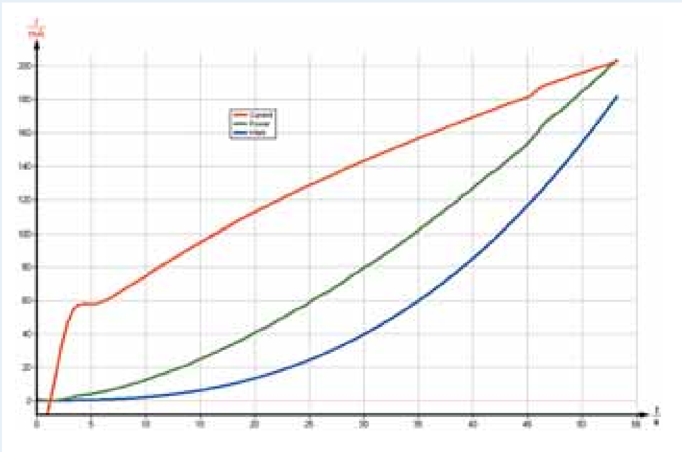
Principle:

The electrical resistance of pure metals increases with increasing temperature. The correlation between voltage and current is to be measured using temperature-in- and dependent resistors. Determine the work and power of an incandescent bulb.

What you need:

Cobra3 Basic-Unit, USB	12150.50	1
Power supply 12V/2A	12151.99	2
Measuring module Function Generator	12111.00	1
Connection box	06030.23	1
Carbon resistor 100 Ω, 1W, G1	39104.63	1
Carbon resistor 220 Ω, 1W, G1	39104.64	1
Carbon resistor 330 Ω, 1W, G1	39104.13	1
Lamp socket E 10, G1	17049.00	1
Filament lamps, 12 V/0.1 A	07505.03	1
Connecting cable, 4 mm plug, 32 A, red, l = 50 cm	07361.01	2
Connecting cable, 4 mm plug, 32 A, blue, l = 50 cm	07361.04	2
Software Cobra3 PowerGraph	14525.61	1
PC, Windows® XP or higher		

Complete Equipment Set, Manual on CD-ROM included
Ohm's Law with FG-Module P2410115



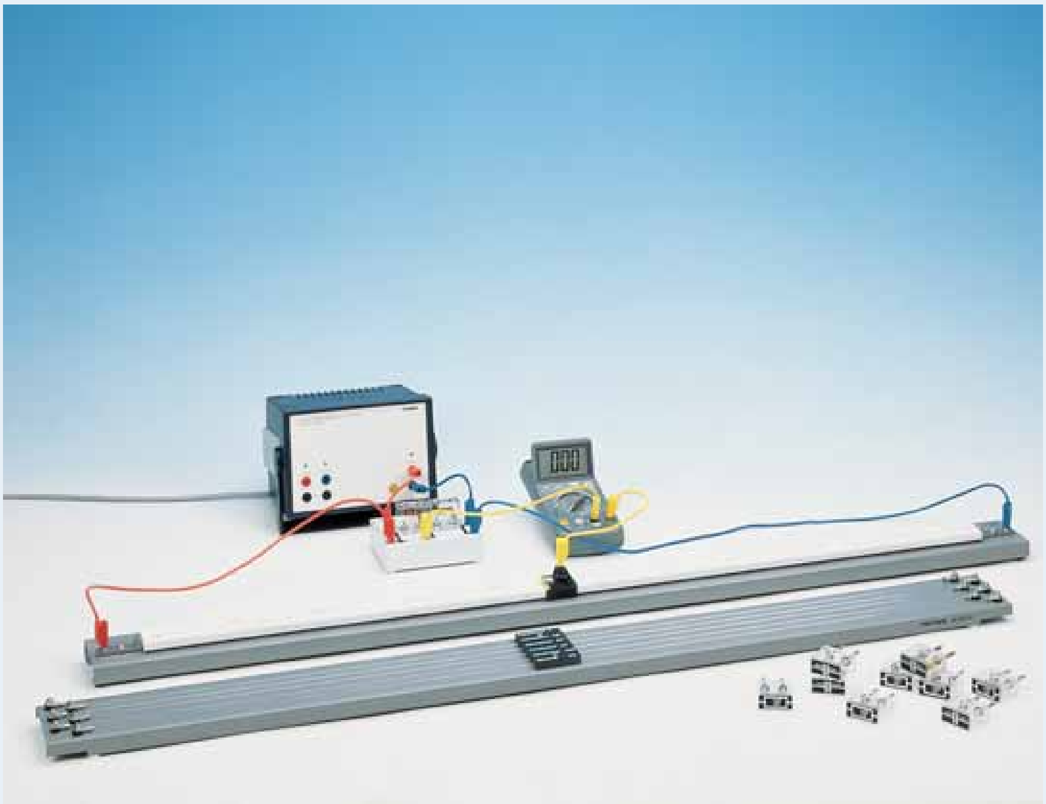
Current, Power and Work of an incandescent bulb.

Tasks:

1. To plot the current/voltage characteristics of Ohm's resistors and of pure metals and to calculate their resistivity.
2. To determine the resistance of various connecting cords by plotting their current/characteristics and calculating the contact resistances.
3. To determine the work and power of an incandescent bulb as a function of the applied voltage.

You can find more experiments in Handbook "Physics Experiments with Cobra3" Order No. 01310.02

Wheatstone Bridge 4.1.02-00



What you can learn about …

- ➔ Kirchhoff's laws
- ➔ Conductor
- ➔ Circuit
- ➔ Voltage
- ➔ Resistance
- ➔ Para llel connection
- ➔ Series connection

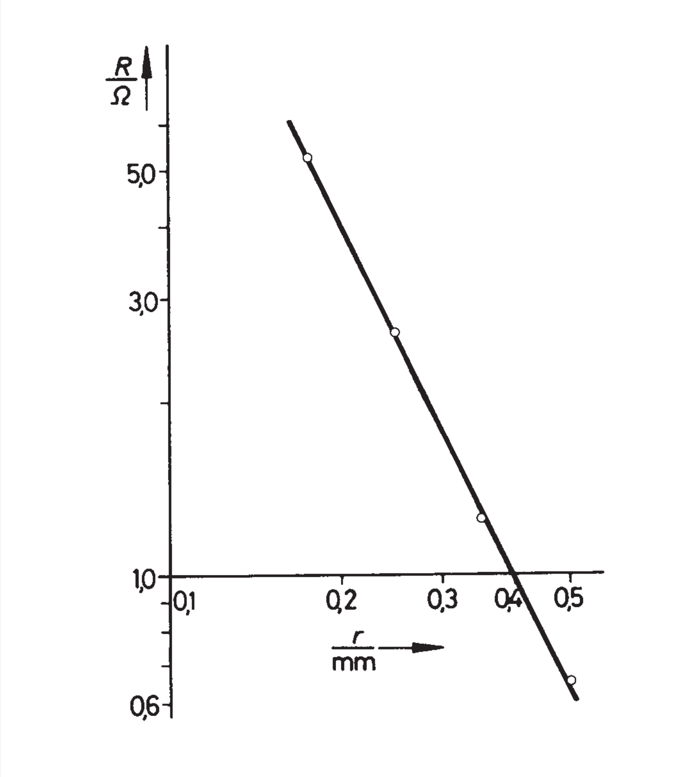
Principle:

The Wheatstone bridge circuit is used to determine unknown resistances. The total resistance of resistors connected in parallel and in series is measured.

What you need:

Resistance board, metal	06108.00	1
Simple slide wire measuring bridge	07182.00	1
Connection box	06030.23	1
Carbon resistor 10 Ω, 1W, G1	39104.01	1
Carbon resistor 100 Ω, 1W, G1	39104.63	1
Carbon resistor 150 Ω, 1W, G1	39104.10	1
Carbon resistor 330 Ω, 1W, G1	39104.13	1
Carbon resistor G1, 680 Ω, 1 W	39104.17	1
Carbon resistor 1 kΩ, 1W, G1	39104.19	1
Carbon resistor 4.7 kΩ, 1W, G1	39104.27	1
Carbon resistor 10 kΩ, 1W, G1	39104.30	1
Carbon resistor 15 kΩ, 1W, G1	39104.32	1
Carbon resistor G1, 82 kΩ, 1 W	39104.40	1
Carbon resistor 100 kΩ, 1W, G1	39104.41	1
Power supply 5 V-/1 A, +/- 15 V	13502.93	1
Digital multimeter 2010	07128.00	1
Connecting cable, 4 mm plug, 32 A, red, l = 50 cm	07361.01	2
Connecting cable, 4 mm plug, 32 A, yellow, l = 50 cm	07361.02	2
Connecting cable, 4 mm plug, 32 A, blue, l = 50 cm	07361.04	2
Resistor 1 Ω 2%, 2W, G1	06055.10	1
Resistor 2 Ω 2%, 2W, G1	06055.20	1
Resistor 5 Ω 2%, 2W, G1	06055.50	1

Complete Equipment Set, Manual on CD-ROM included
Wheatstone Bridge P2410200



Resistance of a conductor wire as a function of its radius r.

Tasks:

1. Determination of unknown resistances.

   Determination of the total resistance
2. of resistors in series,
3. of resistors in parallel.
4. Determination of the resistance of a wire as a function of its cross-section.

4.1.03-00 Internal resistance and matching in voltage source

What you can learn about …

- ➔ Voltage source
- ➔ Electromotive force (e.m.f.)
- ➔ Terminal voltage
- ➔ No-load operation
- ➔ Short circuit
- ➔ Ohm's law
- ➔ Kirchhoff's laws
- ➔ Power matching

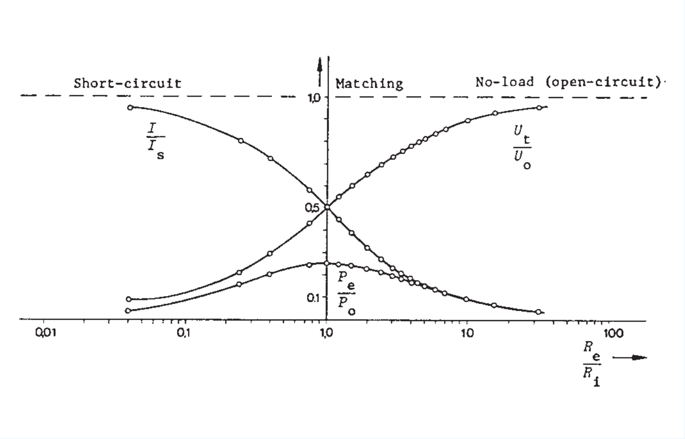
Principle:

Both the terminal voltage of a voltage source and the current depend on the load, i. e. on the external resistance. The terminal voltage is measured as a function of the current and from it the internal resistance and no-load voltage of the voltage source are determined and the power graph plotted.

What you need:

Battery box	06030.21	1
Flat cell battery, 4.5 V	07496.01	1
Power supply 5 V DC/2.4 A with 4 mm plugs	11076.99	1
Rheostats, 10 Ω, 5.7 A	06110.02	1
Rheostats, 100 Ω, 1.8 A	06114.02	1
Digital multimeter 2010	07128.00	2
Double socket, pair red and black	07264.00	1
Connecting cable, 4 mm plug, 32 A, red, l = 50 cm	07361.01	3
Connecting cable, 4 mm plug, 32 A, blue, l = 50 cm	07361.04	2

Complete Equipment Set, Manual on CD-ROM included
Internal resistance and matching in voltage source P2410300



Power diagram of a voltage source.

Tasks:

1. To measure the terminal voltage U_t of a number of voltage source as a function of the current, varying the external resistance R_e, and to calculate the no-load voltage U_0 and the internal resistance R_i.
   - 1.1 Slimline battery
   - 1.2 Power supply
   - 1.2.1 Alternating voltage output
   - 1.2.2 Direct voltage output
2. To measure directly the no-load voltage of the slimline battery (with no external resistance) and its internal resistance (by power matching, $R_i = R_e$).
3. To determine the power diagram from the relationship be tween terminal voltage and current, as illustrated by the slimline battery.

Temperature dependence of different resistors and diodes 4.1.04-01/15

Set-up of experiment P2410401 with multimeter

What you can learn about …

- → Carbon film resistor
- → Metallic film resistor
- → PTC
- → NTC
- → Z diode
- → Avalanche effect
- → Zener effect
- → Charge carrier generation
- → Free path
- → Mathie's rule

Principle:

The temperature dependence of an electrical parameter (e.g. resistance, conducting-state voltage, blocking voltage) of different components is determined. To do this, the immersion probe set is immersed in a water bath and the resistance is measured at regular temperature intervals.

What you need:

		Experiment P2410401 with multimeter	Experiment P2410415 with FG-Module
Immersion probes for determining ct	07163.00	1	1
Immersion thermostat TC10	08492.93	1	1
Accessory set for TC10	08492.01	1	1
Bath for thermostat, Makrolon	08487.02	1	1
Digital multimeter 2010	07128.00	1	
Power supply 0-12 V DC/6 V, 12 V AC	13505.93	1	
Cobra3, sensor –20...110°C	12120.00	1	
Carbon resistor 2.2 kΩ, 1W, G1	39104.23		1
Carbon resistor 4.7 kΩ, 1W, G1	39104.27	1	
Connection box	06030.23	1	1
Connecting cable, 4 mm plug, 32 A, blue, l = 50 cm	07361.04	1	1
Connecting cable, 4 mm plug, 32 A, red, l = 75 cm	07362.01	2	2
Connecting cable, 4 mm plug, 32 A, blue, l = 75 cm	07362.04	2	2
Cobra3 Basic-Unit, USB	12150.50		1
Software Cobra3 PowerGraph	14525.61		1
Measuring module Function Generator	12111.00		1
Power supply 12V/2A	12151.99		2
PC, Windows® XP or higher			

Complete Equipment Set, Manual on CD-ROM included
Temperature dependence of different resistors and diodes P24104 01/15

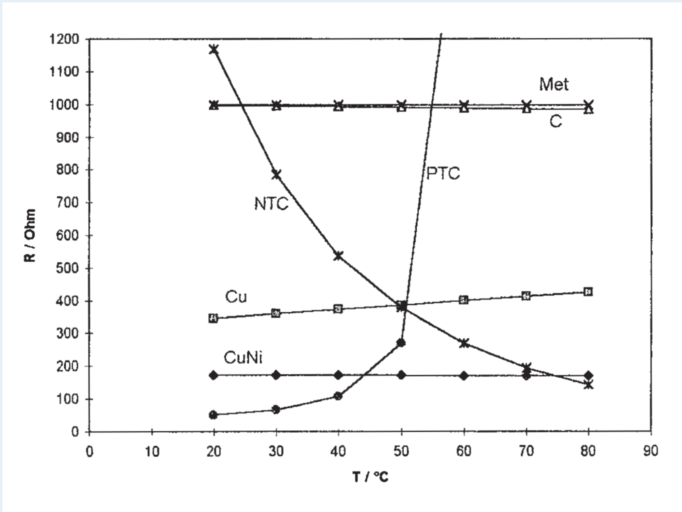


Diagram of resistances.

Tasks:

1. Measurement of the temperature dependence of the resistance of different electrical components.
2. Measurement of the temperature dependence of the conducting state voltage of semiconducting diodes.
3. Measurement of the temperature dependence of the voltage in the Zener and the avalanche effects.

4.1.06-01/15 Current balance / Force acting on a current-carrying conductor

Set-up of experiment P2410615 with Cobra3

What you can learn about ...

- → Uniform magnetic field
- → Magnetic induction (formerly magnetic-flux densitiy)
- → Lorentz force
- → Moving charges
- → Current

Principle:

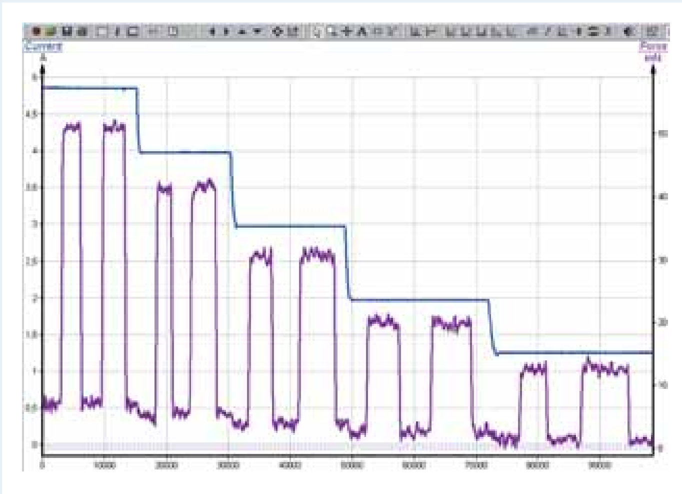
The force acting on a current-carrying conductor loop in a uniform magnetic field (Lorentz force) is measured with a balance.

Conductor loops of various sizes are suspended in turn from the balance, and the Lorentz force is determined as a function of the current and magnetic induction. The uniform magnetic field is generated by an electromagnet. The magnetic induction can be varied with the coil current.

What you need:

		Experiment P2410601 with amperemeter	Experiment P2410615 with Cobra3
Ammeter 1/5 A DC	07038.00	2	
Tripod base -PASS-	02002.55	2	
Support rod -PASS-, square, l = 1000 mm	02028.55	1	
Right angle clamp -PASS-	02040.55	1	
Balance LGN 310, on rod	11081.01	1	
Pole pieces, rectangular, 1 pair	11081.02	1	1
Wire Loop, l = 12,5 mm, n = 1	11081.05	1	1
Wire Loop, l = 25 mm, n = 1	11081.06	1	1
Wire loop, l = 50 mm, n = 2	11081.07	1	1
Wire Loop, l = 50 mm, n = 1	11081.08	1	1
Iron core, U-shaped, laminated	06501.00	1	1
Base for iron cores	06508.00	2	2
Coil, 900 turns	06512.01	2	2
Metal strip with plugs	06410.00	2	2
Distributor	06024.00	1	1
Bridge rectifier, 30 VAC/1 ADC	06031.10	1	1
On/Off switch	06034.01	1	1
Power supply, universal	13500.93	1	1
Connecting cable, 4 mm plug, 32 A, red, l = 10 cm	07359.01	1	1
Connecting cable, 4 mm plug, 32 A, red, l = 25 cm	07360.01	2	2
Connecting cable, 4 mm plug, 32 A, blue, l = 25 cm	07360.04	2	2
Connecting cable, 4 mm plug, 32 A, red, l = 50 cm	07361.01	2	
Connecting cable, 4 mm plug, 32 A, blue, l = 50 cm	07361.04	1	1
Connecting cable, 4 mm plug, 32 A, red, l = 100 cm	07363.01	1	1
Connecting cable, 4 mm plug, 32 A, blue, l = 100 cm	07363.04	1	1
Support base, variable	02001.00		1
Bosshead	02043.00		2
Support rod, stainless steel 18/8, l = 1000 mm	02034.00		1
Cobra3 Basic-Unit, USB	12150.50		1
Newton measuring module	12110.00		1
Newton Sensor	12110.01		1
Cobra3 current probe 6 A	12126.00		2
Software Cobra3 PowerGraph	14525.61		1
Power supply 12V/2A	12151.99		1
PC, Windows® XP or higher			

Complete Equipment Set, Manual on CD-ROM included
Current balance / Force acting on a current-carrying conductor P24106 01/15



Lorentz force F as a function of the current I_L in the conductor loop.

Tasks:

1. The direction of the force is to be determined as a function of the current and the direction of the magnetic field.
2. The force F is to be measured, as a function of the current I_L in the conductor loop, with a constant magnetic induction B and for conductor loops of various sizes. The magnetic induction is to be calculated.
3. The force F is to be measured, as a function of the coil current I_M, for a conductor loop. In the range being considered, the magnetic induction B is, with sufficient accuray, proportional to the coil current I_M.

Semiconductor thermogenerator 4.1.07-00

What you can learn about …

- Seebeck effect (thermoelectric effect)
- Thermoelectric e.m.f.
- Efficiency
- Peltier coefficient
- Thomson coefficient
- Seebeck coefficient
- Direct energy conversion
- Thomson equations

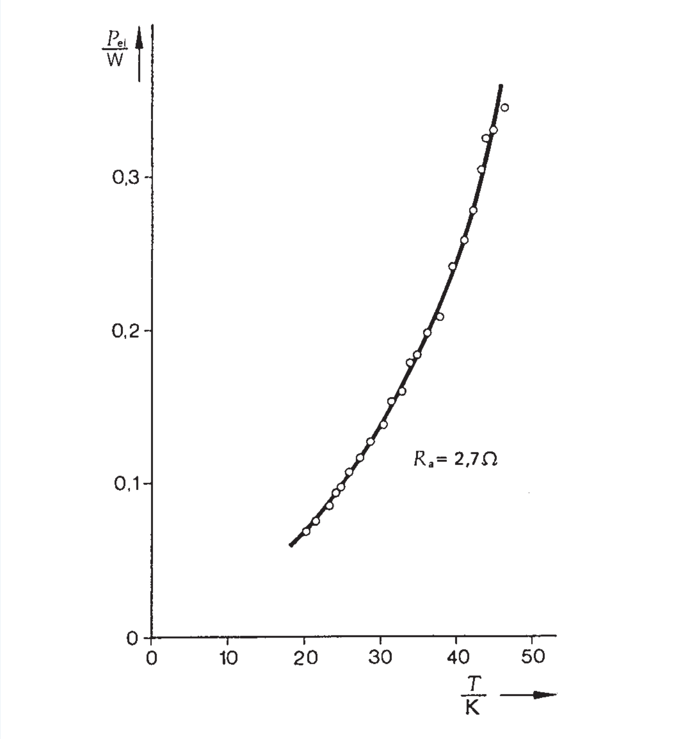
Principle:

In a semi-conductor thermogenerator, the no-load voltage and the short-circuit current are measured as a function of the temperature difference. The internal resistance, the Seebeck coefficient and the efficiency are determined.

What you need:

Thermogenerator	04366.00	1
Flow-through heat exchanger	04366.01	2
Heat conductive paste, 50 g	03747.00	1
Connection box	06030.23	1
Rheostats, 33 Ω, 3.1 A	06112.02	1
Voltmeter 0.3...300 V-, 10...300 V~	07035.00	1
Ammeter 1/5 A DC	07038.00	1
Stopwatch, digital, 1/100 s	03071.01	1
Immersion thermostat TC10	08492.93	1
Accessory set for TC10	08492.01	1
Bath for thermostat, Makrolon	08487.02	1
Laboratory thermometers, -10...+100°C	38056.00	1
Precision mercury thermometers, -10...+ 50°C	38033.00	1
Resistor 2 Ω 2%, 2W, G1	06055.20	1
Rubber tubing, d_i = 6 mm, l = 1 m	39282.00	4
Connecting cable, 4 mm plug, 32 A, red, l = 50 cm	07361.01	3
Connecting cable, 4 mm plug, 32 A, blue, l = 50 cm	07361.04	2
Resistor 1 Ω 2%, 2W, G1	06055.10	1
Resistor 5 Ω 2%, 2W, G1	06055.50	1
Resistor 10 Ω 2%, 2W, G1	06056.10	1

Complete Equipment Set, Manual on CD-ROM included
Semiconductor thermogenerator P2410700

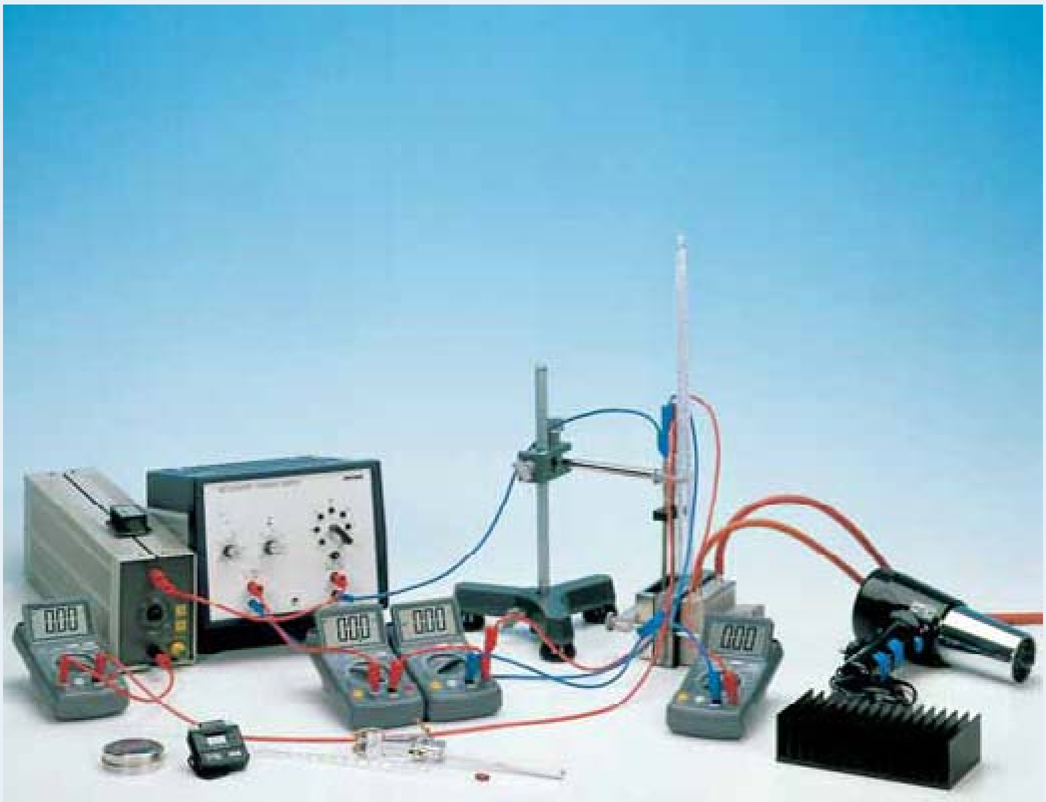


Electrical power generated as a function of the temperature difference.

Tasks:

1. To measure no-load voltage U_0 and short-circuit current I_s at different temperature differences and to determine the Seebeck coefficient.
2. To measure current and voltage at a constant temperature difference but with different load resistors, and to determine the internal resistance R_i from the measured values.
3. To determine the efficiency of energy conversion, from the quantity of heat consumed and the electrical energy produced per unit time.

4.1.08-00 Peltier heat pump



What you can learn about ...

- ➔ Peltier effect
- ➔ Heat pipe
- ➔ Termoelectric e.m.f.
- ➔ Peltier coefficient
- ➔ Cooling capacity
- ➔ Heating capacity
- ➔ Efficiency rating
- ➔ Thomson coefficient
- ➔ Seebeck coefficient
- ➔ Thomson equations
- ➔ Heat conduction
- ➔ Convection
- ➔ Forced cooling
- ➔ Joule effect

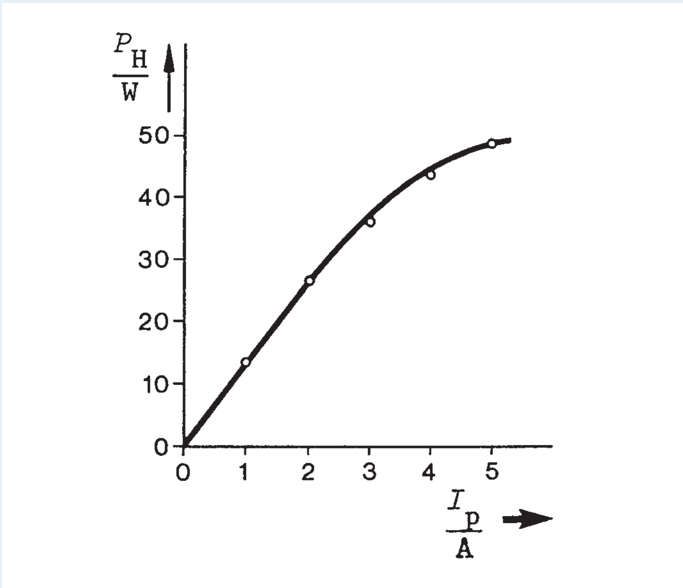
Principle:

The cooling capacity heating capacity and efficiency rating of a Peltier heat pump are determined under different operating conditions.

What you need:

Thermogenerator	04366.00	1
Flow-through heat exchanger	04366.01	1
Air cooler	04366.02	1
Heating coil with sockets	04450.00	1
Distributor	06024.00	1
Rheostats, 33 Ω, 3.1 A	06112.02	1
Connecting plug, pack of 2	07278.05	1
Power supply, universal	13500.93	1
Digital multimeter 2010	07128.00	4
Stopwatch, digital, 1/100 s	03071.01	1
Hot/cold air blower, 1700 W	04030.93	1
Laboratory thermometers, -10...+100°C	38056.00	1
Precision mercury thermometers, -10...+ 50°C	38034.00	2
Rubber tubing, d_i = 6 mm, l = 1 m	39282.00	1
Universal clamp	37718.00	1
Tripod base -PASS-	02002.55	1
Support rod -PASS-, square, l = 250 mm	02025.55	1
Right angle clamp -PASS-	02040.55	1
Connecting cable, 4 mm plug, 32 A, red, l = 25 cm	07360.01	3
Connecting cable, 4 mm plug, 32 A, red, l = 50 cm	07361.01	3
Connecting cable, 4 mm plug, 32 A, blue, l = 50 cm	07361.04	2
Connecting cable, 4 mm plug, 32 A, blue, l = 75 cm	07362.04	2
Connecting cable, 4 mm plug, 32 A, red, l = 75 cm	07362.01	1
Heat conductive paste, 50 g	03747.00	1

Complete Equipment Set, Manual on CD-ROM included
Peltier heat pump P2410800



Pump cooling capacity as a function of the operating current.

Tasks:

1. To determine the cooling capacity P_c the pump as a function of the current and to calculate the efficiency rating hc at maximum output.
2. To determine the heating capacity P_w of the pump and its efficiency rating hw at constant current and constant temperature on the cold side.
3. To determine P_w , η_w and P_c , η_c from the relation ship between temperature and time on the hot and cold sides.
4. To investigate the temperature behaviour when the pump is used for cooling, with the hot side air-cooled.

Characteristic curves of a solar cell 4.1.09-01

What you can learn about …

- → Semiconductor
- → p-n junction
- → Energy-band diagram
- → Fermi characteristic energy level
- → Diffusion potential
- → Internal resistance
- → Efficiency
- → Photo-conductive effect
- → Acceptors
- → Donors
- → Valence band
- → Conduction band

Principle:

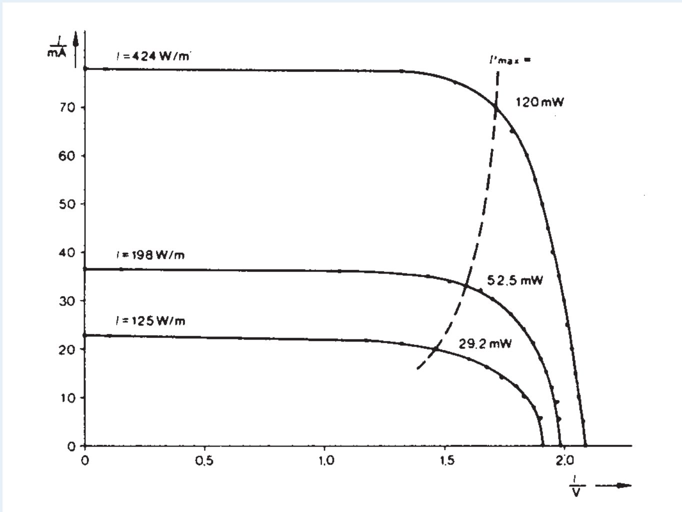
The current-voltage characteristics of a solar cell are measured at different light intensities, the distance between the light source and the solar cell being varied.

The depencence of no-load voltage and short-circuit current on temperature is determined.

What you need:

Solar battery, 4 cells, 2.5 x 5 cm	06752.04	1
Thermopile, Moll type	08479.00	1
Universal measuring amplifier	13626.93	1
Rheostats, 330 Ω, 1.0 A	06116.02	1
Ceramic lamp socket E27 with reflector, switch, safety plug	06751.01	1
Filament lamp with reflector, 230 V/120 W	06759.93	1
Hot/cold air blower, 1700 W	04030.93	1
Meter Scale, l = 1000 x 27 mm	03001.00	1
Tripod base -PASS-	02002.55	2
Barrel base -PASS-	02006.55	2
Support rod -PASS-, square, l = 250 mm	02025.55	1
Right angle clamp -PASS-	02040.55	2
Plate holder, opening width 0...10 mm	02062.00	1
Universal clamp	37718.00	1
G-clamp	02014.00	2
Glass pane, 150 x 100 x 4 mm, 2 off	35010.10	1
Digital multimeter 2010	07128.00	2
Laboratory thermometers, -10...+100°C	38056.00	1
Connecting cable, 4 mm plug, 32 A, red, l = 50 cm	07361.01	3
Connecting cable, 4 mm plug, 32 A, blue, l = 50 cm	07361.04	2

Complete Equipment Set, Manual on CD-ROM included
Characteristic curves of a solar cell P2410901



Current-voltage characteristic at different light intensities J.

Tasks:

1. To determine the light intensity with the thermopile at various distances from the light source.
2. To measure the short-circuit current and no-load voltage at various distances from the light source.
3. To estimate the dependence of no-load voltage, and short-circuit current on temperature.
4. To plot the current-voltage characteristic at different light intensities.
5. To plot the current-votlage characteristic under different operating conditions: cooling the equipment with a blower, no cooling, shining the light through a glass plate.
6. To determine the characteristic curve when illuminating by sunlight.

4.1.09-15 Characteristic curves of semiconductors with FG-Module

What you can learn about ...

- → Semiconductor
- → P-n junction
- → Energy-band diagram
- → Acceptors
- → Donors
- → Valence band
- → Conduction band
- → Transistor
- → Operating point

Principle:

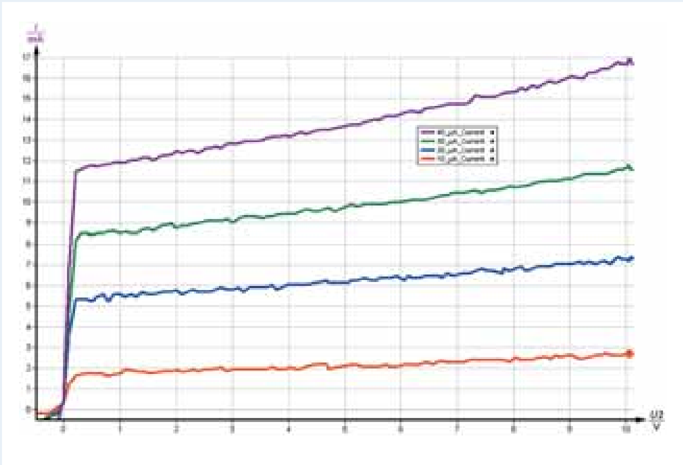
Determine the current strength flowing through a semi-conducting diode.

Determine the collector current with the collector voltage for various values of the base current intensity.

What you need:

Cobra3 Basic-Unit, USB	12150.50	1
Power supply 12V/2A	12151.99	2
Software Cobra3 PowerGraph	14525.61	1
Measuring module Function Generator	12111.00	1
Digital multimeter 2010	07128.00	1
Potentiometer 1 kΩ, 0.4W, G2	39103.04	1
Plug-in board 4 mm plugs	06033.00	1
Transistors BC-337/40, in G3 casing	39127.20	1
Carbon resistor 47 kΩ, 1W, G1	39104.38	1
Silicon diode 1 N 4007, G1	39106.02	1
Silicon diode 1 N 4148, G1	39106.03	1
Connecting cable, 4 mm plug, 32 A, red, l = 25 cm	07360.01	2
Connecting cable, 4 mm plug, 32 A, blue, l = 25 cm	07360.04	2
Connecting cable, 4 mm plug, 32 A, red, l = 50 cm	07361.01	2
Connecting cable, 4 mm plug, 32 A, blue, l = 50 cm	07361.04	3

Complete Equipment Set, Manual on CD-ROM included
Characteristic curves of semiconductors with FG-Module P2410915



Collector current/voltage characteristic of BC337 transistor.

Tasks:

1. To investigate the dependence of the current strength flowing through a semi-conducting diode.
2. To determine the variations of the collector current with the collector voltage for varios values of the base current intensity.

Characteristic and efficiency of PEM fuel cell and PEM electrolyser 4.1.11-00

What you can learn about …

- ➔ Electrolysis
- ➔ Electrode polarisation
- ➔ Decomposition voltage
- ➔ Galvanic elements
- ➔ Faraday´s law

Principle:

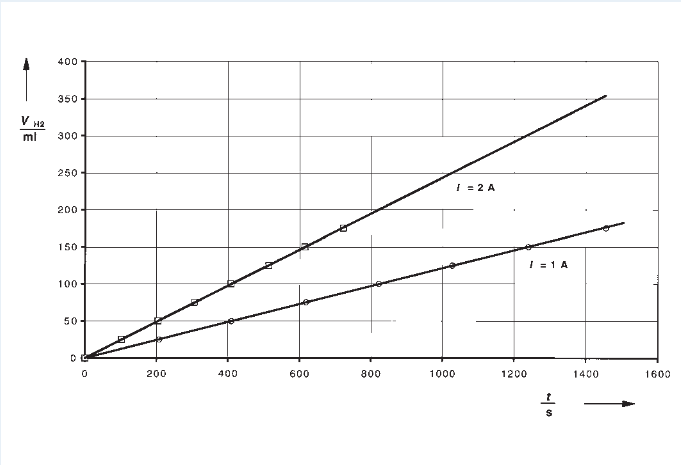
In a PEM electrolyser, the electrolyte consists of a proton-conducting membrane and water (PEM = Proton-Exchange-Membrane). When an electric voltage is applied, hydrogen and oxygen are formed. The PEM fuel cell generates electrical energy from hydrogen and oxygen.

The electrical properties of the electrolyser and the fuel cell are investigated by recording a current-voltage characteristic line. To determine the efficiency, the gases are stored in small gasometers in order to be able to measure the quantities of the gases generated or consumed.

What you need:

PEM fuel cell	06747.00	1
PEM electrolyser	06748.00	1
Connection box	06030.23	1
Resistor 10 Ω 2%, 2W, G1	06056.10	2
Resistor 5 Ω 2%, 2W, G1	06055.50	1
Resistor 2 Ω 2%, 2W, G1	06055.20	1
Resistor 1 Ω 2%, 2W, G1	06055.10	2
Short-circuit plug, black	06027.05	2
Gas bar	40466.00	1
Graduated cylinder, 100 ml, plastic	36629.01	1
Rubber tubing, d = 4 mm	39280.00	1
Rubber tubing, d_i = 6 mm, l = 1 m	39282.00	1
Pinchcock, width 10 mm	43631.10	4
Hose connector, reducing, d = 3-5/6-10 mm	47517.01	2
Wash bottle, plastic, 500 ml	33931.00	1
Beaker, 250 ml, low form, plastic	36013.01	1
Stopwatch, digital, 1/100 s	03071.01	1
Cobra4 Mobile Link	12620.55	1
Cobra4 Sensor-Unit Weather	12670.00	1
Laboratory thermometers, -10...+100°C	38056.00	1
Digital multimeter 2010	07128.00	2
Power supply, universal	13500.93	1
Connecting cable, 4 mm plug, 32 A, red, l = 50 cm	07361.01	3
Connecting cable, 4 mm plug, 32 A, blue, l = 50 cm	07361.04	2
Connecting cable, 4 mm plug, 32 A, red, l = 75 cm	07362.01	1
Connecting cable, 4 mm plug, 32 A, blue, l = 75 cm	07362.04	1
High performance charger for 4 Ni-MH accumulators	07929.99	1
Water, distilled 5 l	31246.81	1

Complete Equipment Set, Manual on CD-ROM included
Characteristic and efficiency of PEM fuel cell and PEM electrolyser P2411100



Volume of the hydrogen generated by the PEM electrolyser as a function of time at different current I.

Tasks:

1. Recording the characteristic line of the PEM electrolyser.
2. Recording the characteristic line of the PEM fuel cell.
3. Determination of the efficiency of the PEM electrolysis unit.
4. Determination of the efficiency of the PEM fuel cell.

4.1.12-00 Faraday's law

What you can learn about …

- ➔ Electrolysis
- ➔ Coulometry
- ➔ Charge
- ➔ Amount of substance
- ➔ Faraday´s law
- ➔ Faraday´s contant
- ➔ Avogadro´s number
- ➔ General equation of state for ideal gases

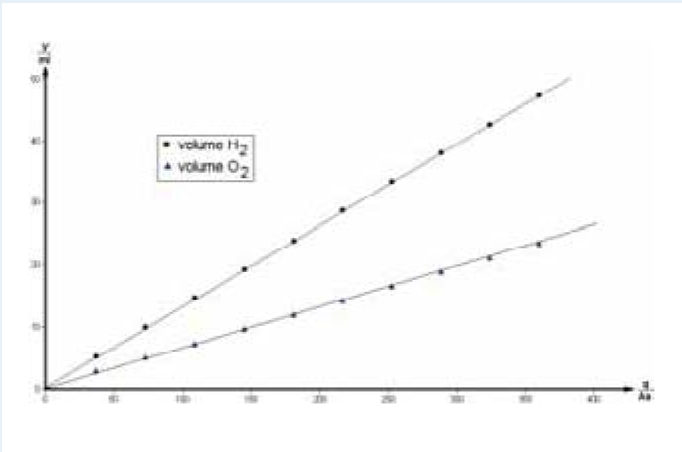
Principle:

The correlation between the amounts of substances transformed in the electrode reaction and the applied charge (amount of electricity) is described by Faraday´s law. Faraday´s constant, which appears as a proportionality factor, can be determined experimentally from this dependence.

What you need:

Power supply, universal	13500.93	1
Digital multimeter 2010	07128.00	1
Electrolysis apparatus - Hofmann	44518.00	1
Platinum electrode in protective tube, d = 8 mm	45206.00	2
On/Off switch	06034.01	1
Connecting cable, 4 mm plug, 32 A, blue, l = 75 cm	07362.04	1
Connecting cable, 4 mm plug, 32 A, red, l = 50 cm	07361.01	1
Connecting cable, 4 mm plug, 32 A, red, l = 25 cm	07360.01	2
Retort stand, h = 750 mm	37694.00	1
Right angle clamp	37697.00	3
Universal clamp	37715.00	2
Stopwatch, digital, 1/100 s	03071.01	1
Beaker, DURAN®, short form, 600 ml	36015.00	1
Precision Balance, Sartorius LE 623P	45023.93	1
Pasteur pipettes, l = 145 ml	36590.00	1
Rubber caps, 10 pcs	39275.03	1
Funnel, glass, d = 80 mm	34459.00	1
Wash bottle, plastic, 500 ml	33931.00	1
Sulphuric acid, 95-98%, 500 ml	30219.50	1
Water, distilled 5 l	31246.81	1
Weather monitor, 6 lines LCD	87997.10	1
Precision Balance, Sartorius CPA 62	49224.88	1

Complete Equipment Set, Manual on CD-ROM included
Faraday's law P2411200



Correlations between the transferred charge and the evolved volumes of hydrogen and oxygen in the electrolysis of diluted sulphuric acid (T = 296.05 K and p = 100.4 kPa)

Tasks:

Determine Faraday´s constant from the dependence of the volumes of hydrogen and oxygen evolved on the applied charge in the hydrolysis of diluted sulphuric acid.

Second order conductors. Electrolysis with FG-Module 4.1.13-15

What you can learn about …

- → Electrolysis
- → Electrode polarisation
- → Conductivity
- → Ohm's law

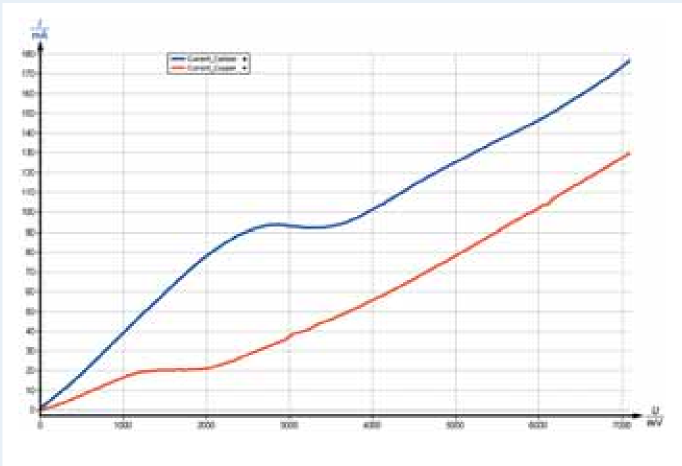
Principle:

In this experiment a copper(II) sulphate solution is to be electrolysed using two different materials – graphite electrodes and copper wires. During the electrolyses the current/voltage curves are recorded.

What you need:

Cobra3 Basic-Unit, USB	12150.50	1
Power supply 12V/2A	12151.99	2
Software Cobra3 PowerGraph	14525.61	1
Measuring module Function Generator	12111.00	1
Retort stand, 210 mm x 130 mm, h = 500 mm	37692.00	1
Right angle clamp	37697.00	1
Support for two electrodes	45284.01	1
Graphite electrodes, d = 5 mm, l = 150 mm, 6 pcs.	44510.00	1
Copper wire, d = 0.5 mm	06106.03	1
Beaker, DURAN®, tall form, 150 ml	36003.00	1
Graduated cylinder, BORO 3.3, 100 ml	36629.00	1
Precision Balance, Sartorius TE 412	48835.93	1
Spoon with spatula end, l = 150 mm, steel, wide	33398.00	1
Stirring rods, BORO 3.3, l = 300 mm, d = 7 mm	40485.05	1
Wash bottle, plastic, 500 ml	33931.00	1
Copper-II sulphate, cryst., 250 g	30126.25	1
Water, distilled 5 l	31246.81	1
Connecting cable, 4 mm plug, 32 A, red, l = 50 cm	07361.01	2
Connecting cable, 4 mm plug, 32 A, blue, l = 50 cm	07361.04	2
PC, Windows® XP or higher		

Complete Equipment Set, Manual on CD-ROM included
Second order conductors.
Electrolysis with FG-Module P2411315



Current/voltage characteristics of an aqueous copper sulphate solution conducted with graphite electrodes and copper wires.

Tasks:

Measure the correlation between voltage and current on second order conductors (copper (II) sulphate solution using two different materials – graphite electrodes and copper wires.

4.2.01-00 Electrical fields and potentials in the plate capacitor

What you can learn about …

- ➔ Capacitor
- ➔ Electric field
- ➔ Potential
- ➔ Voltage
- ➔ Equipotential lines

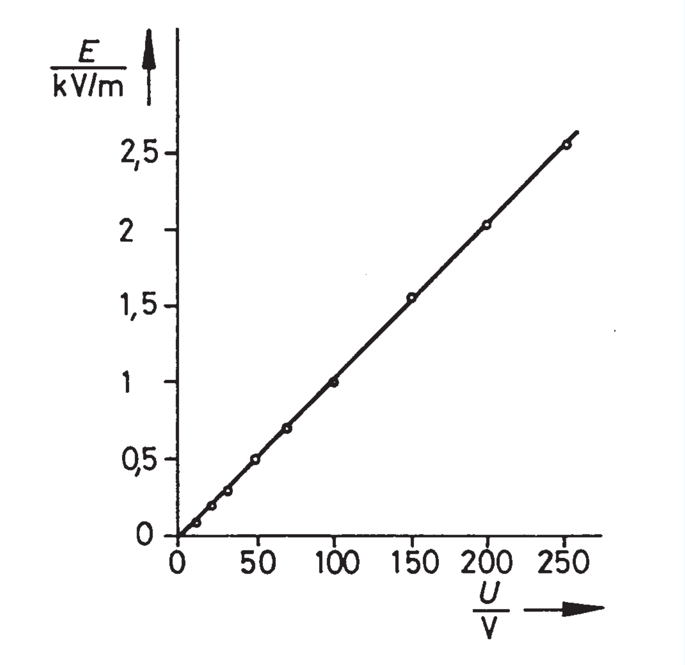
Principle:

A uniform electric field $\vec{E}$ is produced between the charged plates of a plate capacitor. The strength of the field is determined with the electric field strength meter, as a function of the plate spacing d and the voltage U. The potential ϕ within the field is measured with a potential measuring probe.

What you need:

Capacitor plate 283 mm x 283 mm	06233.02	2
Capacitor plate with hole, d = 55 mm	11500.01	1
Spacer plates, 1 set	06228.01	1
Electric field meter	11500.10	1
Potential probe	11501.00	1
Power supply, regulated, 0...600 V-	13672.93	1
Blow lamp, butan cartridge, X2000	46930.00	1
Butane cartridge C 206 without valve	47535.00	1
Rubber tubing, d_i = 6 mm, l = 1 m	39282.00	1
Digital multimeter 2010	07128.00	2
Connecting cable, 4 mm plug, 32 A, green-yellow, l = 10 cm	07359.15	1
Connecting cable, 4 mm plug, 32 A, red, l = 75 cm	07362.01	5
Connecting cable, 4 mm plug, 32 A, blue, l = 75 cm	07362.04	5
Optical profile bench, l = 600 mm	08283.00	1
Base for optical profile bench, adjustable	08284.00	2
Slide mount for optical profil bench, h = 80 mm	08286.02	2
Slide mount for optical profil bench, h = 30 mm	08286.01	1
Support rod, stainless steel 18/8, l = 250 mm, d = 10 mm	02031.00	2
Support rod -PASS-, square, l = 400 mm	02026.55	1
Right angle clamp -PASS-	02040.55	4
Stand tube	02060.00	1
Rule, plastic, 200 mm	09937.01	1
Barrel base -PASS-	02006.55	1
High value resistors, 10 MΩ	07160.00	1

Complete Equipment Set, Manual on CD-ROM included
Electrical fields and potentials in the plate capacitor P2420100



Electric field strength as a function of the plate voltage.

Tasks:

1. The relationship between voltage and electric field strength is investigated, with constant plate spacing.
2. The relationship between electric field strength and plate spacing is investigated, with constant voltage.
3. In the plate capacitor, the potential is measured with a probe, as a function of position.

Charging curve of a capacitor 4.2.02-01

What you can learn about ...

- → Charging
- → Discharging
- → Time constant
- → Exponential function
- → Half life

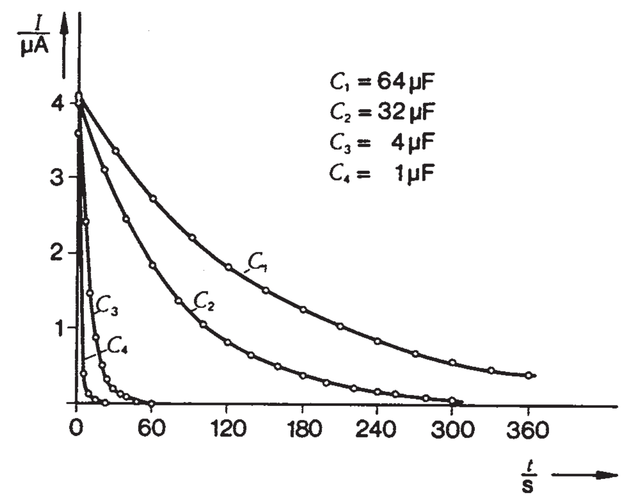
Principle:

A capacitor is charged by way of a resistor. The current is measured as a function of time and the effects of capacitance, resistance and the voltage applied are determined.

What you need:

Connection box	06030.23	2
Two way switch, single pole	06030.00	1
Capacitor 2 x 30 µF	06219.32	1
Carbon resistor 100 Ω, 1W, G1	39104.63	1
Carbon resistor 1 MΩ, 1W, G1	39104.52	4
Connecting plug white 19 mm pitch	39170.00	2
Capacitor 1 microF/ 250 V, G2	39113.01	1
Capacitor 4,7 microF/ 250 V, G2	39113.03	1
Power supply 0-12 V DC/ 6 V, 12 V AC	13505.93	1
Stopwatch, digital, 1/100 s	03071.01	1
Digital multimeter 2010	07128.00	1
Connecting cable, 4 mm plug, 32 A, red, l = 25 cm	07360.01	3
Connecting cable, 4 mm plug, 32 A, blue, l = 25 cm	07360.04	4

Complete Equipment Set, Manual on CD-ROM included
Charging curve of a capacitor P2420201



Course of current with time at different capacitance values; voltage and resistance are constant (U = 9 V, R = 2.2 MΩ).

Tasks:

To measure the charging current over time:

1. using different capacitance values C, with constant voltage U and constant resistance R
2 using different resistance values (C and U constant)
3. using different voltages (R and C constant).

To determine the equation representing the current when a capacitor is being charged, from the values measured.

4.2.02-15 Switch-on behaviour of a capacitor and an inductivity with FG-Module

What you can learn about ...

- ➔ Charging
- ➔ Discharging
- ➔ Time constant
- ➔ Exponential function
- ➔ Half life

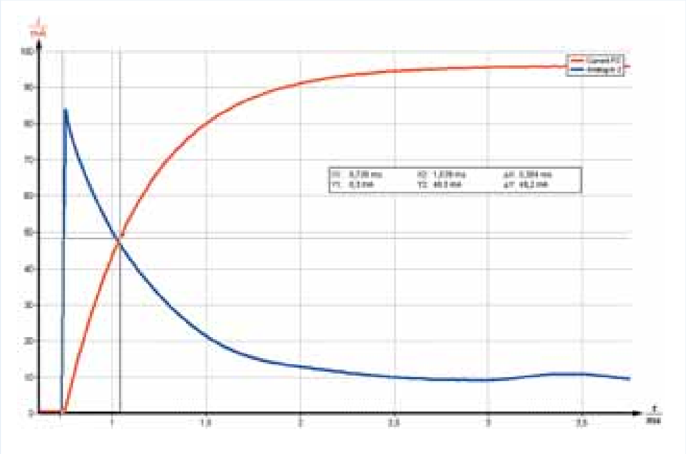
Principle:

To measure the course of current strength and voltage ina capacitance/inductivity in the instant of switching on. The capacitance/inductivity is determined from the measurement curve.

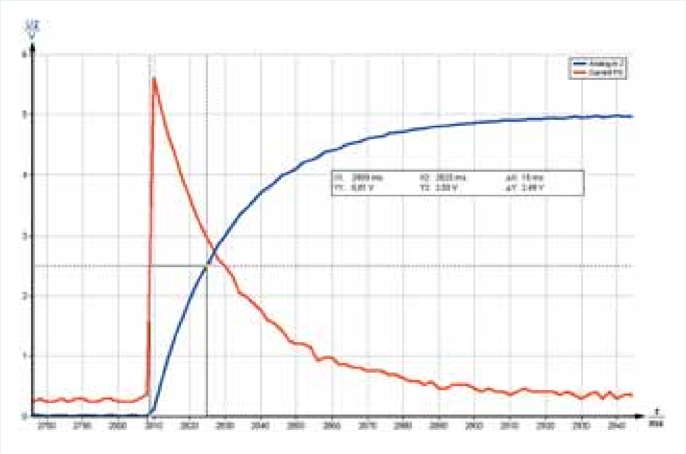
What you need:

Cobra3 Basic-Unit, USB	12150.50	1
Power supply 12V/2A	12151.99	2
Software Cobra3 PowerGraph	14525.61	1
Measuring module Function Generator	12111.00	1
Connection box	06030.23	1
On/Off switch	06034.01	1
Carbon resistor 220 Ω, 1W, G1	39104.64	1
Carbon resistor 470 Ω, 1W, G1	39104.15	1
Electrolyte capacitors non-polarised, G1, 47 µF	39105.45	1
Coil, 900 turns	06512.01	1
Connecting cable, 4 mm plug, 32 A, red, l = 25 cm	07360.01	3
Connecting cable, 4 mm plug, 32 A, blue, l = 25 cm	07360.04	1
Connecting cable, 4 mm plug, 32 A, red, l = 50 cm	07361.01	1
Connecting cable, 4 mm plug, 32 A, blue, l = 50 cm	07361.04	2

Complete Equipment Set, Manual on CD-ROM included
Switch-on behaviour of a capacitor and an inductivity with FG-Module P2420215



The course of the voltage and the current intensity during a switching on process in a coil.



The course of the voltage and the current intensity during a switching on process in a capacitance.

Tasks:

1. To measure the course of current strength and voltage in a capacitance in the instant of switching on. The capacitance is determined from the measurement curve.
2. To measure the course of current strength and voltage in inductivity in the instant of switching on. The inductivity is determined from the measurement curve.

Capacitance of metal spheres and of a spherical capacitor 4.2.03-00

What you can learn about ...

- → Voltage
- → Potential
- → Charge
- → Electric field
- → Electrostatic induction
- → Electrostatic induction constant
- → Capacitance
- → Capacitor
- → Dielectrics

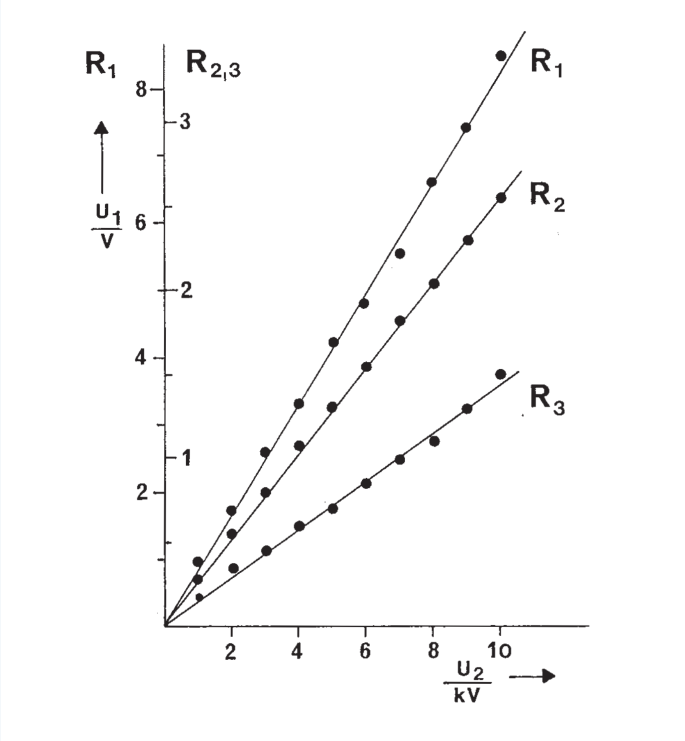
Principle:

Metal spheres with different radii and a spherical capacitor are charged by means of a variable voltage. The induced charges are determined with a measuring amplifier. The corresponding capacitances are deduced from voltage and charge values.

What you need:

Conducting ball, d = 20 mm	06236.00	2
Conducting ball, d = 40 mm	06237.00	1
Conducting ball, d = 120 mm	06238.00	1
Hemispheres, Cavendish type	06273.00	1
Hollow plastic ball with eyelet	06245.00	1
Capillary tube, AR-glass, straight, l = 250 mm	36709.00	1
Copper wire, d = 0.5 mm	06106.03	1
Insulating stem	06021.00	2
High value resistors, 10 MΩ	07160.00	1
High voltage supply 0...10 kV	13670.93	1
Capacitor 10 nF/ 250 V, G1	39105.14	1
Universal measuring amplifier	13626.93	1
Multi range meter, analogue	07028.01	1
Digital multimeter 2010	07128.00	1
Connecting cable, 30 kV, l = 1000 mm	07367.00	1
Screened cable, BNC, l = 750 mm	07542.11	1
Adapter, BNC socket - 4 mm plug	07542.20	1
T type connector, BNC, socket, socket, plug	07542.21	1
Adapter, BNC plug/4 mm socket	07542.26	1
Vernier caliper, plastic	03011.00	1
Barrel base -PASS-	02006.55	2
Support base -PASS-	02005.55	1
Right angle clamp -PASS-	02040.55	4
Support rod -PASS-, square, l = 630 mm	02027.55	1
Support rod -PASS-, square, l = 400 mm	02026.55	1
Universal clamp with joint	37716.00	1
Crocodile clips, black, strong version, pack of 10	29426.03	1
Connecting cable, 4 mm plug, 32 A, green-yellow, l = 10 cm	07359.15	1
Connecting cable, 4 mm plug, 32 A, green-yellow, l = 75 cm	07362.15	2
Connecting cable, 4 mm plug, 32 A, blue, l = 50 cm	07361.04	2
Connecting cable, 4 mm plug, 32 A, red, l = 50 cm	07361.01	2

Complete Equipment Set, Manual on CD-ROM included
Capacitance of metal spheres and of spherical capacitor P2420300



U_1 (measured voltage) as a function of U_2 (charging voltage) measured on conducting spheres with three different diameters.

Tasks:

1. Determination of the capacitance of three metal spheres with different diameters.
2. Determination of the capacitance of a spherical capacitor.
3. Determination of the diameters of each test body and calculation of their capacitance values.

4.2.04-01 Coulomb's law / Image charge

What you can learn about ...

- ➔ Electric field
- ➔ Electric field strenght
- ➔ Electric flux
- ➔ Electrostatic induction
- ➔ Electric constant
- ➔ Surface charge density
- ➔ Dielectric displacement
- ➔ Electrostatic potential

Principle:

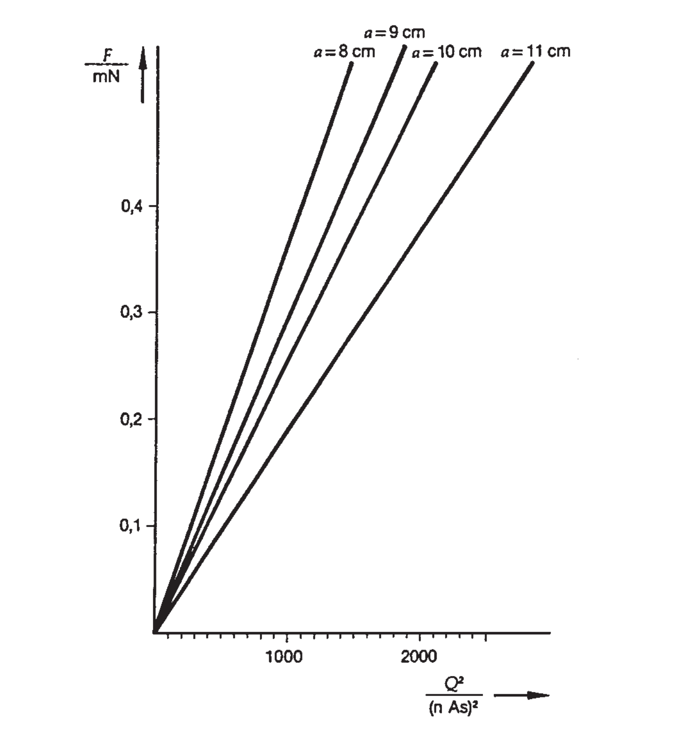
A small electrically charged ball is positioned at a certain distance in front of a metal plate lying at earth potential. The surface charge on the plate due to electrostatic induction together with the charged ball forms an electric field analogous to that which exists between two oppositely charged point garges.

The electrostatic force acting on the ball can be measured with a sensitive torsion dynamometer.

What you need:

Capacitor plate 283 mm x 283 mm	06233.02	1
Insulating stem	06021.00	2
Conducting ball, d = 40 mm	06237.00	2
Conducting spheres with suspension	02416.01	1
Torsion dynamometer, 0.01 N	02416.00	1
Weight holder for slotted weights	02204.00	1
Slotted weights, 1 g, polished	03916.00	4
Direct current measuring amplifier	13620.93	1
Power supply, high voltage, 0-25 kV	13671.93	1
Digital multimeter 2010	07128.00	1
Connecting cable, 30 kV, l = 1000 mm	07367.00	1
Screened cable, BNC, l = 1500 mm	07542.12	1
Adapter, BNC socket - 4 mm plug	07542.20	1
Connecting cable, 4 mm plug, 32 A, red, l = 50 cm	07361.01	3
Connecting cable, 4 mm plug, 32 A, red, l = 75 cm	07362.01	1
Connecting cable, 4 mm plug, 32 A, blue, l = 75 cm	07362.04	1
Connecting cable, 4 mm plug, 32 A, green-yellow, l = 100 cm	07363.15	2
Support base -PASS-	02005.55	1
Right angle clamp -PASS-	02040.55	1
Support rod -PASS-, square, l = 1000 mm	02028.55	1
Holder for U-magnet	06509.00	1
Barrel base -PASS-	02006.55	2

Complete Equipment Set, Manual on CD-ROM included
Coulomb's law / Image charge P2420401



Relationship between electrostatic force F and the square of the charge Q for various distances (a) between ball and plate.

Tasks:

1. Establishment of the relation between the active force and the charge on the ball.
2. Establishment of the relation between force and distance, ball to metal plate.
3. Determination of the electric constant.

Coulomb's law with Cobra3 4.2.04-15

What you can learn about …

- ➔ Electric field strength
- ➔ Electrostatic induction
- ➔ Surface charge density
- ➔ Dielectric displacement
- ➔ Electrostatic potential
- ➔ Law of distance

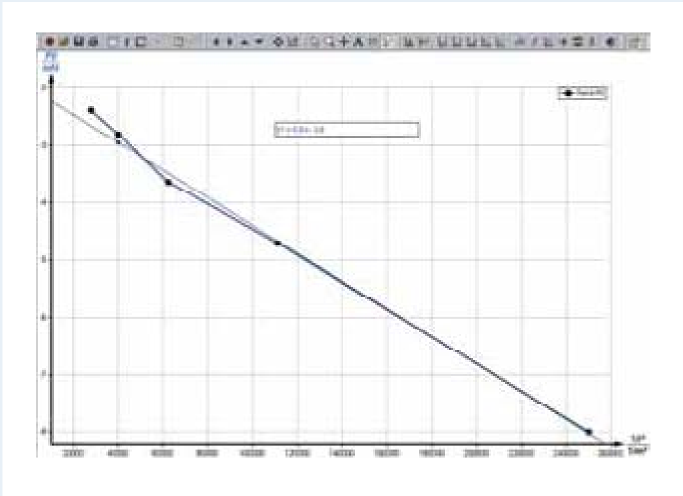
Principle:

A small electrically charged ball is positioned at a certain distance in front of a second charged ball. The force between these balls is measured as a function of their charge and distance (Coulomb's law). For the measurements a sensitive force sensor and an electrometer amplifier are used.

What you need:

Cobra3 Basic-Unit, USB	12150.50	1
Software Cobra3 Power Graph	14525.61	1
Newton measuring module	12110.00	1
Newton Sensor	12110.01	1
Insulating bar for Force Sensor	12110.02	1
Plug with socket and crosshole, 2 pcs.	07206.01	1
Conducting ball, d = 40 mm	06237.00	2
Power supply 12V/2A	12151.99	1
High voltage supply 0...10 kV	13670.93	1
Connecting cable, 30 kV, l = 1000 mm	07367.00	2
Connecting cable, 4 mm plug, 32 A, green-yellow, l = 10 cm	07359.15	1
Connecting cable, 4 mm plug, 32 A, blue, l = 25 cm	07360.04	1
Optical profile bench, l = 600 mm	08283.00	1
Base for optical profile bench, adjustable	08284.00	2
Slide mount for optical profil bench, h = 30 mm	08286.01	1
Slide mount for optical profil bench, h = 80 mm	08286.02	1
Sliding device, horizontal	08713.00	1
Electrometer Amplifier	13621.00	1
Data cable for Cobra probes	12150.07	1
Connecting plug white 19 mm pitch	39170.00	1
Capacitor 10 nF/ 250 V, G1	39105.14	1
Power supply 12V AC/500 mA	11074.93	1

Complete Equipment Set, Manual on CD-ROM included
Coulomb's law with Cobra3 P2420415



The force as a function of $1/r^2$, where r is the distance between the balls.

Tasks:

1. Measure the force between two small electrically charged balls as a function of their charge if both balls are positively charged (+ +), both negatively (- -) or one positive one negative (+ -).
2. Measure the force between the charged balls as a function of the distance.
3. Compare the measured results with theoretical values.

4.2.05-00 Coulomb potential and Coulomb field of metal spheres

What you can learn about …

- ➔ Electric field
- ➔ Field intensity
- ➔ Electric flow
- ➔ Electric charge
- ➔ Gaussian rule
- ➔ Surface charge density
- ➔ Induction
- ➔ Induction constant
- ➔ Capacitance
- ➔ Gradient
- ➔ Image charge
- ➔ Electrostatic potential
- ➔ Potential difference

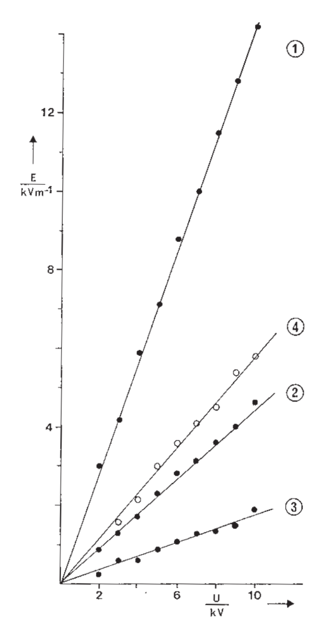
Principle:

Conducting spheres with different diameters are charged electrically. The static potentials and the accompanying electric field intensities are determined by means of an electric field meter with a potential measuring probe, as a function of position and voltage.

What you need:

Electric field meter	11500.10	1
Potential probe	11501.00	1
Capacitor plate with hole, d = 55 mm	11500.01	1
High voltage supply 0...10 kV	13670.93	1
Conducting ball, d = 20 mm	06236.00	1
Conducting ball, d = 40 mm	06237.00	1
Conducting ball, d = 120 mm	06238.00	1
High value resistors, 10 MΩ	07160.00	1
Insulating stem	06021.00	2
Power supply 0-12 V DC/ 6 V, 12 V AC	13505.93	1
Multi range meter, analogue	07028.01	1
Barrel base -PASS-	02006.55	3
Stand tube	02060.00	1
Tripod base -PASS-	02002.55	1
Meter Scale, l = 1000 x 27 mm	03001.00	1
Rubber tubing, d_i = 6 mm, l = 1 m	39282.00	1
Butane burner Labogaz 206	32178.00	1
Butane cartridge C 206 without valve	47535.00	2
Connecting cable, 30 kV, l = 500 mm	07366.00	1
Connecting cable, 4 mm plug, 32 A, red, l = 75 cm	07362.01	3
Connecting cable, 4 mm plug, 32 A, blue, l = 75 cm	07362.04	2
Connecting cable, 4 mm plug, 32 A, green-yellow, l = 75 cm	07362.15	2
Connecting cable, 4 mm plug, 32 A, green-yellow, l = 25 cm	07360.15	2

Complete Equipment Set, Manual on CD-ROM included
Coulomb potential and Coulomb field of metal spheres P2420500



Field strenght as a function of voltage.

Graphs 1-3: sphere with 2R = 12 cm; r_1 = 25 cm, r_2 = 50 cm, r_3 = 75 cm; graph 4: sphere with 2R = 4 cm; r_1 = 25 cm.

Tasks:

1. For a conducting sphere of diameter 2R = 12 cm, electro static potential is determined as a function of voltage at a constant distance from the surface of the sphere.
2. For the conducting spheres of diameters 2R = 12 cm and 2R = 4 cm, electrostatic potential at constant voltage is determined as a function of the distance from the surface of the sphere.
3. For both conducting spheres, electric field strenght is determined as a function of charging voltage at three different distances from the surface of the sphere.
4. For the conducting sphere of dia meter 2R = 12 cm, electric field strenght is determined as a function of the distance from the surface of the sphere at constant charging voltage.

Dielectric constant of different materials 4.2.06-00

What you can learn about ...

- Maxwell's equations
- Electric constant
- Capacitance of a plate capacitor
- Real charges
- Free charges
- Dielectric displacement
- Dielectric polarisation
- Dielectric constant

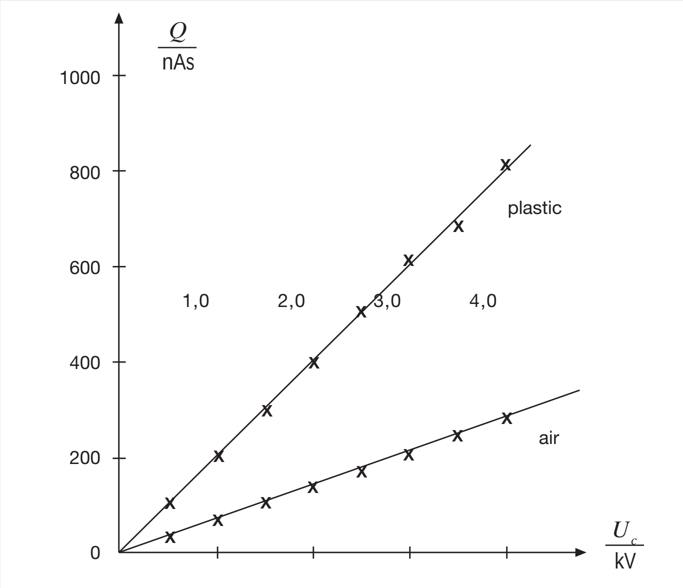
Principle:

The electric constant ε_0 is determined by measuring the charge of a plate capacitor to which a voltage is applied. The dielectric constant ε is determined in the same way, with plastic or glass filling the space between the plates.

What you need:

Plate capacitor, d = 260 mm	06220.00	1
Plastic plate 283 x 283 mm	06233.01	1
Glass plate for current conductors	06406.00	1
High value resistors, 10 MΩ	07160.00	1
Universal measuring amplifier	13626.93	1
High voltage supply 0...10 kV	13670.93	1
Capacitor 220 nF/250 V, G2	39105.19	1
Voltmeter 0.3...300 V-, 10...300 V~	07035.00	1
Connecting cable, 4 mm plug, 32 A, green-yellow, l = 10 cm	07359.15	1
Connecting cable, 4 mm plug, 32 A, red, l = 50 cm	07361.01	1
Connecting cable, 4 mm plug, 32 A, blue, l = 50 cm	07361.04	1
Connecting cable, 30 kV, l = 500 mm	07366.00	1
Screened cable, BNC, l = 750 mm	07542.11	1
Adapter, BNC socket - 4 mm plug	07542.20	1
T type connector, BNC, socket, socket, plug	07542.21	1
Adapter, BNC plug/4 mm socket	07542.26	1

Complete Equipment Set, Manual on CD-ROM included
Dielectric constant of different materials P2420600



Electrostatic charge Q of a plate capacitor as a function of the applied voltage U_c, with and with out dielectric (plastic) between the plates (d = 0.98 cm)

Tasks:

1. The relation between charge Q and voltage U is to be measured using a plate capacitor.
2. The electric constant ε_0 is to be determined from the relation measured under point 1.
3. The charge of a plate capacitor is to be measured as a function of the inverse of the distance between the plates, under constant voltage.
4. The relation between charge Q and voltage U is to be measured by means of a plate capacitor, between the plates of which different solid dielectric media are introduced. The corresponding dielectric constants are determined by comparison with measurements performed with air between the capacitor plates.

4.3.01-00 Earth's magnetic field

What you can learn about ...

- ➔ Magnetic inclination and declination
- ➔ Isoclinic lines
- ➔ Isogenic lines
- ➔ Inclinometer
- ➔ Magnetic flow density
- ➔ Helmholtz coils

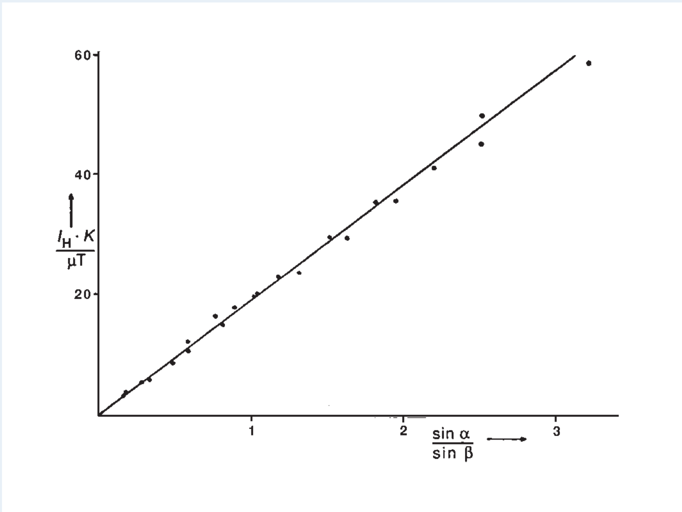
Principle:

A constant magnetic field, its magnitude and direction known, is superimposed on the unknown earth-magnetic field. The earth-magnetic field can then be calculated from the magni tude and direction of the resulting flux density.

What you need:

Helmholtz coils, one pair	06960.00	1
Power supply, universal	13500.93	1
Rheostats, 100 Ω, 1.8 A	06114.02	1
Teslameter, digital	13610.93	1
Hall probe, axial	13610.01	1
Digital multimeter 2010	07128.00	1
Magnetometer	06355.00	1
Barrel base -PASS-	02006.55	1
Right angle clamp -PASS-	02040.55	1
Support rod -PASS-, square, l = 250 mm	02025.55	1
Stand tube	02060.00	1
Connecting cable, 4 mm plug, 32 A, red, l = 100 cm	07363.01	1
Connecting cable, 4 mm plug, 32 A, blue, l = 100 cm	07363.04	4

Complete Equipment Set, Manual on CD-ROM included
Earth's magnetic field P2430100



Linear function to determine the horizontal component ^hB_E of the magnetic flux density of the earth-magnetic field.

Tasks:

1. The magnetic flux of a pair of Helmholtz coils is to be determined and plotted graphically as a function of the coil current. The Helmholtz system calibration factor is calculated from the slope of the line.
2. The horizontal component of the earth-magnetic field is determined through superimposition of the Helmholtz field.
3. The angle of inclination must be determined in order to calculate the vertical component of the earth-magnetic field.

Magnetic field of single coils / Biot-Savart's law 4.3.02-01/15

Set-up of experiment P2430215 with Cobra3

What you can learn about ...

- ➔ Wire loop
- ➔ Biot-Savart's law
- ➔ Hall effect
- ➔ Magnetic field
- ➔ Induction
- ➔ Magnetic flux density

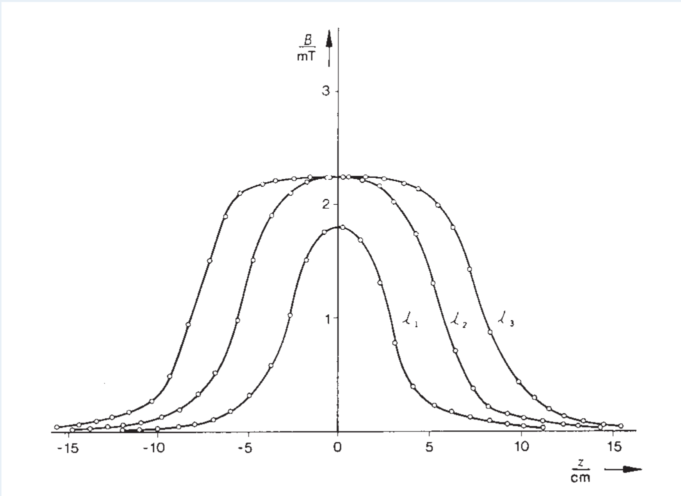
Principle:

The magnetic field along the axis of wire loops and coils of different dimensions is measured with a teslameter (Hall probe). The relationship between the maximum field strength and the dimensions is investigated and a comparison is made be tween the measured and the theoretical effects of position.

What you need:

Experiment P2430215 with Cobra3
Experiment P2430201 with teslameter

Teslameter, digital	13610.93	1	
Digital multimeter 2010	07128.00	1	
Induction coil, 300 turns, d = 40 mm	11006.01	1	1
Induction coil, 300 turns, d = 32 mm	11006.02	1	1
Induction coil, 300 turns, d = 25 mm	11006.03	1	1
Induction coil, 200 turns, d = 40 mm	11006.04	1	1
Induction coil, 100 turns, d = 40 mm	11006.05	1	1
Induction coil, 150 turns, d = 25 mm	11006.06	1	1
Induction coil, 75 turns, d = 25 mm	11006.07	1	1
Hall probe, axial	13610.01	1	1
Power supply, universal	13500.93	1	1
Meter Scale, l = 1000 x 27 mm	03001.00	1	1
Barrel base -PASS-	02006.55	2	2
Support rod -PASS-, square, l = 250 mm	02025.55	1	1
Right angle clamp -PASS-	02040.55	1	2
G-clamp	02014.00	2	2
Lab jack, 200 x 230 mm	02074.01	1	1
Reducing plug 4 mm/2 mm socket, 1 pair	11620.27	1	1
Connecting cable, 4 mm plug, 32 A, blue, l = 50 cm	07361.04	1	1
Connecting cable, 4 mm plug, 32 A, red, l = 50 cm	07361.01	2	2
Bench clamp -PASS-	02010.00		1
Stand tube	02060.00		1
Plate holder, opening width 0...10 mm	02062.00		1
Silk thread on spool, l = 200 mm	02412.00		1
Cobra3 Basic-Unit, USB	12150.50		1
Software Cobra3 Force/Tesla	14515.61		1
Cobra3 measuring module Tesla	12109.00		1
Cobra3 current probe 6 A	12126.00		1
Movement sensor with cable	12004.10		1
Adapter BNC socket/4 mm plug pair	07542.27		2
Adapter, BNC socket - 4 mm plug	07542.20		1
Power supply 12V/2A	12151.99		1
PC, Windows® XP or higher			



Curve of magnetic flux density (measured values) for coils with a constant density of turns n/l, coils radius R = 20 mm, lengths l_1 = 53 mm, l_2 = 105 mm and l_3 = 160 mm.

Tasks:

1. To measure the magnetic flux density in the middle of various wire loops with the Hall probe and to investigate its dependence on the radius and number of turns.
2. To determine the magnetic field constant μ_0.
3. To measure the magnetic flux density along the axis of long coils and compare it with theoretical values.

Complete Equipment Set, Manual on CD-ROM included
Magnetic field of a single coils / Biot-Savart's law P24302 01/15

4.3.03-01/15 Magnetic field of paired coils in Helmholtz arrangement

Set-up of experiment P2430315 with Cobra3

What you can learn about …

- ➔ Maxwell's equations
- ➔ Wire loop
- ➔ Flat coils
- ➔ Biot-Savart's law
- ➔ Hall effect

Principle:

The spatial distribution of the field strength between a pair of coils in the Helmholtz arrangement is measured. The spacing at which a uniform magnetic field is produced is investigated and the superposition of the two individual fields to form the combined field of the pair of coils is demonstrated.

What you need:

		Experiment P2430301 with teslameter	Experiment P2430315 with Cobra3
Teslameter, digital	13610.93	1	
Digital multimeter 2010	07128.00	1	
Helmholtz coils, one pair	06960.00	1	1
Power supply, universal	13500.93	1	1
Hall probe, axial	13610.01	1	1
Meter Scale, l = 1000 x 27 mm	03001.00	2	2
Barrel base -PASS-	02006.55	1	1
Support rod -PASS-, square, l = 250 mm	02025.55	1	1
Right angle clamp -PASS-	02040.55	1	2
G-clamp	02014.00	3	3
Connecting cable, 4 mm plug, 32 A, blue, l = 50 cm	07361.04	2	2
Connecting cable, 4 mm plug, 32 A, red, l = 50 cm	07361.01	2	2
Bench clamp -PASS-	02010.00		1
Stand tube	02060.00		1
Plate holder, opening width 0...10 mm	02062.00		1
Silk thread on spool, l = 200 mm	02412.00		1
Weight holder, 1g, silver bronzing	02407.00		1
Cobra3 Basic-Unit, USB	12150.50		1
Software Cobra3 Force/Tesla	14515.61		1
Cobra3 measuring module Tesla	12109.00		1
Cobra3 current probe 6 A	12126.00		1
Movement sensor with cable	12004.10		1
Adapter BNC socket/4 mm plug pair	07542.27		2
Adapter, BNC socket - 4 mm plug	07542.20		1
Power supply 12V/2A	12151.99		1
PC, Windows® XP or higher			

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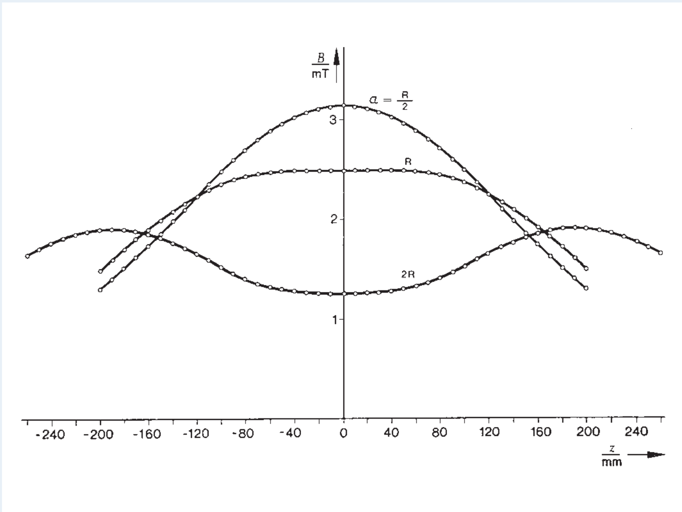
Magnetic field of paired coils in Helmholtz arrangement P24303 01/15



B (r = 0; r is the distance perpendicular to the axis of the coils) as a function of z (z is the distance from the center of the coils in the direction of the axis of the coils) with the parameter α.

Tasks:

1. To measure the magnetic flux density along the z-axis of the flat coils when the distance between them a = R (R = radius of the coils) and when it is larger and smaller than this.
2. To measure the spatial distribution of the magnetic flux density when the distance between coils a = R, using the rotational symmetry of the set-up:
   a) measurement of the axial component B_z
   b) measurement of radial component Br.
3. To measure the radial components B'_r and B''_r of the two individual coils in the plane midway between them and to demonstrate the overlapping of the two fields at B_r = 0.

Magnetic moment in the magnetic field 4.3.04-00

What you can learn about ...
- ➔ Torque
- ➔ Magnetic flux
- ➔ Uniform magnetic field
- ➔ Helmholtz coils

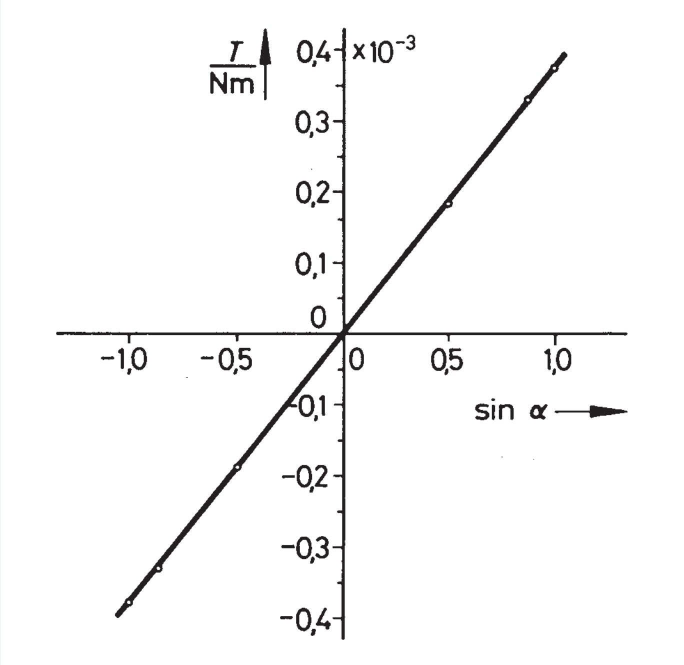
Principle:

A conductor loop carrying a current in a uniform magnetic field experiences a torque. This is determined as a function of the radius, of the number of turns and the current in the conductor loop and of the strength of the external field.

What you need:

Helmholtz coils, one pair	06960.00	1
Conductors, circular, set	06404.00	1
Torsion dynamometer, 0.01 N	02416.00	1
Coil carrier for torsion dynamometer	02416.02	1
Distributor	06024.00	1
Power supply, universal	13500.93	1
Variable transformer with rectifier 15 V~/12 V- , 5 A	13530.93	1
Digital multimeter 2010	07128.00	2
Support base -PASS-	02005.55	1
Support rod -PASS-, square, l = 630 mm	02027.55	1
Right angle clamp -PASS-	02040.55	2
Connecting cable, 4 mm plug, 32 A, red, l = 75 cm	07362.01	5
Connecting cable, 4 mm plug, 32 A, blue, l = 75 cm	07362.04	5

Complete Equipment Set, Manual on CD-ROM included
Magnetic moment in the magnetic field P2430400



Torque due to a magnetic moment in a uniform magnetic field as a function of the angle between the magnetic field and magnetic moment.

Tasks:

Determination of the torque due to a magnetic moment in a uniform magnetic field, as a function

1. of the strength of the magnetic field,
2. of the angle between the magnetic field in the magnetic moment,
3. of the strength of the magnetic moment.

4.3.05-00 Magnetic field outside a straight conductor

What you can learn about …

- → Maxwell's equations
- → Magnetic flux
- → Induction
- → Superimposition of magnetic fields

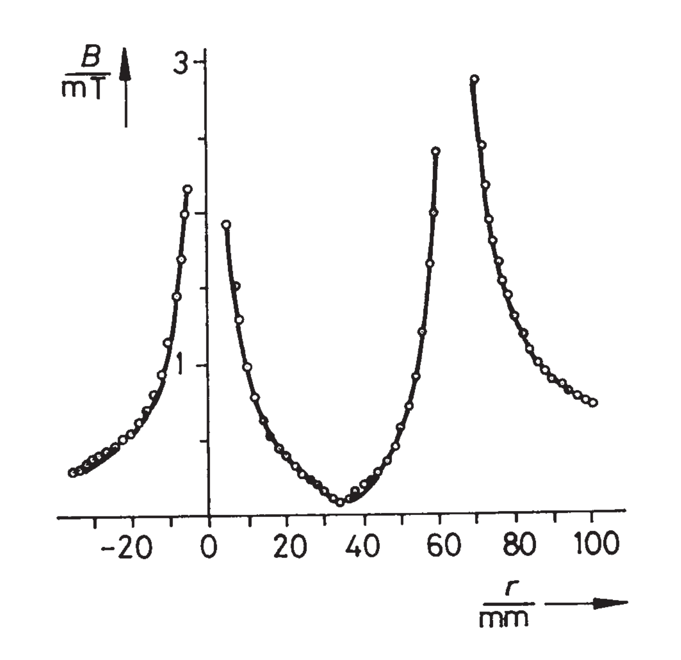
Principle:

A current which flows through one or two neighbouring straight conductors produces a magnetic field around them. The dependences of these magnetic fields on the distance from the conductor and on the current are determined.

What you need:

Electric conductors, set of 4	06400.00	1
Coil, 6 turns	06510.00	1
Coil, 140 turns, 6 tappings	06526.01	1
Clamping device	06506.00	1
Iron core, rod shaped, laminated	06500.00	1
Iron core, U-shaped, laminated	06501.00	1
Variable transformer with rectifier 15 V~/12 V- , 5 A	13530.93	1
Teslameter, digital	13610.93	1
Hall probe, axial	13610.01	1
Current transformer/Clamp Ampermeter adaptor	07091.00	1
Digital multimeter 2010	07128.00	1
Meter Scale, l = 1000 x 27 mm	03001.00	1
Barrel base -PASS-	02006.55	1
Support rod -PASS-, square, l = 400 mm	02026.55	1
Right angle clamp -PASS-	02040.55	1
G-clamp	02014.00	2
Connecting cable, 4 mm plug, 32 A, yellow, l = 50 cm	07361.02	2

Complete Equipment Set, Manual on CD-ROM included
Magnetic field outside a straight conductor P2430500



Magnetic field component B_y of two parallel conductors on the x-axis as a function of the distance from one conductor, if the current in both conductors is in the same direction.

Tasks:

Determination of the magnetic field

1. of a straight conductor as a function of the current,
2. of a straight conductor as a function of the distance from the conductor,
3. of two parallel conductors, in which the current is flowing in the same direction, as a function of the distance from one conductor on the line joining the two conductors,
4. of two parallel conductors, in which the current is flowing in opposite directions, as a function of the distance from one conductor on the line joining the two conductors.

Magnetic field inside a conductor 4.3.06-00

What you can learn about …

- → Maxwell's equations
- → Magnetic flux
- → Induction
- → Current density
- → Field strength

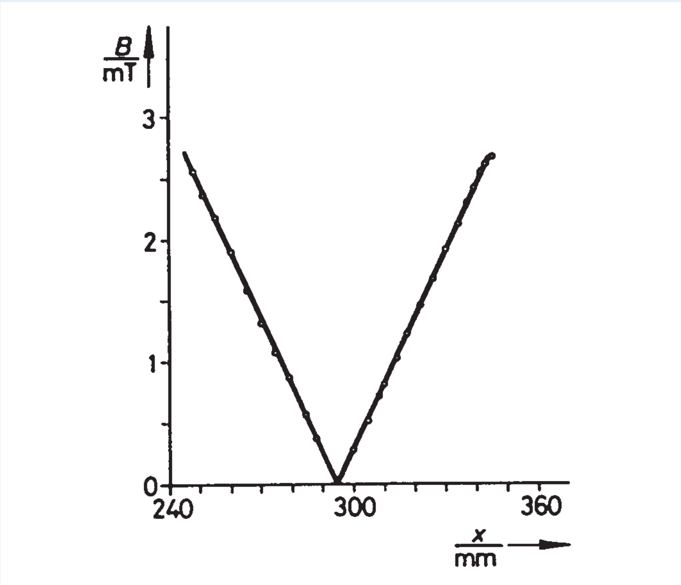
Principle:

A current which produces a magnetic field is passed through an electrolyte. This magnetic field inside the conductor is determined as a function of position and current.

What you need:

Hollow cylinder, PLEXIGLAS	11003.10	1
Search coil, plane	11004.00	1
Power frequency generator, 1 MHz	13650.93	1
LF amplifier, 220 V	13625.93	1
Digital multimeter 2010	07128.00	2
Adapter BNC socket/4 mm plug pair	07542.27	1
Distributor	06024.00	1
Meter Scale, l = 1000 x 27 mm	03001.00	1
Cursor for scale, 2 pieces, plastic, red	02201.00	1
Tripod base -PASS-	02002.55	1
Barrel base -PASS-	02006.55	1
Support rod -PASS-, square, l = 400 mm	02026.55	1
Right angle clamp -PASS-	02040.55	1
Screened cable, BNC, l = 1500 mm	07542.12	1
Connecting cable, 4 mm plug, 32 A, yellow, l = 50 cm	07361.02	3
Connecting cable, 4 mm plug, 32 A, blue, l = 50 cm	07361.04	3
Hydrochloric acid 37 %, 1000 ml	30214.70	1

Complete Equipment Set, Manual on CD-ROM included
Magnetic field inside a conductor P2430600



Magnetic field inside a conductor as a function of the position x (x = height of the probe perpendicular to the axis of the cylinder).

Tasks:

Determination of the magnetic field inside a conductor as a function

1. of the current in the conductor,
2. of the distance from the axis of the conductor.

4.3.07-11 Ferromagnetic hysteresis with PC interface system

What you can learn about …

- ➔ Induction
- ➔ Magnetic flux, coil
- ➔ Magnetic field strength
- ➔ Magnetic field of coils
- ➔ Remanence
- ➔ Coercive field strength

Principle:

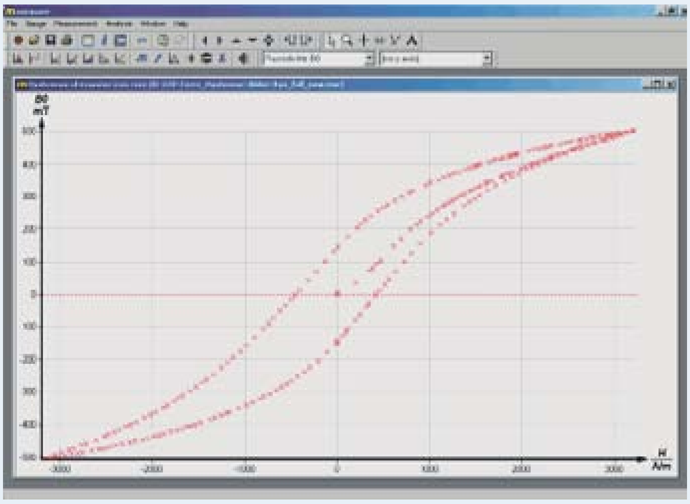
A magnetic field is generated in a ring-shaped iron core by a continuous adjustable direct current applied to two coils. The field strength H and the flux density B are measured and the hysteresis recorded.

The remanence and the coercive field strength of two different iron cores can be compared.

What you need:

Coil, 600 turns	06514.01	2
Iron core, U-shaped, solid	06491.00	1
Iron core, rod shaped, solid	06490.00	1
Iron core, U-shaped, laminated	06501.00	1
Iron core, rod shaped, laminated	06500.00	1
Commutator switch	06034.03	1
Power supply, universal, with analog display	13501.93	1
Rheostats, 10 Ω, 5.7 A	06110.02	1
Hall probe, tangential, with protective cap	13610.02	1
Barrel base -PASS-	02006.55	1
Right angle clamp -PASS-	02040.55	1
Support rod with hole, stainless steel, l = 150 mm	02030.15	1
Connecting cable, 4 mm plug, 32 A, red, l = 75 cm	07362.01	4
Connecting cable, 4 mm plug, 32 A, blue, l = 75 cm	07362.04	4
Cobra3 Basic-Unit, USB	12150.50	1
Power supply 12V/2A	12151.99	1
Cobra3 measuring module Tesla	12109.00	1
Software Cobra3 Force/Tesla	14515.61	1
PC, Windows® XP or higher		

Complete Equipment Set, Manual on CD-ROM included
Ferromagnetic hysteresis with PC interface system P2430711



Hysteresis for a massive iron core.

Tasks:

Record the hysteresis curve for a massive iron core and for a laminated one.

Magnetostriction with the Michelson interferometer 4.3.08-00

What you can learn about …

- Interference
- Wavelength
- Diffraction index
- Speed of light
- Phase
- Virtual light source
- Ferromagnetic material
- Weiss molecular magnetic fields
- Spin-orbit coupling

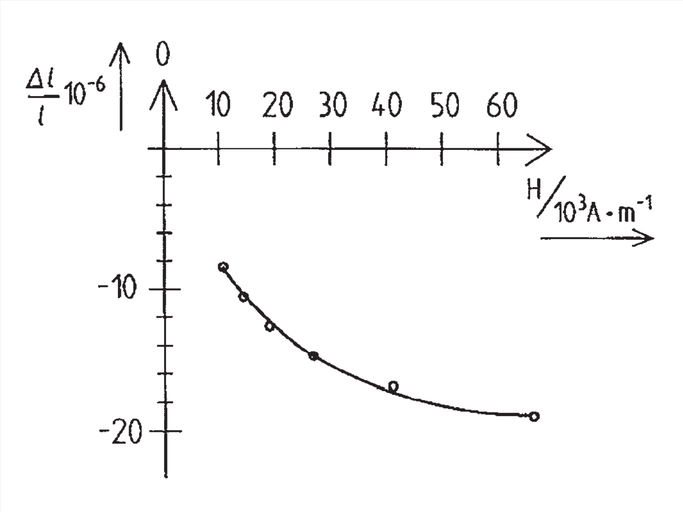
Principle:

With the aid of two mirrors in a Michelson arrangement, light is brought to interference. Due to the magnetostrictive effect, one of the mirrors is shifted by variation in the magnetic field applied to a sample, and the change in the interference pattern is observed.

What you need:

Optical base plate with rubberfeet	08700.00	1
He/Ne Laser, 5mW with holder	08701.00	1
Power supply for laser head 5 mW	08702.93	1
Adjusting support 35 x 35 mm	08711.00	3
Surface mirror 30 x 30 mm	08711.01	4
Magnetic foot for optical base plate	08710.00	7
Holder for diaphragm/ beam plitter	08719.00	1
Beam plitter 1/1, non polarizing	08741.00	1
Lens, mounted, f = +20 mm	08018.01	1
Lens holder for optical base plate	08723.00	1
Screen, white, 150 x 150 mm	09826.00	1
Faraday modulator for optical base plate	08733.00	1
Rods for magnetotriction, set of 3	08733.01	1
Power supply, universal	13500.93	1
Digital multimeter 2010	07128.00	1
Flat cell battery, 9 V	07496.10	1
Connecting cable, 4 mm plug, 32 A, blue, l = 50 cm	07361.04	1

Complete Equipment Set, Manual on CD-ROM included
Magnetostriction with the Michelson interferometer P2430800



Measuring results of the magnetostriction of nickel with the relative change in length $\Delta l / l$ plotted against applied field strength H.

Tasks:

1. Construction of a Michelson interferometer using separate optical components.
2. Testing various ferromagnetic materials (iron and nickel) as well as a non-ferromagnetic material (copper), with regard to their magnetostrictive properties.

4.4.01-00 Transformer

What you can learn about ...

- ➔ Induction
- ➔ Magnetic flux
- ➔ Loaded transformer
- ➔ Unloaded transformer
- ➔ Coil

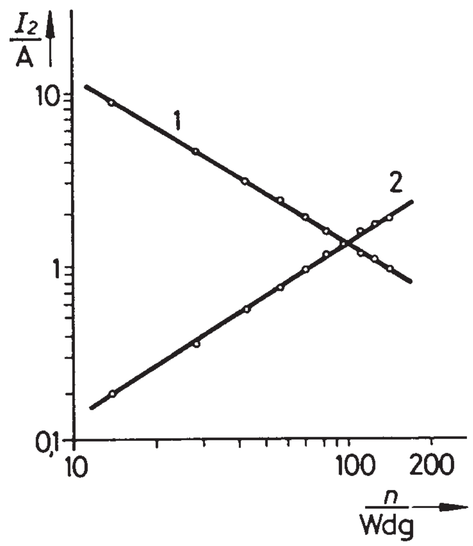
Principle:

An alternating voltage is applied to one of two coils (primary coil) which are located on a common iron core. The voltage induced in the second coil (secondary coil) and the current flowing in it are investigated as functions of the number of turns in the coils and of the current flowing in the primary coil.

What you need:

Coil, 140 turns, 6 tappings	06526.01	2
Clamping device	06506.00	1
Iron core, U-shaped, laminated	06501.00	1
Iron core, rod shaped, laminated	06500.00	1
Multi-tap transformer with rectifier 14 VAC/12 VDC, 5 A	13533.93	1
Two-way switch, double pole	06032.00	1
Rheostats, 10 Ω, 5.7 A	06110.02	1
Digital multimeter 2010	07128.00	3
Connecting cable, 4 mm plug, 32 A, red, l = 50 cm	07361.01	6
Connecting cable, 4 mm plug, 32 A, blue, l = 50 cm	07361.04	6

Complete Equipment Set, Manual on CD-ROM included
Transformer P2440100



Secondary short-circuit current of the transformer as a function
1. of the number of turns in the secondary coil,
2. of the number of turns in the primary coil.

Tasks:

The secondary voltage on the open circuited transformer is determined as a function

1. of the number of turns in the primary coil,
2. of the number of turns in the secondary coil,
3. of the primary voltage.

The short-circuit current on the secondary side is determined as a function

4. of the number of turns in the primary coil,
5. of the number of turns in the secondary coil,
6. of the primary current.

With the transformer loaded, the primary current is determined as a function

7. of the secondary current,
8. of the number of turns in the secondary coil,
9. of the number of turns in the primary coil.

Magnetic Induction 4.4.02-01/15

Set-up of experiment P2440215 with FG-Module

What you can learn about …

- → Maxwell's equations
- → Electrical eddy field
- → Magnetic field of coils
- → Coil
- → Magnetic flux
- → Induced voltage

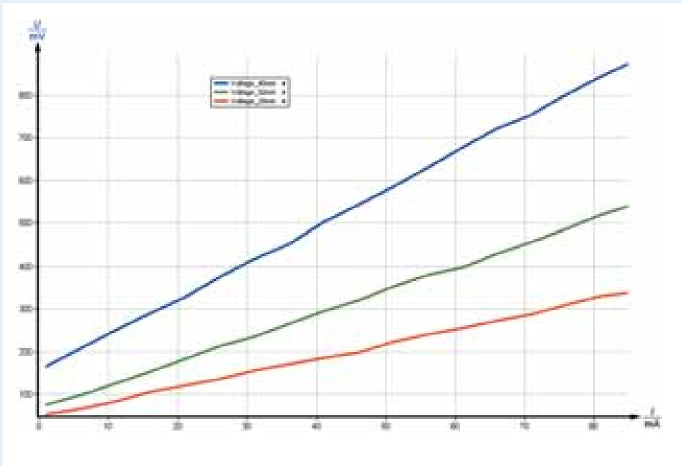
Principle:

A magnetic field of variable frequency and varying strength is produced in a long coil. The voltages induced across thin coils which are pushed into the long coil are determined as a function of frequency, number of turns, diameter and field strength.

What you need:

	Order No.	Experiment P2440201 with counter	Experiment P2440215 with FG-Module
Function generator	13652.93	1	
Universal counter	13601.99	1	
Digital multimeter 2010	07128.00	2	
Field coil 750 mm, 485 turns/m	11001.00	1	1
Induction coil, 300 turns, d = 40 mm	11006.01	1	1
Induction coil, 300 turns, d = 32 mm	11006.02	1	1
Induction coil, 300 turns, d = 25 mm	11006.03	1	1
Induction coil, 200 turns, d = 40 mm	11006.04	1	1
Induction coil, 100 turns, d = 40 mm	11006.05	1	1
Induction coil, 150 turns, d = 25 mm	11006.06	1	1
Induction coil, 75 turns, d = 25 mm	11006.07	1	1
Connecting cable, 4 mm plug, 32 A, red, l = 75 cm	07362.01	4	2
Connecting cable, 4 mm plug, 32 A, blue, l = 75 cm	07362.04	2	1
Connecting cable, 4 mm plug, 32 A, blue, l = 200 cm	07365.04	1	1
Cobra3 Basic-Unit, USB	12150.50		1
Power supply 12V/2A	12151.99		2
Software Cobra3 PowerGraph	14525.61		1
Measuring module Function Generator	12111.00		1
PC, Windows® XP or higher			

Complete Equipment Set, Manual on CD-ROM included
Magnetic Induction P24402 01/15



Induced voltage as a function of current for different coils.

Tasks:

Determination of the induction voltage as a function

1. of the strength of the magnetic field,
2. of the frequency of the magnetic field,
3. of the number of turns of the induction coil,
4. of the cross-section of the induction coil.

4.4.03-01/11 Inductance of solenoids

Set-up of experiment P2440311 with FG-Module

What you can learn about …

- ➔ Lenz's law
- ➔ Self-inductance
- ➔ Solenoids
- ➔ Transformer
- ➔ Oscillatory circuit
- ➔ Resonance
- ➔ Damped oscillation
- ➔ Logarithmic decrement
- ➔ Q factor

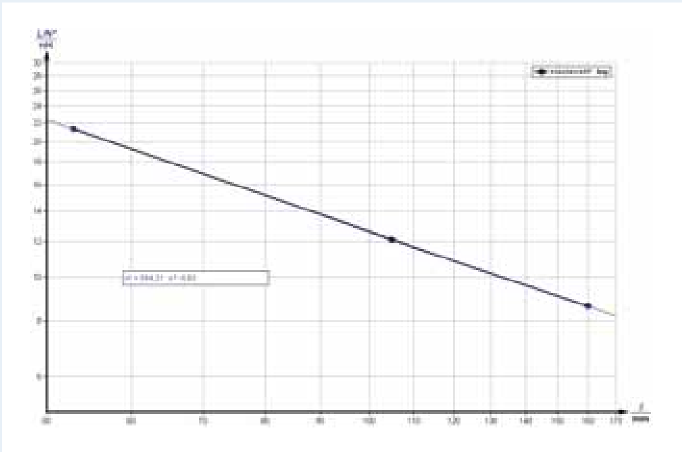
Principle:

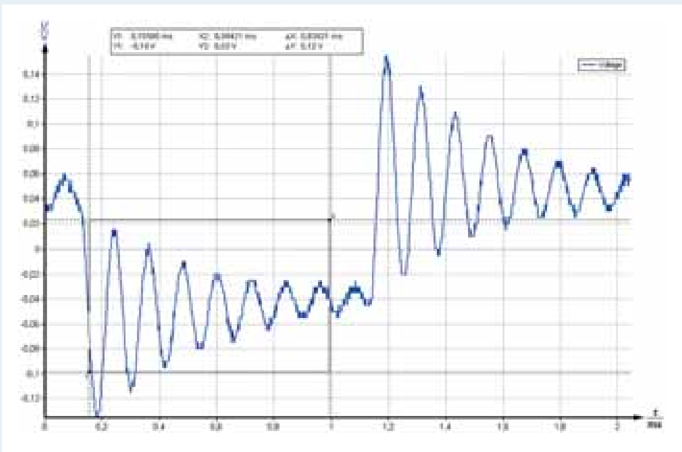
A square wave voltage of low frequency is applied to oscillatory circuits comprising coils and capacitors to produce free, damped oscillations. The values of inductance are calculated from the natural frequencies measured, the capacitance being known.

What you need:

		Experiment P2440301 with oscilloscope	Experiment P2440311 with FG-Module
Function generator	13652.93	1	
Oscilloscope 30 MHz, 2 channels	11459.95	1	
Adapter, BNC plug/4 mm socket	07542.26	1	
Induction coil, 300 turns, d = 40 mm	11006.01	1	1
Induction coil, 300 turns, d = 32 mm	11006.02	1	1
Induction coil, 300 turns, d = 25 mm	11006.03	1	1
Induction coil, 200 turns, d = 40 mm	11006.04	1	1
Induction coil, 100 turns, d = 40 mm	11006.05	1	1
Induction coil, 150 turns, d = 25 mm	11006.06	1	1
Induction coil, 75 turns, d = 25 mm	11006.07	1	1
Coil, 1200 turns	06515.01	1	1
Capacitor 470 nF/250 V, G1	39105.20	1	1
Connection box	06030.23	1	1
Connecting cable, 4 mm plug, 32 A, red, l = 25 cm	07360.01	1	1
Connecting cable, 4 mm plug, 32 A, blue, l = 25 cm	07360.04	1	1
Connecting cable, 4 mm plug, 32 A, red, l = 50 cm	07361.01	2	2
Connecting cable, 4 mm plug, 32 A, blue, l = 50 cm	07361.04	2	2
Cobra3 Basic-Unit, USB	12150.50		1
Power supply 12V/2A	12151.99		2
Software Cobra3 Universal recorder	14504.61		1
Software Cobra3 PowerGraph	14525.61		1
Measuring module Function Generator	12111.00		1
PC, Windows® XP or higher			

Complete Equipment Set, Manual on CD-ROM included
Inductance of solenoids with Cobra3 P24403 01/11


Inductance per turn as a function of the length of the coil at constant radius.


Measurement of the oscillation period with the "Survey Function".

Tasks:

To connect coils of different dimensions (length, radius, number of turns) with a known capacitance C to form an oscillatory circuit. From the measurements of the natural frequencies, to calculate the inductances of the coils and determine the relationships between:

1. inductance and number of turns
2. inductance and length
3. inductance and radius.

Coil in the AC circuit 4.4.04-01/11

Set-up of experiment P2440411 with FG-Module

What you can learn about …

- → Inductance
- → Kirchhoff's laws
- → Maxwell's equations
- → AC impedance
- → Phase displacement

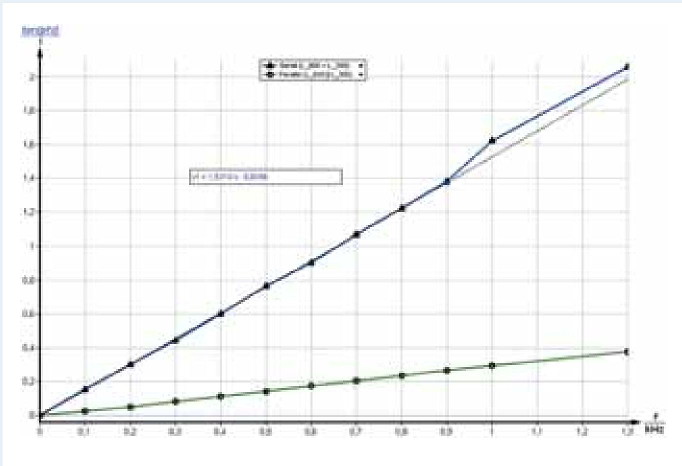
Principle:

The coil is connected in a circuit with a voltage source of variable frequency. The impedance and phase displacements are determined as functions of frequency. Parallel and series impedances are measured.

What you need:

		Experiment P2440401 with oscilloscope	Experiment P2440411 with FG-Module
Function generator	13652.93	1	
Oscilloscope 30 MHz, 2 channels	11459.95	1	
Difference amplifier	11444.93	1	
Universal counter	13601.99	1	
Screened cable, BNC, l = 750 mm	07542.11	2	
Connecting cable, 4 mm plug, 32 A, red, l = 10 cm	07359.01	3	
Coil, 300 turns	06513.01	1	1
Coil, 600 turns	06514.01	1	1
Connection box	06030.23	1	1
Connecting cable, 4 mm plug, 32 A, red, l = 50 cm	07361.01	5	2
Connecting cable, 4 mm plug, 32 A, blue, l = 50 cm	07361.04	4	2
Cobra3 Basic-Unit, USB	12150.50		1
Power supply 12V/2A	12151.99		1
Software Cobra3 PowerGraph	14525.61		1
Measuring module Function Generator	12111.00		1
Connecting cable, 4 mm plug, 32 A, red, l = 25 cm	07360.01		2
Connecting cable, 4 mm plug, 32 A, blue, l = 25 cm	07360.04		1
Carbon resistor 47 Ω, 1W, G1	39104.62		1
Carbon resistor 100 Ω, 1W, G1	39104.63		1
Carbon resistor 220 Ω, 1W, G1	39104.64		1
Resistor 50 Ω 2%, 1W, G1	06056.50	1	
Resistor 100 Ω 2%, 2W, G1	06057.10	1	
Resistor 200 Ω 2%, 2W, G1	06057.20	1	
PC, Windows® XP or higher			

Complete Equipment Set, Manual on CD-ROM included
Coil in the AC circuit P24404 01/11

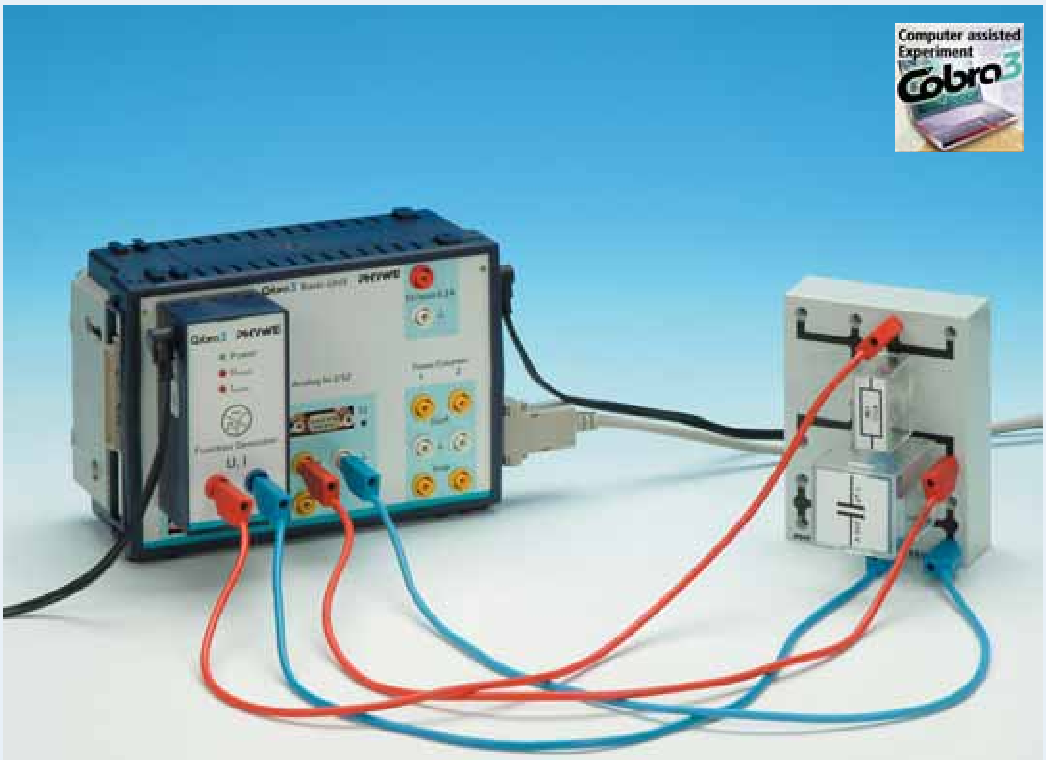


Tangent of the current-voltage phase displacement as a function of the frequency used for calculation of the total inductance of coils connected in parallel and in series.

Tasks:

1. Determination of the impedance of a coil as a function of frequency.
2. Determination of the inductance of the coil.
3. Determination of the phase displacement between the terminal voltage and total current as a function of the frequency in the circuit.
4. Determination of the total impedance of coils connected in parallel and in series.

4.4.05-01/15 Capacitor in the AC circuit



Set-up of experiment P2440515 with FG-Module

What you can learn about …

- ➔ Capacitance
- ➔ Kirchhoff's laws
- ➔ Maxwell's equations
- ➔ AC impedance
- ➔ Phase displacement

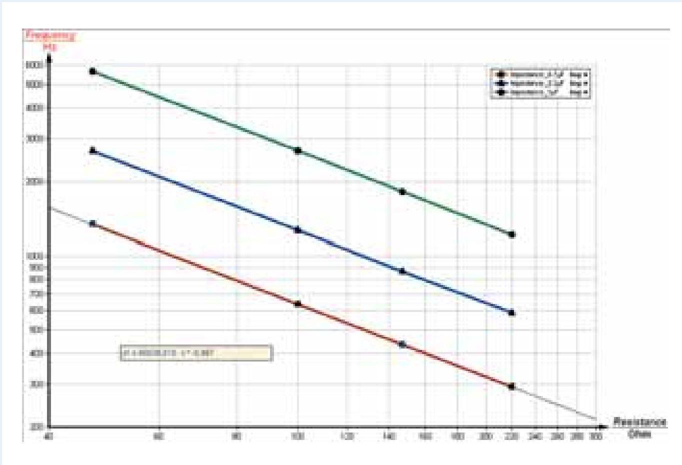
Principle:

A capacitor is connected in a circuit with a variable-frequency voltage source. The impedance and phase displacement are determined as a function of frequency and of capacitance. Parallel and series impedances are measured.

What you need:

Item	Order No.	Experiment P2440501 with oscilloscope	Experiment P2440515 with FG-Module
Function generator	13652.93	1	
Oscilloscope 30 MHz, 2 channels	11459.95	1	
Difference amplifier	11444.93	1	
Universal counter	13601.99	1	
Screened cable, BNC, l = 750 mm	07542.11	2	
Connecting cable, 4 mm plug, 32 A, red, l = 10 cm	07359.01	2	
Carbon resistor 47 Ω, 1W, G1	39104.62		1
Carbon resistor 100 Ω, 1W, G1	39104.63	1	1
Carbon resistor 220 Ω, 1W, G1	39104.64		1
Resistor 50 Ω 2%, 1W, G1	06056.50	1	
Resistor 10 Ω 2%, 2W, G1	39104.01	1	
Capacitor 1 microF/ 250 V, G2	39113.01	1	1
Capacitor 4,7microF/ 250 V, G2	39113.02	1	1
Capacitor 4,7microF/ 250 V, G2	39113.03	1	1
Connection box	06030.23	1	1
Connecting cable, 4 mm plug, 32 A, red, l = 50 cm	07361.01	4	2
Connecting cable, 4 mm plug, 32 A, blue, l = 50 cm	07361.04	2	2
Cobra3 Basic-Unit, USB	12150.50		1
Power supply 12V/2A	12151.99		2
Software Cobra3 PowerGraph	14525.61		1
Measuring module Function Generator	12111.00		1
PC, Windows® XP or higher			

Complete Equipment Set, Manual on CD-ROM included
Capacitor in the AC circuit P24405 01/15



Impedance of various capacitors as a function of the frequency.

Tasks:

1. Determination of the impedance of a capacitor as a function of frequency.
2. Determination of the phase displacement between the terminal voltage and total current as a function of the frequency in the circuit.
3. Determination of the total impedance of capacitors connected in parallel and in series.

RLC Circuit 4.4.06-01/11

Set-up of experiment P2440611 with FG-Module

What you can learn about …

- → Series-tuned circuit
- → Parallel-tuned circuit
- → Resistance
- → Capacitance
- → Inductance
- → Capacitor
- → Coil
- → Phase displacement
- → Q factor
- → Band-width
- → Loss resistance
- → Damping

Principle:

The current and voltage of parallel and series-tuned circuits are investigated as a function of frequency. Q-factor and bandwidth are determined.

What you need:

		Experiment P2440601 with multimeter	Experiment P2440611 with FG-Module
Function generator	13652.93	1	
Universal counter	13601.99	1	
Multi-range meter with amplifier	07042.00	1	
Coil, 300 turns	06513.01	1	
Coil, 3600 turns, tapped	06516.01		1
Connecting plug white 19 mm pitch	39170.00	2	2
Carbon resistor 10 Ω, 1W, G1	39104.01	1	
Carbon resistor 47 Ω, 1W, G1	39104.62	1	
Carbon resistor 470 Ω, 1W, G1	39104.15	1	1
Carbon resistor 1 kΩ, 1W, G1	39104.19	2	
Resistor 100 Ω, 1W, G1	39104.63		1
Resistor 220 Ω, 2W, G1	39104.64		1
Capacitor 1 microF/ 250 V, G2	39113.01	1	1
Capacitor 100 nF/250 V, G1	39105.18	1	
Capacitor 2.2 microF/100 V, G2	39113.02		1
Capacitor 4.7 microF/100 V, G2	39113.03		1
Connecting cable, 4 mm plug, 32 A, red, l = 25 cm	07360.01	3	2
Connecting cable, 4 mm plug, 32 A, blue, l = 25 cm	07360.04	2	1
Connecting cable, 4 mm plug, 32 A, red, l = 50 cm	07361.01	2	1
Connecting cable, 4 mm plug, 32 A, blue, l = 50 cm	07361.04	2	2
Connection box	06030.23	1	1
Cobra3 Basic-Unit, USB	12150.50		1
Power supply 12V/2A	12151.99		2
Software Cobra3 PowerGraph	14525.61		1
Software Cobra3 Universal recorder	14504.61		1
Measuring module Function Generator	12111.00		1
PC, Windows® XP or higher			

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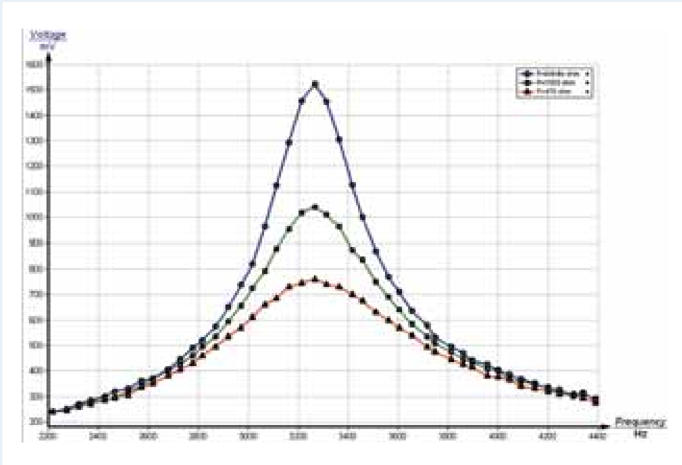
RLC Circuit P24406 01/11



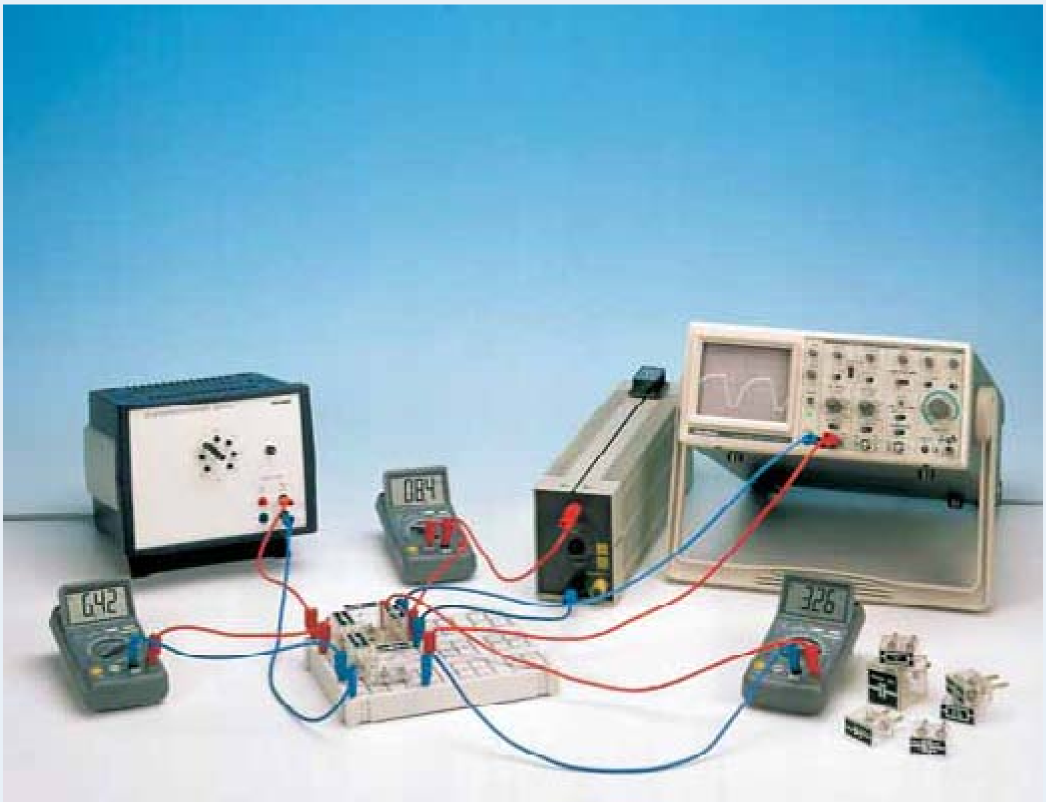
Total voltage as a function of frequency in the parallel tuned circuit. Curves recorded for different resistors (top down): $R = \infty$ Ω, 1000 Ω, 470 Ω.

Tasks:

Determination of the frequency performance of a

1. Series-tuned circuit for
   a) voltage resonance without damping resistor,
   b) current resonance without damping resistor,
   c) current resonance with damping resistor.
2. Parallel-tuned circuit for
   a) current resonance without parallel resistor,
   b) voltage resonance without parallel resistor
   c) voltage resonance with parallel resistor.

4.4.07-00 Rectifier circuits



What you can learn about …

- ➔ Half-wave rectifier
- ➔ Full-wave rectifier
- ➔ Graetz rectifier
- ➔ Diode and Zener diode
- ➔ Avalanche effect
- ➔ Charging capacitor
- ➔ Ripple
- ➔ r.m.s. value
- ➔ Internal resistance
- ➔ Smoothing factor
- ➔ Ripple voltage
- ➔ Voltage stabilisation
- ➔ Voltage doubling

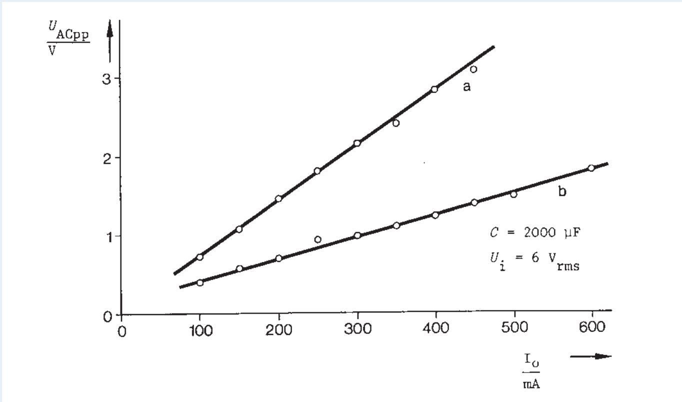
Principle:

The ripple of the output voltage of various rectifier circuits is measured as a function of the load current strength and the charging capacitance. The characteristics of a voltage stabilizer and of a multiplier are investigated.

What you need:

Plug-in board 4 mm plugs	06033.00	1
Silicon diode 1 N 4007, G1	39106.02	4
Electrolyte capacitors, G1, 470 µF	39105.26	1
Electrolyte capacitors G1, 10 µF	39105.28	4
Electrolyte capacitors, G2, 2200 µF	39113.08	1
Electrolyte capacitors G1, 1000 µF	06049.09	1
Carbon resistor 470 Ω, 1W, G1	39104.15	1
Carbon resistor 47 Ω, 1W, G1	39104.62	1
Siliziumdiode ZF 4.7, G1	39132.01	1
Multi-tap transformer with rectifier 14 VAC/12 VDC, 5 A	13533.93	1
Oscilloscope 30 MHz, 2 channels	11459.95	1
Digital multimeter 2010	07128.00	3
Rheostats, 330 Ω, 1.0 A	06116.02	1
Adapter, BNC plug/4 mm socket	07542.26	1
Connecting plug white 19 mm pitch	39170.00	3
Connecting cable, 4 mm plug, 32 A, red, l = 25 cm	07360.01	2
Connecting cable, 4 mm plug, 32 A, blue, l = 25 cm	07360.04	2
Connecting cable, 4 mm plug, 32 A, red, l = 50 cm	07361.01	4
Connecting cable, 4 mm plug, 32 A, blue, l = 50 cm	07361.04	4

Complete Equipment Set, Manual on CD-ROM included
Rectifier circuits P2440700

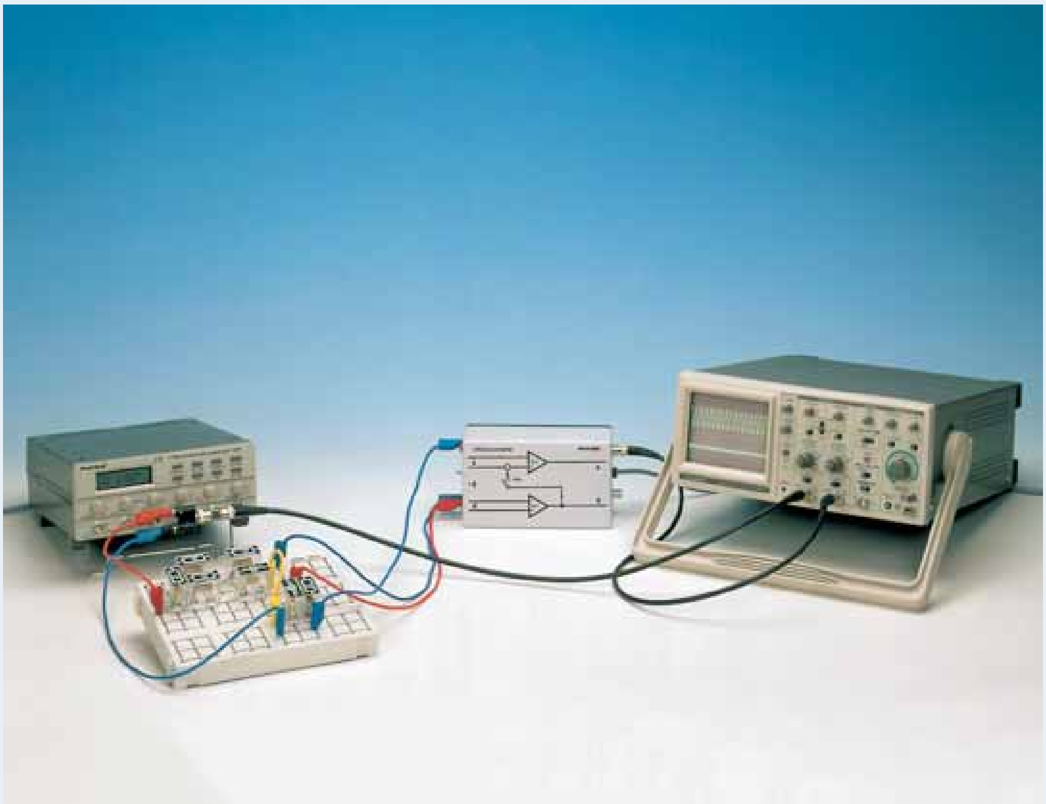


Ripple of the output voltage as a function of the charging current:
a) half-wave rectifier, b) bridge rectifier.

Tasks:

1. Using the half-wave rectifier:
   a) to display the output voltage (without charging capacitor) on the oscilloscope
   b) to measure the diode current I_D as a function of the output current strength I_o (with the charging capacitor)
   c) to measure the ripple component U_{ACpp} of the output voltage as a function of the output current (C = constant)
   d) to measure the ripple as a function of the capacitance (I_o = constant)
   e) to measure the output voltage U_o as a function of the input voltage U_i (I_o = 0).
2. Using the bridge rectifier:
   a) to display the output voltage (without charging capacitor) on the oscilloscope
   b) to measure the current through one diode, I_D, as a func tion of the output current Io (with the charging capacitor)
   c) to measure the ripple of the output voltage as a function of the output current (C = constant)
   d) to measure the ripple as a function of the capacitance (I_o = constant)
   e) to measure the output voltage as a function of the input voltage.
3. To measure the voltage at the charging capacitor, U_c, and the output voltage of a stabilized voltage source as a func tion of the input voltage U_i.
4. To measure the output voltage of a voltage multiplier circuit as a function of the input voltage.

RC Filters 4.4.08-00



What you can learn about ...

- ➔ High-pass
- ➔ Low-pass
- ➔ Wien-Robinson bridge
- ➔ Parallel-T filters
- ➔ Differentiating network
- ➔ Integrating network
- ➔ Step response
- ➔ Square wave
- ➔ Transfer function

Principle:

The frequency response of simple RC filters is recorded by point-by-point measurements and the sweep displayed on the oscilloscope.

What you need:

Plug-in board 4 mm plugs	06033.00	1
Resistor 500 Ω 2%, 1W, G1	06057.50	1
Capacitor 10 nF/ 250 V, G1	39105.14	4
Carbon resistor 1kΩ, 1W, G1	39104.19	5
Connecting plug white 19 mm pitch	39170.00	5
Difference amplifier	11444.93	1
Wobble-functiongenerator 20 MHz	11768.99	1
Oscilloscope 30 MHz, 2 channels	11459.95	1
Adapter, BNC plug/4 mm socket	07542.26	2
Connecting cable, 4 mm plug, 32 A, yellow, l = 10 cm	07359.02	1
Connecting cable, 4 mm plug, 32 A, red, l = 50 cm	07361.01	2
Connecting cable, 4 mm plug, 32 A, blue, l = 50 cm	07361.04	3
Screened cable, BNC, l = 750 mm	07542.11	1
Connector, T-type, BNC	07542.21	1

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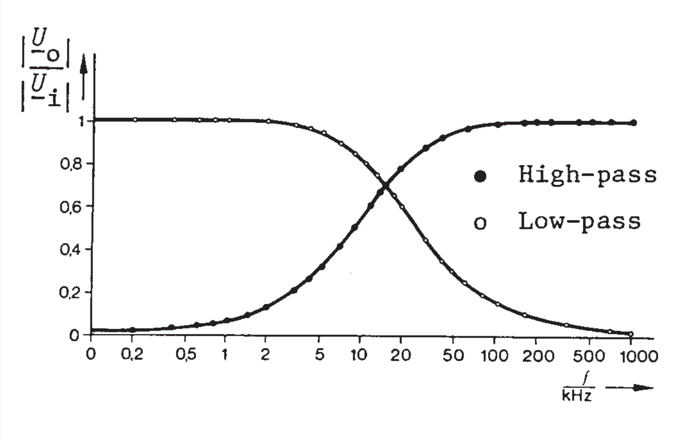
RC Filters P2440800



Frequency response of high-pass and low pass filter.

Tasks:

To record the frequency response of the output voltage of

1. a high-pass filter
2. a low-pass filter
3. a band-pass filter
4. a Wien-Robinson bridge
5. a parallel-T filter,

point by point and to display the sweep on the oscilloscope.

To investigate the step response of

6. a differentiating network
7. an integrating network

4.4.09-01/15 High-pass and low-pass filters

Set-up of experiment P2440915 with FG-Module

What you can learn about ...

- ➔ Circuit
- ➔ Resistance
- ➔ Capacitance
- ➔ Inductance
- ➔ Capacitor
- ➔ Coil
- ➔ Phase displacement
- ➔ Filter
- ➔ Kirchhoff's laws
- ➔ Bode diagram

Principle:

A coil, a capacitor, an ohmic resistance and combinations of these components are investigated for their filter characteristics as a function of frequency. The phase displacement of the filters is determined also as a function of frequency.

What you need:

Item	Order No.	Experiment P2440901 with oscilloscope	Experiment P2440915 with FG-Module
Function generator	13652.93	1	
Oscilloscope 30 MHz, 2 channels	11459.95	1	
Universal counter	13601.99	1	
Difference amplifier	11444.93	1	
Screened cable, BNC, l = 750 mm	07542.11	2	
Connecting cable, 4 mm plug, 32 A, blue, l = 10 cm	07359.04	1	
Coil, 300 turns	06513.01	1	1
Carbon resistor 47 Ω, 1W, G1	39104.62		1
Carbon resistor 1 kΩ, 1W, G1	39104.19	2	2
Resistor 50 Ω 2%, 1W, G1	06056.50	1	
Capacitor 1 microF/ 250 V, G2	39113.01	1	1
Capacitor 4,7microF/ 250 V, G2	39113.02	1	1
Connecting cable, 4 mm plug, 32 A, red, l = 50 cm	07361.01	4	2
Connecting cable, 4 mm plug, 32 A, blue, l = 50 cm	07361.04	4	2
Connection box	06030.23	1	
Connecting plug white 19 mm pitch	39170.00		4
Plug in board, 4 mm plugs	06033.00		1
Cobra3 Basic-Unit, USB	12150.50		1
Power supply 12V/2A	12151.99		2
Software Cobra3 PowerGraph	14525.61		1
Measuring module Function Generator	12111.00		1
Connecting cable, 4 mm plug, 32 A, red, l = 25 cm	07360.01		1
Connecting cable, 4 mm plug, 32 A, blue, l = 25 cm	07360.04		1
PC, Windows® XP or higher			

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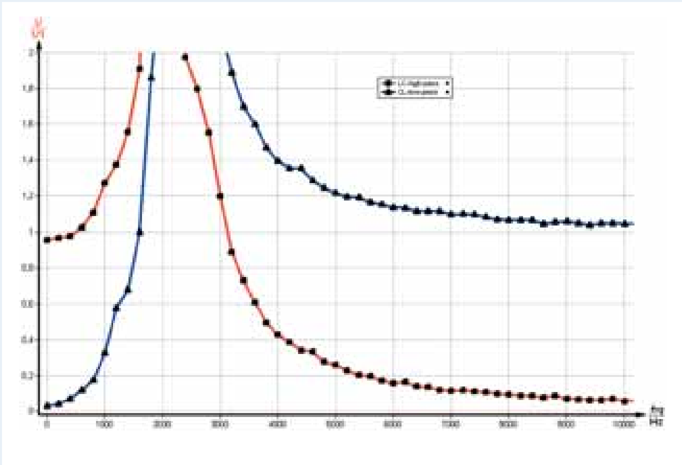
High-pass and low-pass filters P24409 01/15



U/U_1 as a function of the frequency with the LC and CL network.

Tasks:

Determination of the ratio of output voltage to input voltage with the

1. RC/CR network,
2. RL/LR network,
3. CL/LC network,
4. Two CR networks connected in series.
5. Determination of the phase displacement with the RC/CR network.
6. Determination of the phase displacement with two CR networks connected in series.

RLC measuring bridge 4.4.10-00

What you can learn about ...

- → Wheatstone bridge
- → Inductive and capacitive reactance
- → Ohmic resistance
- → Impedance
- → Kirchhoff's laws

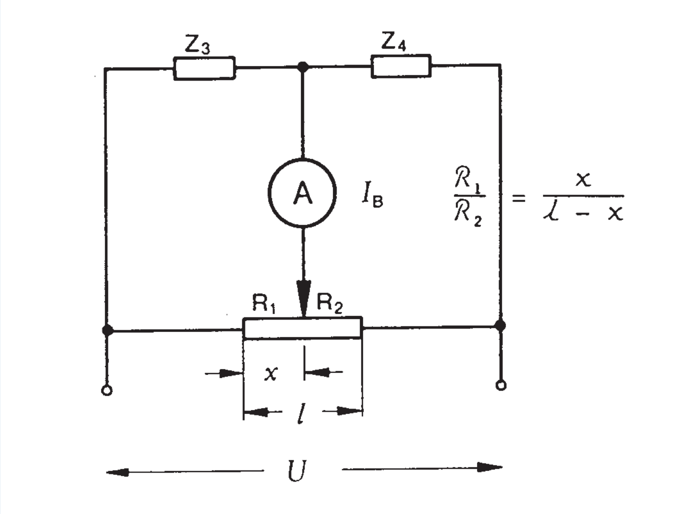
Principle:

Ohmic resistances, inductances and capacitances are determined in a Wheatstone bridge circuit operated on AC. Balancing is done aurally through head phones, using the high sensitivity of the human ear.

What you need:

Simple slide wire measuring bridge	07182.00	1
Head phones, stereo	65974.00	1
Function generator	13652.93	1
Coil, 6 turns	06510.00	1
Coil, 300 turns	06513.01	1
Coil, 600 turns	06514.01	1
Coil, 1200 turns	06515.01	1
Coil, 600 turns, short	06522.01	1
Induction coil, 300 turns, d = 40 mm	11006.01	1
Carbon resistor 330 Ω, 1W, G1	39104.13	1
Carbon resistor 470 Ω, 1W, G1	39104.15	1
Carbon resistor G1, 680 Ω, 1 W	39104.17	1
Carbon resistor 1 kΩ, 1W, G1	39104.19	1
Carbon resistor 1,5 kΩ, 1W, G1	39104.21	1
Carbon resistor 2.2 kΩ, 1W, G1	39104.23	1
Carbon resistor 3.3 kΩ, 1W, G1	39104.25	1
Potentiometer 100 Ω, 0.4W, G2	39103.01	1
Carbon resistor 1 kΩ, 1W, G1	39104.19	1
Capacitor 100 pF/100 V, G2	39105.04	1
Capacitor 470 pF/100 V, G1	39105.07	1
Capacitor 1 nF/ 100 V, G2	39105.10	1
Capacitor 10 nF/ 250 V, G1	39105.14	1
Capacitor 47 nF/ 250 V, G2	39105.17	1
Capacitor 100 nF/250 V, G1	39105.18	1
Connection box	06030.23	1
Connecting cable, 4 mm plug, 32 A, blue, l = 25 cm	07360.04	3
Connecting cable, 4 mm plug, 32 A, blue, l = 50 cm	07361.04	2
Connecting cable, 4 mm plug, 32 A, blue, l = 75 cm	07362.04	2
Headphone Adapter jack plug/2 x 4 mm plug	65974.01	1

Complete Equipment Set, Manual on CD-ROM included
RLC measuring bridge P2441000



Wheatstone bridge.

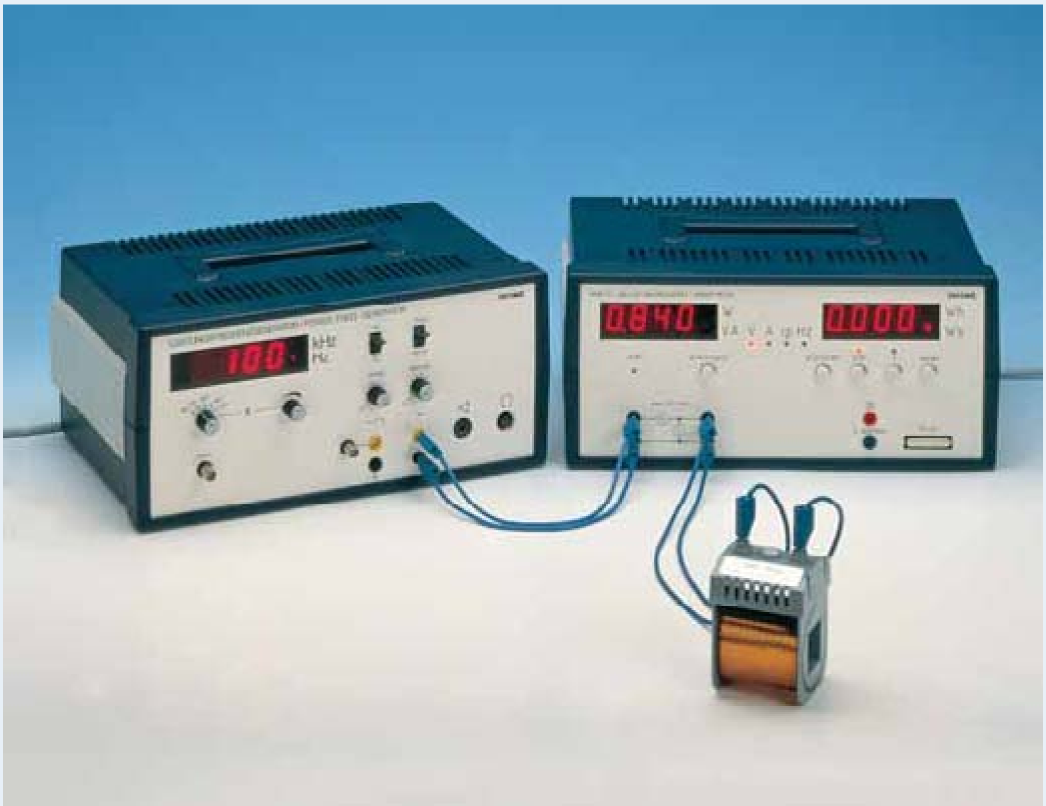
Tasks:

To determine

1. ohmic resistances
2. inductances
3. capacitances

with the Wheatstone bridge, using bridge balancing.

4.4.11-00 Resistance, phase shift and power in AC circuits



What you can learn about ...

- → Impedance
- → Phase shift
- → Phasor diagram
- → Capacitance
- → Self-inductance

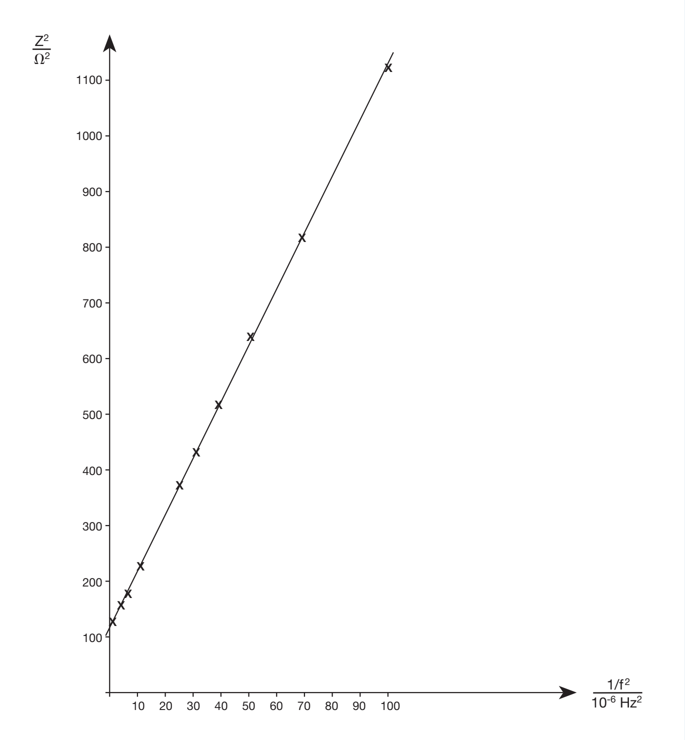
Principle:

Series circuits containing self-inductances or capacitances and ohmic resistances are investigated as a function of frequency. Measuring the electrical magnitudes with a work or power measurement instrument, real power or apparent power can be displayed directly.

What you need:

Work and power meter	13715.93	1
Power frequency generator, 1 MHz	13650.93	1
Coil, 300 turns	06513.01	1
Connection box	06030.23	1
Electrolyte capacitors non-polarised, G1, 47 µF	39105.45	1
Carbon resistor 10 Ohm, 1W, G1	39104.01	1
Connecting cable, 4 mm plug, 32 A, black, l = 50 cm	07361.05	4

Complete Equipment Set, Manual on CD-ROM included
Resistance, phase shift and power in AC circuits P2441100



Capacitor and resistor in series, Z^2 as a function of $1/f^2$.

Tasks:

1. Series circuit of self-inductance and resistor (real coil)
   - Investigation of impedance and phase shift as a function of frequency
   - Investigation of the relation between real power and current intensity
   - Determination of self-inductance and ohmic resistance
2. Series circuit of capacitor and resistor
   - Investigation of impedance and phase shift as a function of frequency
   - Investigation of the relation between real power and current intensity
   - Determination of capacitance and ohmic resistance

Induction impulse 4.4.12-11

What you can learn about …

- → Law of induction
- → Magnetic flux
- → Maxwell's equations

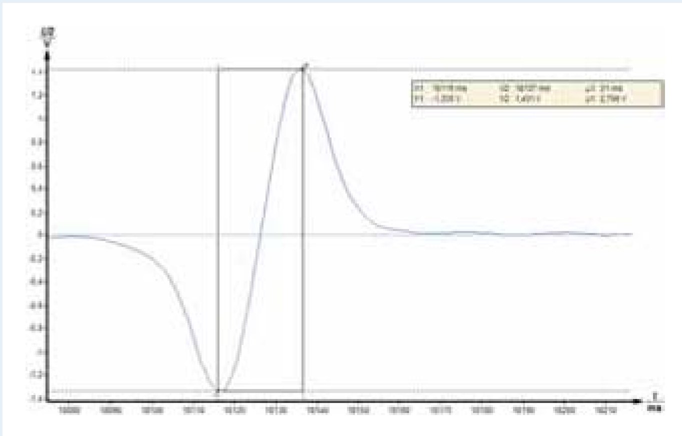
Principle:

A permanent magnet falls with different velocities through a coil. The change in the magnetic flux Φ generates an induced voltage impulse. The induced voltage impulse U_{ss} is recorded with a computer interface system. Depending on the polarity of the permanent magnet the induced voltage impulse is negative or positive.

What you need:

Cobra3 Basic-Unit, USB	12150.50	1
Power supply 12V/2A	12151.99	1
Software Cobra3 Universal recorder	14504.61	1
Light barrier, compact	11207.20	1
Support rod, stainless steel 18/8, l = 600 mm	02037.00	1
Bosshead	02043.00	3
Tripod base -PASS-	02002.55	1
Universal clamp	37718.00	1
Glass tubes, AR-glass, d = 12 mm, l = 300 mm	45126.01	1
Coil holder	06528.00	1
Coil, 600 turns, short	06522.01	1
Magnet, d = 8 mm, l = 60 mm	06317.00	1
Connecting cable, 4 mm plug, 32 A, red, l = 50 cm	07361.01	2
Connecting cable, 4 mm plug, 32 A, blue, l = 50 cm	07361.04	2
Connecting cable, 4 mm plug, 32 A, yellow, l = 50 cm	07361.02	2
PC, Windows® XP or higher		

Complete Equipment Set, Manual on CD-ROM included
Induction impulse P2441211



Measured induction voltage U_{ss} versus time. Additionally the evaluation of the peak-to-peak voltage U_{ss} = 2.766 V is shown.

Tasks:

1. Measurement of the induced voltage impulse U_{ss} and the falling magnet's velocity.
2. Evaluation of the induced voltage impulse U_{ss} as a function of the magnet's velocity.
3. Calculation of the magnetic flux induced by the falling magnet as a function of the magnet's velocity.

4.5.02-00 Coupled oscillating circuits

What you can learn about …

- → Resonance
- → Q factor
- → Dissipation factor
- → Band width
- → Critical or optimum coupling
- → Characteristic impedance
- → Pauli method
- → Parallel conductance
- → Band-pass filter
- → Sweep

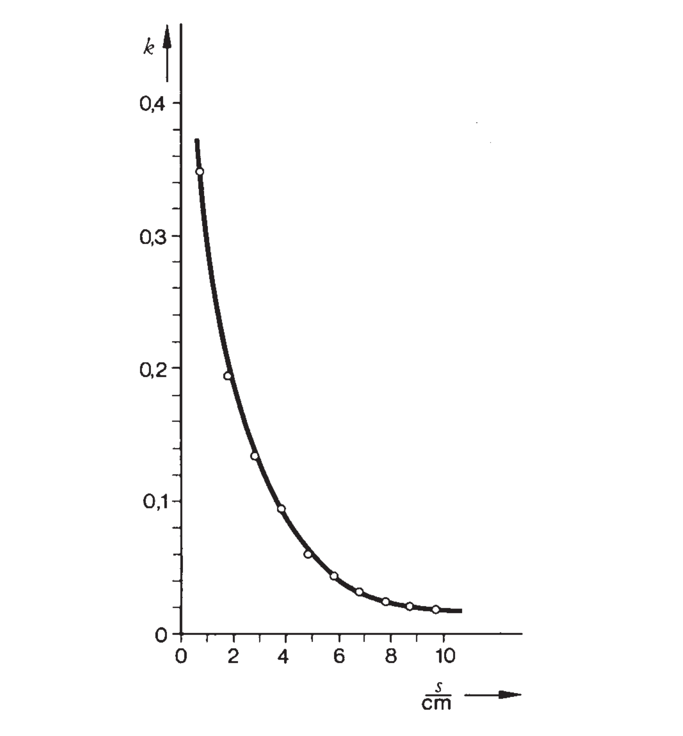
Principle:

The Q fac tor of oscillating circuits is determined from the band width and by the Pauli method. In inductively coupled circuits (band-pass filters) the coupling factor is determined as a function of the coil spacing.

What you need:

Wobble-functiongenerator 20 MHz	11768.99	1
Oscilloscope 30 MHz, 2 channels	11459.95	1
HF coils, 35 turns; 75 µH	06915.00	2
HF coils, 50 turns, 150 µH	06916.00	2
HF coils, 75 turns, 350 µH	06917.00	2
Coil, 150 turns, short	06520.01	1
Variable capacitor, Casing G3	06049.10	2
Carbon resistor 22 kΩ, 1W, G1	39104.34	1
Carbon resistor 47 kΩ, 1W, G1	39104.38	1
Carbon resistor 100 kΩ, 1W, G1	39104.41	1
Carbon resistor 1 MΩ, 1W, G1	39104.52	2
Carbon resistor G1, 82 kΩ, 1 W	39104.40	1
Capacitor 470 pF/100 V, G2	39105.07	1
Connecting plug white 19 mm pitch	39170.00	7
Connection box	06030.23	2
G-clamp	02014.00	2
Meter Scale, l = 1000 x 27 mm	03001.00	1
Adapter BNC socket/4 mm plug pair	07542.27	2
Connecting cable, 4 mm plug, 32 A, yellow, l = 25 cm	07360.02	2
Screened cable, BNC, l = 750 mm	07542.11	2
Screened cable, BNC, l = 1500 mm	07542.12	1

Complete Equipment Set, Manual on CD-ROM included
Coupled oscillating circuits P2450200



Coupling constant k as a function of the distance s be tween the coils when the coupling is supercritical.

Tasks:

1. To determine the dissipation factor tan δ_k and the quality factor Q from the band width of oscillating circuits.
2. To determine the dissipation factor and Q factor of oscillating circuits from the resonant frequency (ω_0), the capacitance C_{tot} and the parallel conductance G_p determined by the Pauli method.
3. To determine the coupling factor k and the band width Δ_f of a band-pass filter as a function of the coil spacing s.

Interference of microwaves 4.5.04-00

What you can learn about …

- → Wavelength
- → Standing wave
- → Reflection
- → Transmission
- → Michelson interferometer

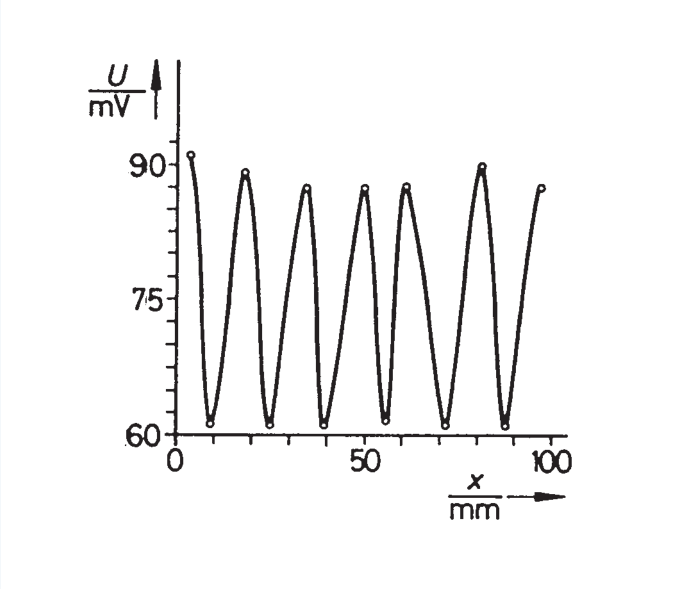
Principle:

A microwave beam, after reflection from a metal screen or glass plate, interferes with the primary waves. The wavelength is determined from the resultant standing waves.

What you need:

Microwave transmitter with clystron	11740.01	1
Microwave receiver	11740.02	1
Microwave receiving dipole	11740.03	1
Microwave power supply, 220 VAC	11740.93	1
Protractor scale with pointer	08218.00	1
Glass plate, clear glass, 200 x 300 x 4 mm	08204.00	2
Screen, metal, 300 mm x 300 mm	08062.00	2
Plate holder, opening width 0...10 mm	02062.00	3
G-clamp	02014.00	2
Meter Scale, l = 1000 x 27 mm	03001.00	2
Tripod base -PASS-	02002.55	1
Barrel base -PASS-	02006.55	4
Support rod -PASS-, square, l = 250 mm	02025.55	1
Right angle clamp -PASS-	02040.55	1
Multi-range meter with amplifier	07042.00	1
Adapter, BNC plug/4 mm socket	07542.26	1
Connecting cable, 4 mm plug, 32 A, red, l = 75 cm	07362.01	1
Connecting cable, 4 mm plug, 32 A, blue, l = 75 cm	07362.04	1

Complete Equipment Set, Manual on CD-ROM included
Interference of microwaves P2450400



Intensity distribution during interference of microwaves in the Michelson arrangement, as a function of the position of the reflection screens.

Tasks:

Measurement of the wavelength of microwaves through the production of standing waves with

1. reflection at the metal screen,
2. plane-parallel plate,
3. the Michelson interferometer.

4.5.05-00 Diffraction of microwaves

What you can learn about …

- Fresnel zones
- Huygens' principle
- Fraunhofer diffraction
- Diffraction at the slit

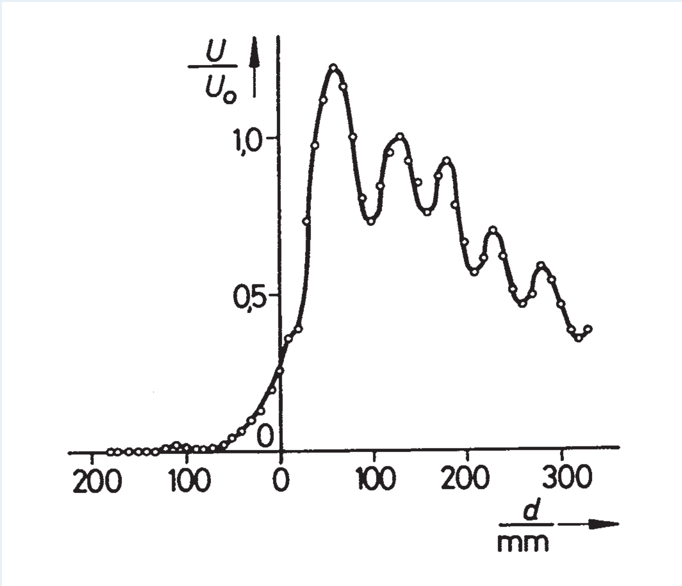
Principle:

Microwaves impinge on a slit and the edge of a screen. The diffraction pattern is determined on the basis of diffraction at these obstacles.

What you need:

Microwave transmitter with clystron	11740.01	1
Microwave receiving dipole	11740.03	1
Microwave power supply, 220 VAC	11740.93	1
Screen, metal, 300 mm x 300 mm	08062.00	2
Multi-range meter with amplifier	07042.00	1
Measuring tape, l = 2 m	09936.00	1
Meter Scale, l = 1000 x 27 mm	03001.00	2
Tripod base -PASS-	02002.55	1
Barrel base -PASS-	02006.55	3
Right angle clamp -PASS-	02040.55	1
Support rod -PASS-, square, l = 250 mm	02025.55	1
G-clamp	02014.00	2
Adapter, BNC plug/4 mm socket	07542.26	1
Connecting cable, 4 mm plug, 32 A, red, l = 50 cm	07361.01	1
Connecting cable, 4 mm plug, 32 A, blue, l = 50 cm	07361.04	1

Complete Equipment Set, Manual on CD-ROM included
Diffraction of microwaves P2450500



Intensity distribution in the diffraction of the microwaves at the edge of a screen, parallel to the plane of the screen.

Tasks:

Determination of the diffraction pattern of the microwave intensity

1. behind the edge of a screen,
2. after passing through a slit,
3. behind a slit of variable width, with a fixed receiving point.

Diffraction and polarization of microwaves 4.5.06-00

What you can learn about ...

- → Diffraction
- → Focal point
- → Linearity
- → Circularly and elliptically polarized waves
- → Transverse waves
- → Polarizer and Analyzer
- → Constructive and destructive interference

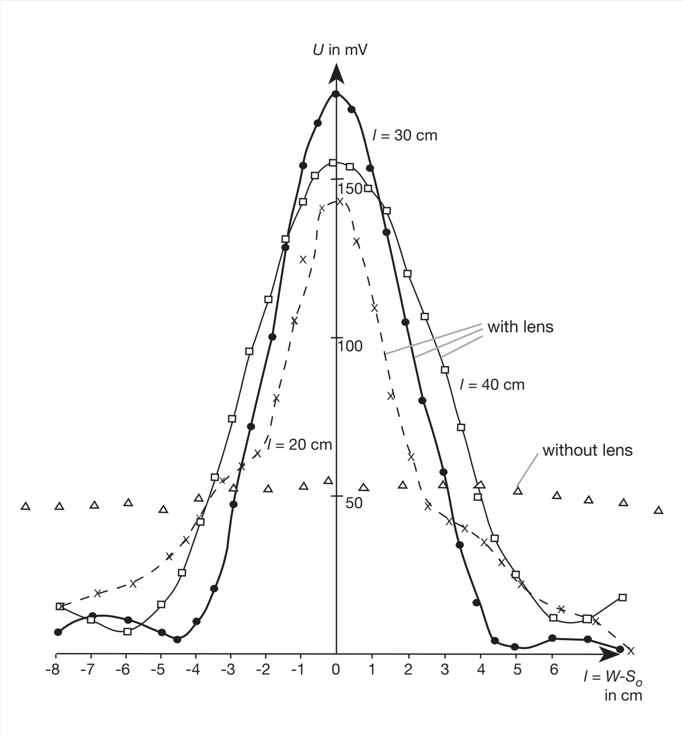
Principle:

The equivalence between visible light and microwaves as special cases of the total spectrum of electromagnetic waves can be demonstrated using diffraction and polarization of microwaves as an example. The focusing of microwaves through a plane convex convergent lens is observed and the focal distance of the lens is determined. After that, polarizability of micro waves is demonstrated by means of a metallic grating.

What you need:

Microwave transmitter with clystron	11740.01	1
Microwave receiving dipole	11740.03	1
Microwave power supply, 220 VAC	11740.93	1
Universal measuring amplifier	13626.93	1
Polarisation grid	06866.00	1
Convergent lens, synthetic resin	06872.00	1
Protractor scale with pointer	08218.00	1
Voltmeter 0.3...300 V-, 10...300 V~	07035.00	1
Screened cable, BNC, l = 1500 mm	07542.12	1
Connecting cable, 4 mm plug, 32 A, red, l = 50 cm	07361.01	1
Connecting cable, 4 mm plug, 32 A, blue, l = 50 cm	07361.04	1
Connecting cable, 4 mm plug, 32 A, red, l = 200 cm	07365.01	1
Connecting cable, 4 mm plug, 32 A, blue, l = 200 cm	07365.04	1
Adapter BNC socket/4 mm plug pair	07542.27	1
Tripod base -PASS-	02002.55	1
Barrel base -PASS-	02006.55	1
H-base -PASS-	02009.55	1
Bench clamp -PASS-	02010.00	2
Support rod -PASS-, square, l = 250 mm	02025.55	1
Support rod -PASS-, square, l = 630 mm	02027.55	4
Right angle clamp -PASS-	02040.55	4
Stand tube	02060.00	1
Meter Scale, l = 1000 x 27 mm	03001.00	1

Complete Equipment Set, Manual on CD-ROM included
Diffraction and polarization of microwaves P2450600



Profile of the intensity of radiation.

Tasks:

1. Measuring the irradiance of the microwave field behind a converging lens
   – along the optical axis
   – transversally to the optical axis.

Determination of the focal length of a synthetic resin converging lens and comparison of the results with the distribution of irradiance when no lens is used.

2. Measurement of the irradiance transmitted through a metal grating as a function of the angle between the direction of polarization and the grating bars.

4.5.08-00 Radiation field of a horn antenna / Microwaves

What you can learn about …

- ➔ Horn antenna
- ➔ Directional characteristic pattern
- ➔ Directivity
- ➔ Law of distance
- ➔ Phase center

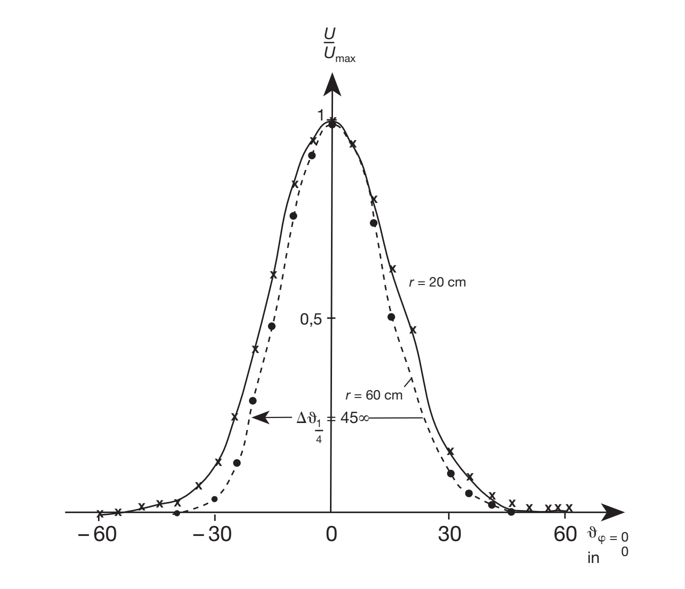
Principle:

The directional characteristic of a horn antenna is received in two perpendicular planes by means of a receiving dipole. The law of distance for the antenna is verified.

What you need:

Microwave transmitter with clystron	11740.01	1
Microwave receiver	11740.02	1
Microwave power supply, 220 VAC	11740.93	1
Tripod base -PASS-	02002.55	1
Barrel base -PASS-	02006.55	1
Support rod -PASS-, square, l = 250 mm	02025.55	3
Support rod -PASS-, square, l = 400 mm	02026.55	1
Support rod -PASS-, square, l = 1000 mm	02028.55	1
Right angle clamp -PASS-	02040.55	5
Articulated radial holder	02053.01	1
Graduated disk, for demonstration	02053.02	1
Digital multimeter 2010	07128.00	1
Screened cable, BNC, l = 1500 mm	07542.12	1
Adapter BNC socket/4 mm plug pair	07542.27	1
Measuring tape, l = 2 m	09936.00	1

Complete Equipment Set, Manual on CD-ROM included
Radiation field of a horn antenna / Microwaves P2450800



Directional characteristic $C_u(\vartheta, \varphi = 0)$ of the horn antenna in the polarization plane for different distances.

Tasks:

1. Measurement of the directional characteristic of the horn antenna in two perpendicular planes and evaluation of the corresponding directivity from the direction al characteristic.
2. Determination of the microwave irradiance I as a function of the distance r between the receiving dipole and the horn antenna, which verifies the validity of the law.

Frustrated total reflection / Microwaves 4.5.09-00

What you can learn about …

- ➔ Transmission
- ➔ Reflection
- ➔ Absorption
- ➔ Refraction
- ➔ Phase velocity
- ➔ Total reflection
- ➔ Surface waves
- ➔ Frustrated total reflection
- ➔ Tunnel effect

Principle:

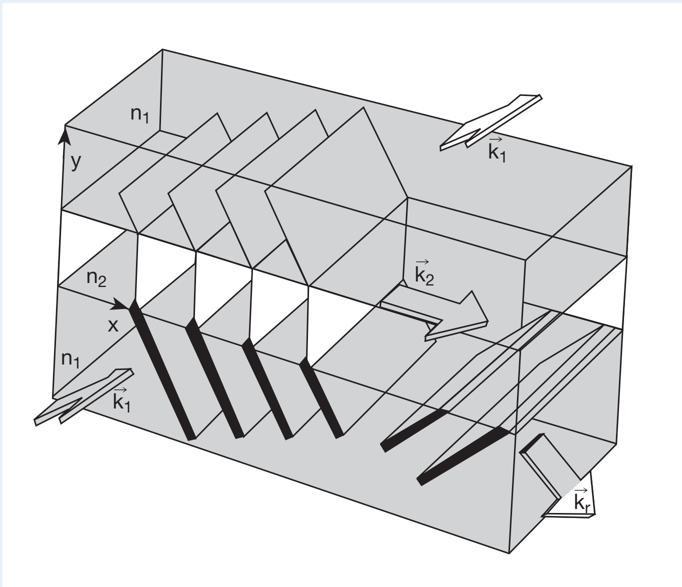
In the first part, the transmission and reflection characteristics of glass, acrylic glass and metal are studied with a microwave transmitter-receiver pair and are compared to each other.

In the second part, total reflection of microwaves on a prismatic surface is suppressed by bringing a second prism with the same refractive index close to the first one.

What you need:

Microwave transmitter with clystron	11740.01	1
Microwave receiver	11740.02	1
Microwave power supply, 220 VAC	11740.93	1
Screen, metal, 300 mm x 300 mm	08062.00	2
Glass plate, clear glass, 200 x 300 x 4 mm	08204.00	1
Plexiglas plate 200 x 200 x 4 mm	11613.00	1
Barrel base -PASS-	02006.55	4
Plate holder, opening width 0...10 mm	02062.00	1
Supporting block 105 x 10 5x 57 mm	02073.00	2
Prism, synthetic resin	06873.00	2
Digital multimeter 2010	07128.00	1
Screened cable, BNC, l = 750 mm	07542.11	1
Adapter BNC socket/4 mm plug pair	07542.27	1
Vernier caliper, plastic	03011.00	1

Complete Equipment Set, Manual on CD-ROM included
Frustrated total reflection / Microwaves P2450900

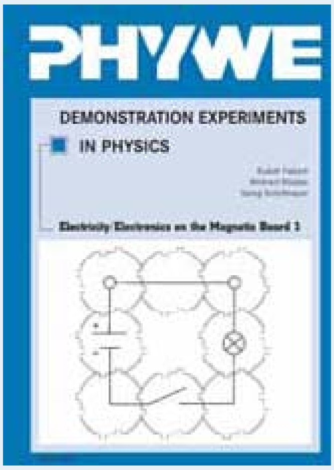


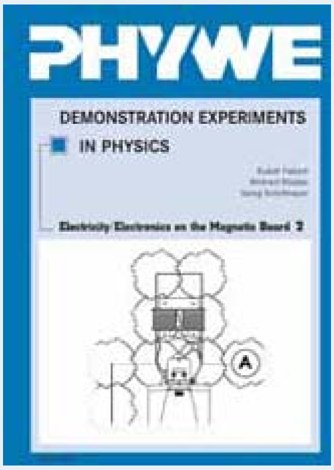
Frustrated total internal reflection.

Tasks:

1. Determination of the reflecting and transmitting characteristics of glass, acrylic glass and metal.
2. Observation of the effect of frustrated total reflection and determination of the transmitted irradiance as a function of distance d to the prismatic surface. The refractive index of the prism material can be calculated by determining the attenuation coefficient γ.

Demonstration Experiments Physics – Electricity/Electronics on the Magnetic Board 1+2





Electricity/Electronics on the Magnetic Board 1 • No. 01001.02

36 described Experiments

Please ask for a complete equipment list Ref. No. 24510

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Measurement of current

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1.5 (13805)
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Electricity/Electronics on the Magnetic Board 2 • No. 01003.02

61 described Experiments

Please ask for a complete equipment list Ref. No. 24511

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The light dependent resistor (LDR)

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18 The operational amplifier and applications

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The generation of oscillations

5

Physical Structure of Matter

5 Physical Structure of Matter

Contents

Elementary charge and Millikan experiment 5.1.01-00

What you can learn about …

- → Electric field
- → Viscosity
- → Stokes' law
- → Droplet method
- → Electron charge

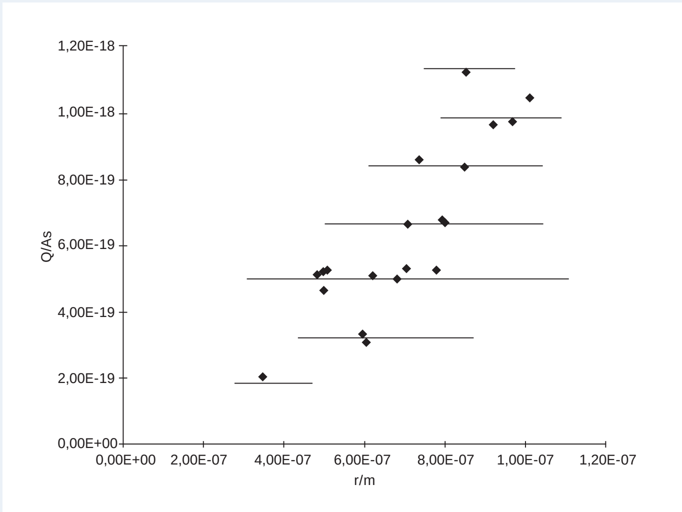
Principle:

Charged oil droplets subjected to an electric field and to gravity between the plates of a capacitor are accelerated by application of a voltage. The elementary charge is determined from the velocities in the direction of gravity and in the opposite direction.

What you need:

Millikan apparatus	09070.00	1
Multi-range meter, with overl. prot.	07021.01	1
Power supply, 0...600 VDC	13672.93	1
Object micrometer 1 mm i.100 parts	62171.19	1
Stopwatch, interruption type	03076.01	2
Cover glasses, 18 x 18 mm, pack of 50 pcs.	64685.00	1
Polarity Switch for Millikan Apparatus	06034.07	1
Tripod base -PASS-	02002.55	1
Stand tube	02060.00	1
Circular level	02122.00	1
Connecting cord, safety, 32 A, 50 cm, red	07336.01	1
Connecting cord, safety, 32 A,100 cm, red	07337.01	2
Connecting cord, safety, 32 A,100 cm, blue	07337.04	2
Connecting cord, 32 A, 750 mm, black	07362.05	2
Connecting cord, 32 A, 750 mm, green-yellow	07362.15	1

Complete Equipment Set, Manual on CD-ROM included
Elementary charge and Millikan experiment P2510100



Measurements on various droplets for determining the elementary charge by the Millikan method.

Tasks:

1. Measurement of the rise and fall times of oil droplets with various charges at different voltages.
2. Determination of the radii and the charge of the droplets.

5.1.02-00 Specific charge of the electron – e/m

What you can learn about …

- → Cathode rays
- → Lorentz force
- → Electron in crossed fields
- → Electron mass
- → Electron charge

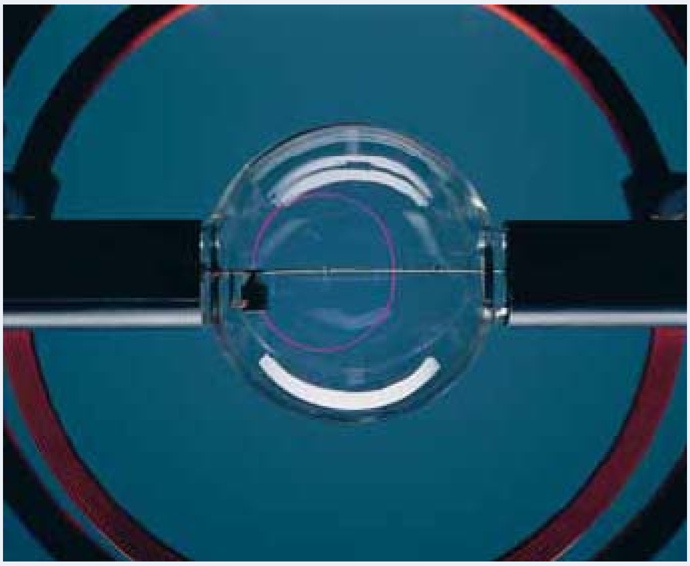
Principle:

Electrons are accelerated in an electric field and enter a magnetic field at right angles to the direction of motion. The specific charge of the electron is determined from the accelerating voltage, the magnetic field strength and the radius of the electron orbit.

What you need:

Narrow beam tube with socket	06959.00	1
Helmholtz coils, one pair	06960.00	1
Power supply, regulated, 0...600 V-	13672.93	1
Power supply, universal	13500.93	1
Digital multimeter 2010	07128.00	2
Connecting cable, 4 mm plug, 32 A, red, l = 10 cm	07359.01	1
Connecting cable, 4 mm plug, 32 A, blue, l = 10 cm	07359.04	1
Connecting cable, 4 mm plug, 32 A, red, l = 75 cm	07362.01	5
Connecting cable, 4 mm plug, 32 A, blue, l = 75 cm	07362.04	3
Connecting cable, 4 mm plug, 32 A, yellow, l = 75 cm	07362.02	3

Complete Equipment Set, Manual on CD-ROM included
Specific charge of the electron – e/m P2510200



Tasks:

Determination of the specific charge of the electron (e/m_0) from the path of an electron beam in crossed electric and magnetic fields of variable strength.

Franck-Hertz experiment with Hg-tube 5.1.03-11

What you can learn about …

- ➔ Energy quantum
- ➔ Electron collision
- ➔ Excitation energy

Principle:

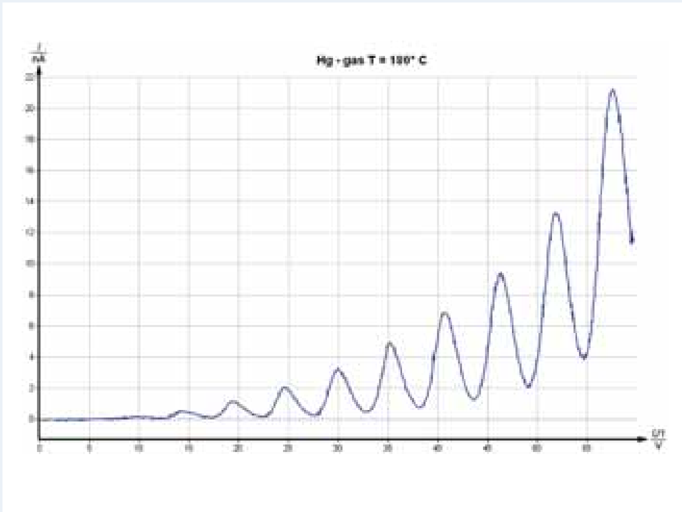
Electrons are accelerated in a tube filled with mercury vapour.

The excitation energy of mercury is determined from the distance between the equidistant minima of the electron current in a variable opposing electric field.

What you need:

Franck-Hertz control unit	09105.99	1
Franck-Hertz Hg-tube on plate	09105.10	1
Franck-Hertz oven for Hg-tube	09105.93	1
Thermocouple NiCr-Ni, sheathed	13615.01	1
Connecting cable for Franck-Hertz Hg-tube	09105.30	1
Screened cable, BNC, l = 750 mm	07542.11	1
Data cable 2 x SUB-D, plug/socket, 9 pole	14602.00	1
Software Measure Franck-Hertz experiment	14522.61	1
PC, Windows® XP or higher		
Optional equipment:		
Oscilloscope, 30 MHz, 2 channels	11459.95	1
Adapter, BNC-socket/4mm plug pair	07542.27	2
Screened cable, BNC, l = 75 cm	07542.11	2

Complete Equipment Set, Manual on CD-ROM included
Franck-Hertz experiment with Hg-tube P2510311



Example of a Franck-Hertz curve for Hg-gas recorded with T = 180°C.

Tasks:

1. Record the counter current strength I_S in a Franck-Hertz tube as a function of the anode voltage U_a.
2. To determine the excitation energy E_a from the positions of the current strength minima or maxima by difference formation.

5.1.03-15 Franck-Hertz experiment with Ne-tube

What you can learn about …

- ➔ Energy quantum
- ➔ Quantum leap
- ➔ Electron collision
- ➔ Excitation energy

Principle:

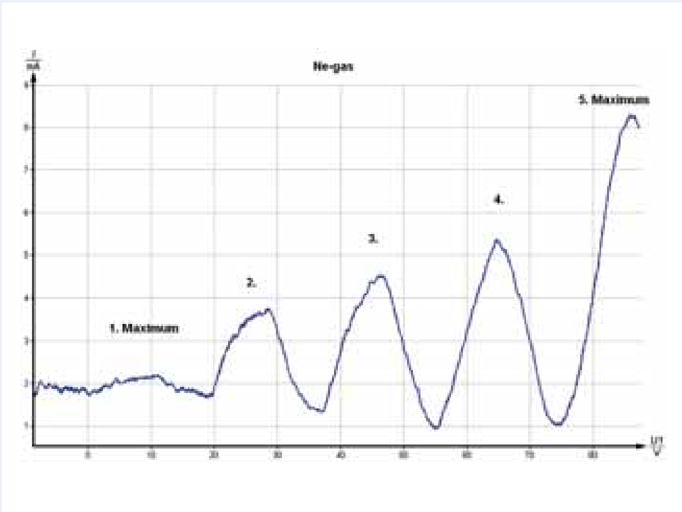
Electrons are accelerated in a tube filled with neon vapour.

The excitation energy of neon is determined from the distance between the equidistant minima of the electron current in a variable opposing electric field.

What you need:

Franck-Hertz control unit	09105.99	1
Franck-Hertz Ne-tube with housing	09105.40	1
Connecting cable for Franck-Hertz Ne-tube	09105.50	1
Screened cable, BNC, *l* = 750 mm	07542.11	1
Data cable 2 x SUB-D, plug/socket, 9 pole	14602.00	1
Software Measure Franck-Hertz experiment	14522.61	1
PC, Windows® XP or higher		
Optional equipment:		
Oscilloscope, 30 MHz, 2 channels	11459.95	1
Adapter, BNC-socket/4mm plug pair	07542.27	2
Screened cable, BNC, *l* = 75 cm	07542.11	2

Complete Equipment Set, Manual on CD-ROM included
Franck-Hertz experiment with Ne-tube P2510315



Example of a Franck-Hertz curve for Ne-gas.

Tasks:

1. Record the counter current strength I_S in a Franck-Hertz tube as a function of the anode voltage U_a.
2. To determine the excitation energy E_a from the positions of the current strength minima or maxima by difference formation.

Planck's "quantum of action" from the photoelectric effect (line separation by interference filters)

5.1.04-01/05

Set-up of experiment P2510405 with electrometer

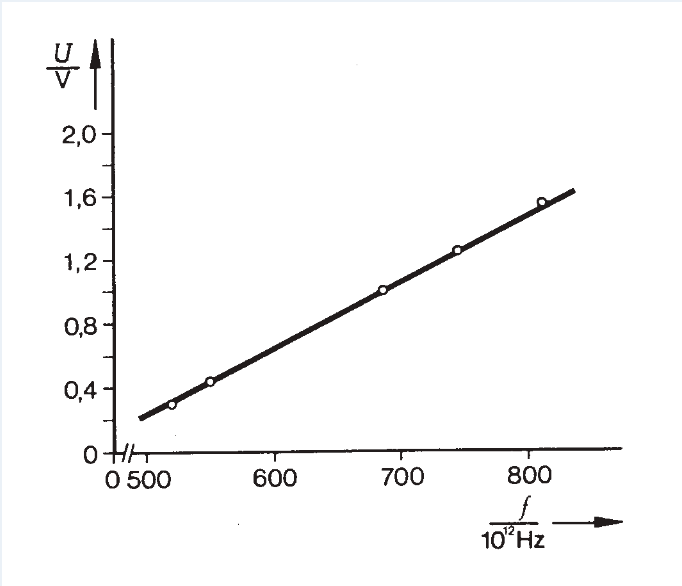
What you can learn about …
- → External photoelectric effect
- → Work function
- → Absorption
- → Photon energy
- → Anode
- → Cathode

Principle:
A photo-cell is illuminated with light of different wavelengths. Planck's quantum of action, or Planck's constant (h), is determined from the photoelectric voltages measured.

What you need:

		Experiment P2510401 with amplifier	Experiment P2510405 with electrometer
Photocell, for h detection, with housing	06778.00	1	1
Interference filters, set of 3	08461.00	1	1
Interference filters, set of 2	08463.00	1	1
Experiment lamp 6	11615.05	1	1
Spectral lamp Hg 100, pico 9 base	08120.14	1	1
Power supply for spectral lamps	13662.97	1	1
Universal measuring amplifier	13626.93	1	
Digital multimeter 2010	07128.00	1	1
Screened cable, BNC, l = 30 cm	07542.10	1	1
Connecting cable, 4 mm plug, 32 A, red, l = 25 cm	07360.01	1	1
Connecting cable, 4 mm plug, 32 A, blue, l = 25 cm	07360.04	1	2
Electrometer Amplifier	13621.00		1
Adapter BNC socket/4 mm plug pair	07542.27		1
Power supply 12V AC/500 mA	11074.93		1

Complete Equipment Set, Manual on CD-ROM included
Planck's "quantum of action" from the photoelectric effect (line separation by interference filters) **P25104 01/05**



Voltage of the photo-cell as a function of the frequency of the irradiated light.

Tasks:
To determine Planck's quantum of action from the photoelectric voltages measured at different wavelengths.

5.1.05-01/05 Planck's "quantum of action" from the photoelectric effect
(line separation by defraction grating)

Set-up of experiment P2510501 with amplifier

What you can learn about …

- ➔ External photoelectric effect
- ➔ Work function
- ➔ Adsorption
- ➔ Photon energy

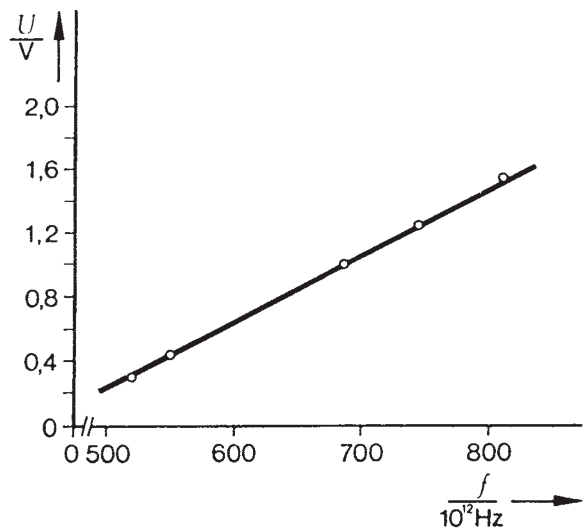
Principle:

A photocell is illuminated with monochromatic light of different wavelengths. Planck's quantum of action, or Planck's constant h, is determined from the photoelectric voltages measured.

What you need:

		Experiment P2510501 with amplifier	Experiment P2510505 with electrometer
Photocell, for h detection, with housing	06778.00	1	1
Diffraction grating, 600 lines/mm	08546.00	1	1
Colour filter, 580 nm	08415.00	1	1
Colour filter, 525 nm	08414.00	1	1
Diaphragm holder, attachable	11604.09	2	2
Slit, adjustable	08049.00	1	1
Lens holder	08012.00	2	2
Lens, mounted, f = +100 mm	08021.01	1	1
Mercury vapour high pressure lamp, 80 W	08147.00	1	1
Screened cable, BNC, l = 30 cm	07542.10	1	1
Connecting cable, 4 mm plug, 32 A, red, l = 25 cm	07360.01	1	1
Connecting cable, 4 mm plug, 32 A, blue, l = 25 cm	07360.04	1	1
Lamp socket E 27 on stem	06176.00	1	1
Power supply for spectral lamps	13662.97	1	1
Universal measuring amplifier	13626.93	1	
Digital multimeter 2010	07128.00	1	1
Optical profile bench, l = 600 mm	08283.00	2	2
Base for optical profile bench, adjustable	08284.00	3	3
Turning knuckle for optical profile bench	08285.00	1	1
Slide mount for optical profil bench, h = 80 mm	08286.02	4	4
Electrometer Amplifier	13621.00		1
Adapter BNC socket/4 mm plug pair	07542.27		1
Power supply 12V AC/500 mA	11074.93		1

Complete Equipment Set, Manual on CD-ROM included
Planck's "quantum of action" from the photoelectric effect (line separation by defraction grating) **P25105 01/05**



Voltage of the photo-cell as a function of the frequency of the irradiated light.

Fine structure, one-electron and two-electron spectra 5.1.06-00

What you can learn about …

- Diffraction spectrometer
- Spin
- Angular momentum
- Spin-orbital angular momentum interaction
- Multiplicity
- Energy level
- Excitation energy
- Selection rules
- Doublets
- Parahelium
- Orthohelium
- Exchange energy
- Angular momentum
- Singlet and triplet series
- Selection rules
- Forbidden transition

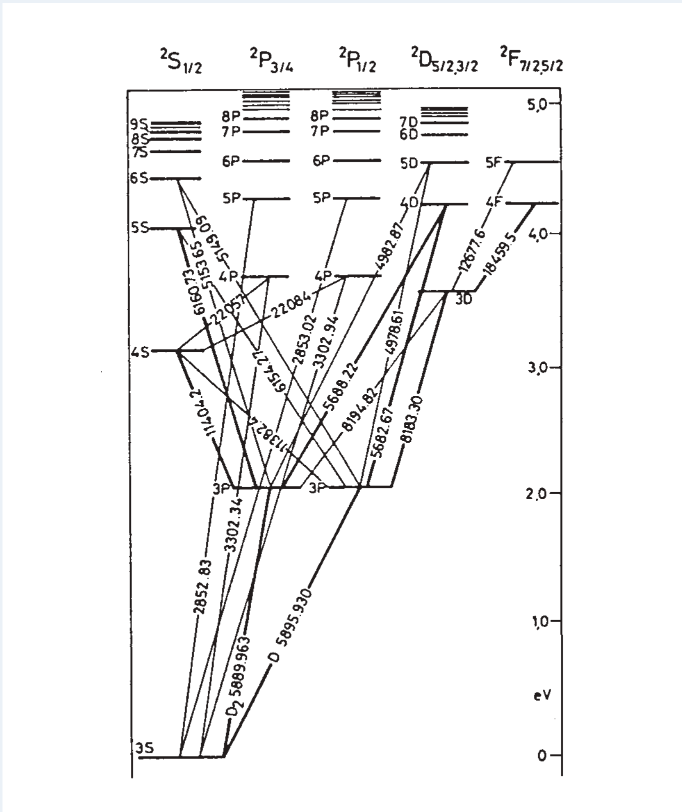
Principle:

The well-known spectral lines of He are used for calibrating the diffraction spectrometer. The wave-lengths of the spectral lines of Na, Hg, Cd and Zn are determined using the spectrometer.

What you need:

Spectrometer/goniometer with verniers	35635.02	1
Diffraction grating, 600 lines/mm	08546.00	1
Spectral lamp He, pico 9 base	08120.03	1
Spectral lamp Na, pico 9 base	08120.07	1
Spectral lamp Hg 100, pico 9 base	08120.14	1
Spectral lamp Cd, pico 9 base	08120.01	1
Spectral lamp Zn, pico 9 base	08120.11	1
Power supply for spectral lamps	13662.97	1
Lamp holder, pico 9, for spectral lamps	08119.00	1
Tripod base -PASS-	02002.55	1

Complete Equipment Set, Manual on CD-ROM included
Fine structure, one-electron and two-electron spectra P2510600



Spectrum of sodium.

Tasks:

1. Calibration of the spectrometer using the He spectrum, and the determination of the constant of the grating;
2. Determination of the spectrum of Na;
3. Determination of the fine structure splitting.
4. Determination of the most intense spectral lines of Hg, Cd and Zn.

5.1.07-00 Balmer series / Determination of Rydberg's constant

What you can learn about …

- Diffraction image of a diffraction grating
- Visible spectral range
- Single electron atom
- Atomic model according to Bohr
- Lyman-, Paschen-, Brackett- and Pfund-Series
- Energy level
- Planck's constant
- Binding energy

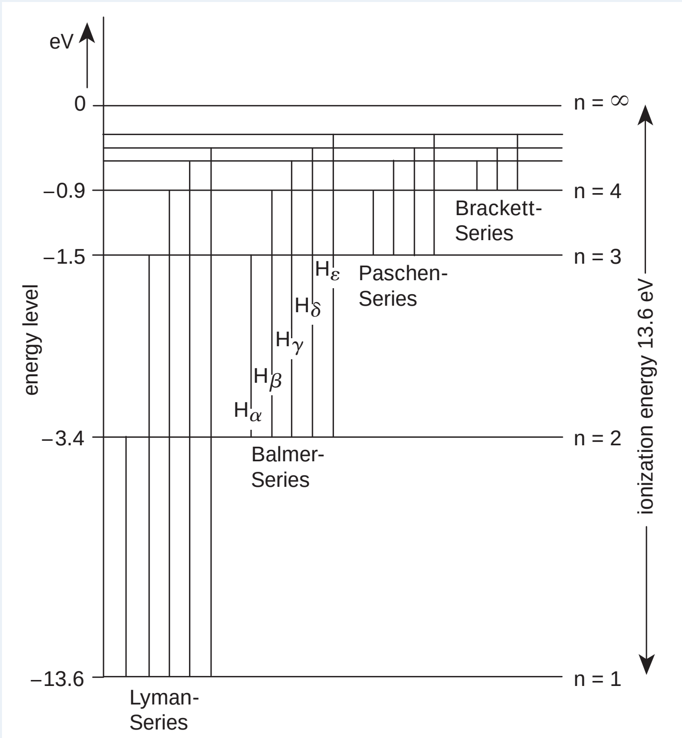
Principle:

The spectral lines of hydrogen and mercury are examined by means of a diffraction grating. The known spectral lines of Hg are used to determine the grating constant. The wave lengths of the visible lines of the Balmer series of H are measured.

What you need:

Spectral tube, H2	06665.00	1
Spectral tube, Hg	06664.00	1
Holders for spectral tubes, 1 pair	06674.00	1
Cover tube for spectral tubes	06675.00	1
Connecting cable, 30 kV, l = 1000 mm	07367.00	2
Object holder 50 mm x 50 mm	08041.00	1
Diffraction grating, 600 lines/mm	08546.00	1
High voltage supply 0...10 kV	13670.93	1
Insulating support	06020.00	2
Tripod base -PASS-	02002.55	1
Barrel base -PASS-	02006.55	1
Support rod -PASS-, square, l = 400 mm	02026.55	1
Right angle clamp -PASS-	02040.55	3
Stand tube	02060.00	1
Meter Scale, l = 1000 x 27 mm	03001.00	1
Cursor for scale, 2 pieces, plastic, red	02201.00	1
Measuring tape, l = 2 m	09936.00	1

Complete Equipment Set, Manual on CD-ROM included
Balmer series / Determination of Rydberg's constant P2510700



Energy level diagram of the H atom.

Tasks:

1. Determination of the diffraction grating constant by means of the Hg spectrum.
2. Determination of the visible lines of the Balmer series in the H spectrum, of Rydberg's constant and of the energy levels.

Atomic spectra of two-electron systems: He, Hg 5.1.08-00

What you can learn about …

- ➔ Parahelium
- ➔ Orthohelium
- ➔ Exchange energy
- ➔ Spin
- ➔ Angular momentum
- ➔ Spinorbit interaction
- ➔ Singlet and triplet series
- ➔ Multiplicity
- ➔ Rydberg series
- ➔ Selection rules
- ➔ Forbidden transition
- ➔ Metastable state
- ➔ Energy level
- ➔ Excitation energy

Principle:

The spectral lines of He and Hg are examined by means of a diffraction grating. The wavelengths of the lines are determined from the geometrical arrangement and the diffraction grating constants.

What you need:

Spectral tube, Hg	06664.00	1
Spectral tube, He	06668.00	1
Holders for spectral tubes, 1 pair	06674.00	1
Cover tube for spectral tubes	06675.00	1
Connecting cable, 30 kV, l = 1000 mm	07367.00	2
Object holder 50 mm x 50 mm	08041.00	1
Diffraction grating, 600 lines/mm	08546.00	1
High voltage supply 0...10 kV	13670.93	1
Insulating support	06020.00	2
Tripod base -PASS-	02002.55	1
Barrel base -PASS-	02006.55	1
Support rod -PASS-, square, l = 400 mm	02026.55	1
Right angle clamp -PASS-	02040.55	3
Stand tube	02060.00	1
Meter Scale, l = 1000 x 27 mm	03001.00	1
Cursor for scale, 2 pieces, plastic, red	02201.00	1
Measuring tape, l = 2 m	09936.00	1

Complete Equipment Set, Manual on CD-ROM included
Atomic spectra of two-electron systems: He, Hg P2510800

Colour	λ/nm	Transition
red	665 ± 2	3 ^{1}D R 2 ^{1}P
yellow-orange	586 ± 2	3 ^{3}D R 2 ^{3}P
green	501 ± 2	3 ^{1}D R 2 ^{1}P
blue-green	490 ± 2	4 ^{1}D R 2 ^{1}P
blue	470 ± 3	4 ^{3}S R 2 ^{3}P
violet	445 ± 1	4 ^{3}D R 2 ^{3}P

Colour	λ/nm	Transition
yellow	581 ± 1	{ 6 ^{1}D1 R 6 ^{1}P1 6 ^{3}D1 R 6 ^{1}P1
green	550 ± 1	7 ^{3}S1 R 6 ^{3}P1
green	494 ± 2	8 ^{1}S1 R 6 ^{1}P1
blue	437 ± 2	7 ^{1}S R 6 ^{1}P1

Measured spectral lines of He/Hg and the corresponding energy-level transitions.

Tasks:

1. Determination of the wavelengths of the most intense spectral lines of He.
2. Determination of the wavelengths of the most intense spectral lines of Hg.

5.1.10-05/07 Zeeman effect / normal and anomalous version

What you can learn about …

- ➔ Bohr's atomic model
- ➔ Quantisation of energy levels
- ➔ Electron spin
- ➔ Bohr's magneton
- ➔ Interference of electromagnetic waves
- ➔ Fabry-Perot interferometer

Principle:

The "Zeeman effect" is the splitting of the spectral lines of atoms within a magnetic field. The simplest is the splitting up of one spectral line into three components called "normal Zeeman effect". Usualy the phenomenon is more complex and the central line splits into many more components. This is the "anomalous Zeeman effect". Both effects can be studied using a cadmium lamp as a specimen. The cadmium lamp is submitted to different magnetic flux densities and the splitting of the red cadmium line (normal Zeeman effect) and that of a green cadmium line (anomalous Zeeman effect) is investigated using a Fabry-Perot interferometer. The evaluation of the results leads to a fairly precise value for Bohr's magneton.

Interference rings with the anomalous Zeeman effect.

Tasks:

1. Using the Fabry-Perot interferometer and a self made telescope the splitting up of the central lines into different lines is measured in wave numbers as a function of the magnetic flux density.
2. From the results of point 1. a value for Bohr's magneton is evaluated.
3. The light emitted within the direction of the magnetic field is qualitatively investigated.

What you need:

Item	Order No.	P2511007 with Magnetic system, variable	P2511005 with Electromagnet
Fabry-Perot interferometer	09050.02	1	1
Cadmium lamp for Zeeman effect	09050.20	1	1
Electromagnet w/o pole shoes	06480.01		1
Pole pieces, drilled, conical	06480.03		1
Rot.table for heavy loads	02077.00		1
Magnetic System, variable	06327.00	1	
Power supply for spectral lamps	13662.97	1	1
Variable transformer 25 V~/20 V-, 12 A	13531.93		1
Capacitor, electrolyte, 22000 mic-F	06211.00		1
Digital multimeter 2010	07128.00		1
Optical profile-bench, l = 1000mm	08282.00	1	1
Base for optical profile-bench, adjustable	08284.00	2	2
Slide mount for optical bench, h = 30 mm	08286.01	6	5
Slide mount for optical profil-bench, h = 80 mm	08286.02	2	2
Lens holder	08012.00	4	4
Lens, mounted, f = +50 mm	08020.01	2	2
Lens, mounted, f = +300 mm	08023.01	1	1
Iris diaphragm	08045.00	1	1
Polarising filter, on stem	08610.00	1	1
Polarization specimen, mica	08664.00	1	1
Connecting cord, 32 A, l = 250 mm, red	07360.01		1
Connecting cord, 32 A, l = 250 mm, blue	07360.04		1
Connecting cord, 32 A, l = 500 mm, red	07361.01		1
Connecting cord, 32 A, l = 500 mm, blue	07361.04		1
Connecting cord, 32 A, l = 750 mm, red	07362.01		1
Connecting cord, 32 A, l = 1000 mm, red	07363.01		1
Connecting cord, 32 A, l = 1000 mm, blue	07363.04		1
CCD camera Moticam 352 for PC, 0.3 megapixels	88037.01	1	1
PC, Windows® XP or higher			

Complete Equipment Set, Manual on CD-ROM included
Zeeman effect P25110 05/07

Stern-Gerlach experiment 5.1.11-01/11

Set-up of experiment P2511111 with PC interface

What you can learn about …

- ➔ Magnetic moment
- ➔ Bohr magneton
- ➔ Directional quantization
- ➔ g-factor
- ➔ Electron spin
- ➔ Atomic beam
- ➔ Maxwellian velocity distribution
- ➔ Two-wire field

Principle:

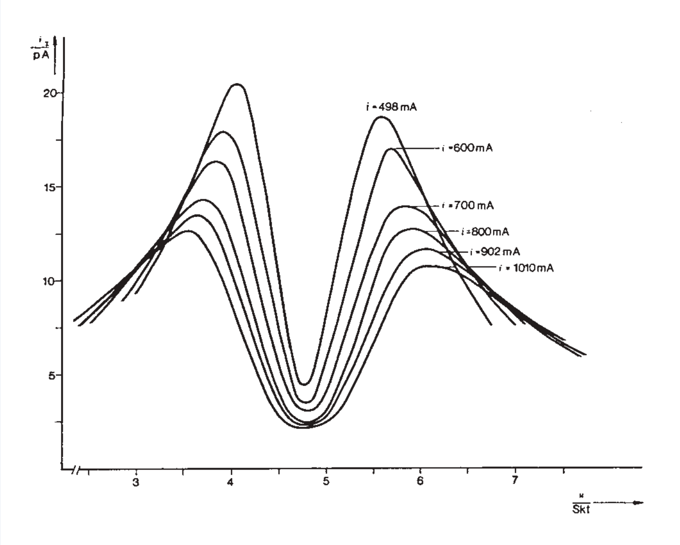
A beam of potassium atoms generated in a hot furnace travels along a specific path in a magnetic two-wire field. Because of the magnetic moment of the potassium atoms, the nonhomogeneity of the field applies a force at right angles to the direction of their motion. The potassium atoms are thereby deflected from their path.

By measuring the density of the beam of particles in a plane of detection lying behind the magnetic field, it is possible to draw conclusions as to the magnitude and direction of the magnetic moment of the potassium atoms.

What you need:

	Order No.	Experiment P2511101 classical	Experiment P2511111 with PC interface
Stern-Gerlach apparatus	09054.88	1	1
Matching transformer	09054.04	1	1
Potassium ampoules, set of 6	09054.05	1	1
High vacuum pump assembly, compact	09059.99	1	1
Electromagnet without pole shoes	06480.01	1	1
Pole piece, plane	06480.02	2	2
Commutator switch	06034.03	1	1
Voltmeter 0.3...300 V-, 10...300 V~	07035.00	2	1
Ammeter, 1 mA...3 A DC/AC	07036.00	2	2
Meter 10/30 mV, 200°C	07019.00	1	1
Storage tray, 413 x 240 x 100 mm	47325.02	1	1
Crystallizing dishes, BORO 3.3., 2300 ml	46246.00	1	1
Isopropyl alcohol, 1000 ml	30092.70	1	1
Direct current measuring amplifier	13620.93	1	1
Variable transformer with rectifier 15 V~/12 V- , 5 A	13530.93	1	1
Power supply 0-12 V DC/ 6 V, 12 V AC	13505.93	2	2
Two tier platform support	02076.03	1	1
Rubber tubing/vacuum, d = 6 mm	39286.00	3	3
Connecting cable, 4 mm plug, 32 A, yellow, l = 25 cm	07360.02	2	2
Connecting cable, 4 mm plug, 32 A, blue, l = 25 cm	07360.04	2	2
Connecting cable, 4 mm plug, 32 A, red, l = 50 cm	07361.01	3	2
Connecting cable, 4 mm plug, 32 A, blue, l = 50 cm	07361.04	2	1
Connect. cable, 4 mm plug, 32 A, green-yellow, l = 50 cm	07361.15	1	1
Connecting cable, 4 mm plug, 32 A, red, l = 75 cm	07362.01	1	1
Connecting cable, 4 mm plug, 32 A, yellow, l = 75 cm	07362.02	3	3
Steel cylinders, nitrogen, 10 l	41763.00	1	1
Pressure-reducing valves, nitrogen	33483.00	1	1
Gas-cylinder Trolley for 10 l	41790.10	1	1
Step motor Stern-Gerlach appartus	09054.06		1
Step motor unit	08087.99		1
Data cable USB, plug type A/B, l = 1.8 m	14608.00		1
Software for stepping motor	14451.61		1
Adapter, BNC-socket/4 mm plug pair	07542.27		1
Screened cable, BNC, l = 1500 mm	07542.12		1
PC, Windows® XP or higher			

Complete Equipment Set, Manual on CD-ROM included
Stern-Gerlach experiment P25111 01/11



Ionization current as a function of position (u) of detector with large excitation currents in the magnetic analyser.

Tasks:

1. Recording the distribution of the particle beam density in the detection plane in the absence of the effective magnetic field.
2. Fitting a curve consisting of a straight line, a parabola, and another straight line, to the experimentally determined special distribution of the particle beam density.
3. Determining the dependence of the particle beam density in the detection plane with different values of the non-homogeneity of the effective magnetic field.
4. Investigating the positions of the maxima of the particle beam density as a function of the non-homogeneity of the magnetic field.

5.1.12-00 Electron spin resonance

What you can learn about …

- ➔ Zeeman effect
- ➔ Energy quantum
- ➔ Quantum number
- ➔ Resonance
- ➔ g-factor
- ➔ Landé factor

Principle:

The g-factor of a DPPH (Diphenyl-pikrylhydrazyl) and the half-width of the absorption line are determined, using the ESR apparatus.

What you need:

ESR resonator with field coils	09050.00	1
ESR power supply	09050.93	1
Power supply, universal	13500.93	1
Oscilloscope 30 MHz, 2 channels	11459.95	1
Digital Mulitmeter	07123.00	1
Screened cable, BNC, l = 750 mm	07542.11	4
Adapter BNC socket/4 mm plug pair	07542.27	1
Connecting cable, 4 mm plug, 32 A, blue, l = 50 cm	07361.04	3
Connecting cable, 4 mm plug, 32 A, red, l = 50 cm	07361.01	2
Connecting cable, 4 mm plug, 32 A, yellow, l = 50 cm	07361.02	2
Teslameter, digital	13610.93	1
Hall probe, tangential, protective cap	13610.02	1

Complete Equipment Set, Manual on CD-ROM included
Electron spin resonance P2511200

Tasks:

With ESR on a DPPH specimen determination of

1. the g-factor of the free electron, and
2. the half-width of the absorption line.

Electron diffraction 5.1.13-00

What you can learn about …

- → Bragg reflection
- → Debye-Scherrer method
- → Lattice planes
- → Graphite structure
- → Material waves
- → De Broglie equation

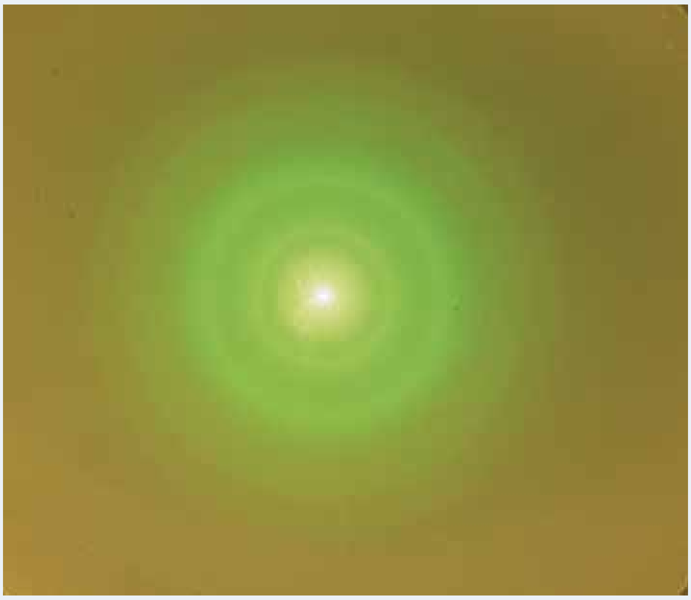
Principle:

Fast electrons are diffracted from a polycrystalline layer of graphite: interference rings appear on a fluorescent screen. The interplanar spacing in graphite is determined from the diameter of the rings and the accelerating voltage.

What you need:

Electron diffraction tube on mounting	06721.00	1
High voltage supply 0...10 kV	13670.93	1
High value resistors, 10 MΩ	07160.00	1
Connecting cable, 30 kV, l = 500 mm	07366.00	1
Power supply, regulated, 0...600 V-	13672.93	1
Vernier caliper, plastic	03011.00	1
Connecting cable, 4 mm plug, 32 A, red, l = 25 cm	07360.01	2
Connecting cable, 4 mm plug, 32 A, blue, l = 25 cm	07360.04	2
Connecting cable, 4 mm plug, 32 A, red, l = 75 cm	07362.01	2
Connecting cable, 4 mm plug, 32 A, yellow, l = 75 cm	07362.02	1
Connecting cable, 4 mm plug, 32 A, blue, l = 75 cm	07362.04	1
Connecting cable, 4 mm plug, 32 A, black, l = 75 cm	07362.05	2

Complete Equipment Set, Manual on CD-ROM included
Electron diffraction P2511300



Tasks:

1. To measure the diameter of the two smallest diffraction rings at different anode voltages.
2. To calculate the wavelength of the electrons from the anode voltages.
3. To determine the interplanar spacing of graphite from the relationship between the radius of the diffraction rings and the wavelength.

5.2.01-01 Half-life and radioactive equilibrium

What you can learn about ...

- ➔ Parent substance
- ➔ Daughter substance
- ➔ Rate of decay
- ➔ Disintegration or decay constant
- ➔ Counting rate
- ➔ Half life
- ➔ Disintegration product

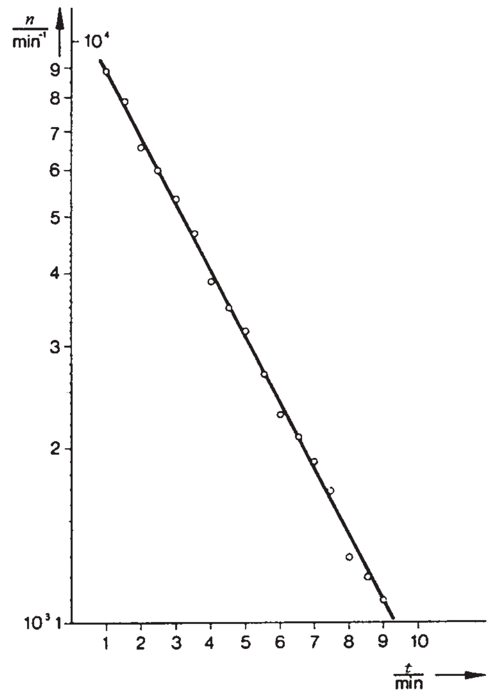
Principle:

The half-life of a Ba-137 m daughter substance eluted (washed) out of a Ca-137 isotope generator is measured directly and is also determined from the increase in activity after elution.

What you need:

Isotope generator Cs-137/ Ba, 370 kBq	09047.60	1
Pulse rate meter	13622.93	1
Digital multimeter 2010	07128.00	1
Counter tube, type A, BNC	09025.11	1
Stopwatch, digital, 1/100 s	03071.01	1
Aluminium, sheet, 1 x 20 x 200 mm, 5 pcs.	31074.00	1
Tripod base -PASS-	02002.55	1
Support rod -PASS-, square, l = 250 mm	02025.55	1
Right angle clamp -PASS-	02040.55	2
Universal clamp	37718.00	2
Beaker, DURAN®, short form, 250 ml	36013.00	2
Test tube, AR-glass, d = 16 mm	37656.10	1
Screened cable, BNC, l = 750 mm	07542.11	1
Connecting cable, 4 mm plug, 32 A, red, l = 50 cm	07361.01	1
Connecting cable, 4 mm plug, 32 A, blue, l = 50 cm	07361.04	1

Complete Equipment Set, Manual on CD-ROM included
Half-line and radioactive equilibrium P2520101



Logarithmic plot of the counting rate of the eluted daughter substance as a function of time.

Tasks:

1. To record the counting rate as a function of the counter tube voltage (counter tube characteristic) when the isotope generator activity is constant (radioactive equilibrium).
2. To measure the activity of the isotope generator as a function of time immediately after elution.
3. To measure the activity of a freshly eluted solution of Ba-137 m as a function of time.

Half-life and radioactive equilibrium with Cobra3 5.2.01-11

What you can learn about …

- → Parent substance
- → Daughter substance
- → Rate of decay
- → Disintegration or decay constant
- → Counting rate
- → Half life
- → Disintegration product

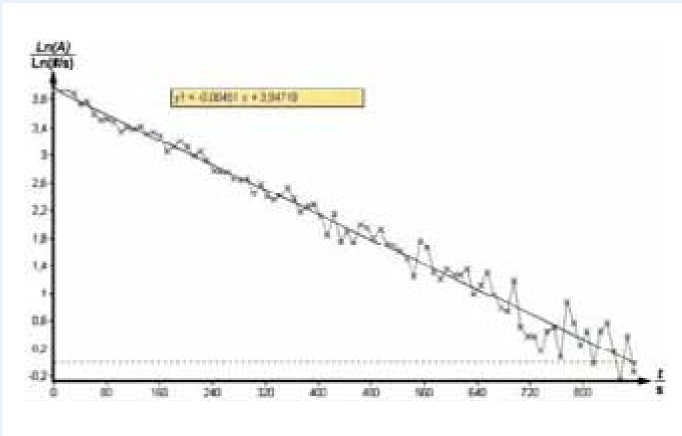
Principle:

The half-life of a Ba-137 m daughter substance eluted (washed) out of a Ca-137 isotope generator is measured directly and is also determined from the increase in activity after elution.

What you need:

Cobra3 Basic-Unit, USB	12150.50	1
Power supply 12V/2A	12151.99	1
Software Cobra3 Radioactivity	14506.61	1
Cobra3 measuring Module GM counting tube	12106.00	1
Base plate for radioactivity	09200.00	1
Counter tube holder on fixing magnet	09201.00	1
Plate holder on fixing magnet	09203.00	1
Source holder on fixing magnet	09202.00	1
Counter tube, type A, BNC	09025.11	1
Screened cable, BNC, l = 750 mm	07542.11	1
Test tube, FIOLAX®, d = 12 mm	36307.10	1
Rubber stopper, d = 14.5/10.5 mm, without hole	39253.00	1
Isotope generator Cs-137/ Ba, 370 kBq	09047.60	1
PC, Windows® XP or higher		

Complete Equipment Set, Manual on CD-ROM included
Half-life and radioactive equilibrium with Cobra3 P2520111



Logarithmic plot of the counting rate of Ba-137m's decay; counting rate as a function of time, with the regression line.

Tasks:

1. To record the counting rate as a function of the counter tube voltage (counter tube characteristic) when the isotope generator activity is constant (radioactive equilibrium).
2. To measure the activity of the isotope generator as a function of time immediately after elution.
3. To measure the activity of a freshly eluted solution of Ba-137 m as a function of time.

5.2.03-11 Poisson's distribution and Gaussian distribution of radioactive decay with Cobra3

– Influence of the dead time of the counter tube

What you can learn about …

- ➔ Poisson's distribution
- ➔ Gaussian distribution
- ➔ Standard deviation
- ➔ Expected value of pulse rate
- ➔ Different symmetries of distributions
- ➔ Dead time
- ➔ Recovering time and resolution time of a counter tube

Principle:

1) The aim of this experiment is to show that the number of pulses counted during identical time intervals by a counter tube which bears a fixed distance to a long-lived radiation emitter correspond to a Poisson's distribution. A special characteristic of the Poisson's distribution can be observed in the case of a small number of counts n < 20: The distribution is unsymmetrical, i.e. the maximum can be found among smaller numbers of pulses than the mean value. In order to show this unsymmetry the experiment is carried out with a short counting period and a sufficiently large gap between the emitter and the counter tube so that the average number of pulses counted becomes sufficiently small.

2) Not only the Poisson's distribution, but also the Guassian distribution which is always symmetrical is very suitable to approximate the pulse distribution measured by means of a long-lived radiation emitter and a counter tube arranged with a constant gap between each other. A premise for this is a sufficiently high number of pulses and a large sampling size.

The purpose of the following experiment is to confirm these facts and to show that the statistical pulse distribution can even be approximated by a Guassian distribution, when (due to the dead time of the counter tube) counting errors occur leading to a distribution which deviates from the Poisson's distribution.

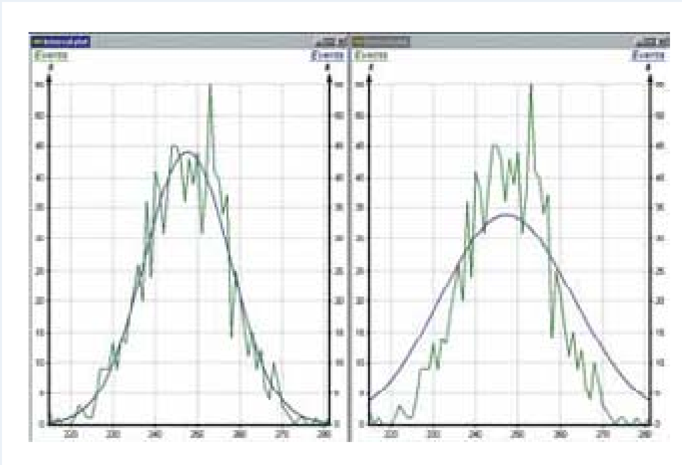
3) If the dead time of the counter tube is no longer small with regard to the average time interval between the counter tube pulses, the fluctuation of the pulses is smaller than in the case of a Poisson's distribution. In order to demonstrate these facts the limiting value of the mean value (expected value) is compared to the limiting value of the variance by means of a sufficiently large sampling size.

What you need:

Counter tube, type A, BNC	09025.11	1
Screened cable, BNC, *l* = 750 mm	07542.11	1
Cobra3 Basic-Unit, USB	12150.50	1
Power supply 12V/2A	12151.99	1
Software Cobra3 Radioactivity	14506.61	1
Cobra3 measuring Module GM counting tube	12106.00	1
Base plate for radioactivity	09200.00	1
Counter tube holder on fixing magnet	09201.00	1
Source holder on fixing magnet	09202.00	1
Plate holder on fixing magnet	09203.00	1
Americium-241 source, 370 kBq	09090.11	1
PC, Windows® XP or higher		

Complete Equipment Set, Manual on CD-ROM included

Poisson's distribution and Gaussian distribution of radioactive decay with Cobra3 – Influence of the dead time of the counter tube P2520311



Pulse rate distribution for high pulse rate (248 pulses/s) with an adapted Gaussian curve (left window) and a Poisson's curve (right window).

Visualisation of radioactive particles / Diffusion cloud chamber 5.2.04-00

What you can learn about …

- → α, β, γ-particles
- → β deflection
- → Ionising particles
- → Mesons
- → Cosmic radiation
- → Radioactive decay
- → Decay series
- → Particle velocity
- → Lorentz force

Principle:

Radioactivity is a subject in our society which has been playing an important role throughout politics, economy and media for many years now. The fact that this radiation cannot be seen or felt by the human being and that the effects of this radiation are still not fully explored yet, causes emotions like no other scientific subject before.

The high-performance diffusion cloud chamber serves for making the tracks of cosmic and terrestrial radiation visible so that a wide range of natural radiation types can be identified. Furthermore, the diffusion cloud chamber offers the opportunity to carry out physical experiments with the aid of artificial radiation sources.

What you need:

Diffusion cloud chamber PJ45, 230 V	09046.93	1
Isopropyl alcohol, 1000 ml	30092.70	2
Thorium-source	09043.41	1
Radioactive source, Sr-90, 74kBq	09047.53	1
Support base -PASS-	02005.55	1
Swinging arm	08256.00	1
Support rod, stainless steel 18/8, l = 250 mm, d = 10 mm	02031.00	1
Right angle clamp -PASS-	02040.55	1
Object holder 50 mm x 50 mm	08041.00	1
Holder for dynamometer	03068.04	1
Scale for demonstration board	02153.00	1
Accessory set for Beta deflection	09043.52	1
Stand tube	02060.00	1

Complete Equipment Set, Manual on CD-ROM included
Visualisation of radioactive particles / Diffusion cloud chamber P2520400

Experimental set-up: deflection of β-particles.

Tasks:

1. Determination of the amount of background radiation
2. Visualisation of α, β, γ-particles and mesons
3. Visualisation of the Thorium (Radon) decay
4. Deflection of β^--particles in a magnetic field

5.2.20-15 Alpha-Energies of different sources with Multi Channel Analyzer

What you can learn about ...

- ➔ Decay series
- ➔ Radioactive equilibrium
- ➔ Isotopic properties
- ➔ Decay energy
- ➔ Particle energy
- ➔ Potential well model of the atomic nucleus
- ➔ Tunnel effect
- ➔ Geiger-Nuttal law
- ➔ Semiconductor
- ➔ Barrier layer

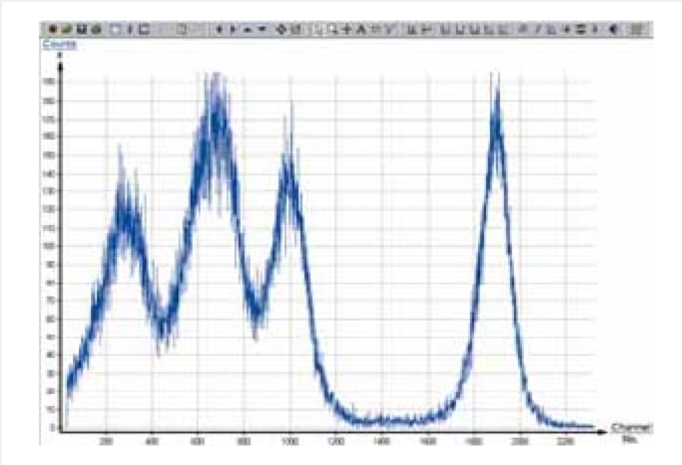
Principle:

An Alpha-spectrometer, consisting of a photodetector, a preamplifier, a pulse height analyser and a recording device for registration of the spectra is calibrated by means of an open Alpha-emitter of known Alpha-energy (^{241}Am). The energy spectrum of a radium source which is in equilibrium with its decay products, is recorded and evaluated. The Alpha-Energies found in this way are allocated to the corresponding nuclides of the radium decay series.

What you need:

Multi-Channel-Analyzer, Extended version	13727.99	1
Software Multi-Channel-Analyzer	14452.61	1
Americium-241 source, 3.7 kBq	09090.03	1
Radioactive Source Ra-226, 4 kBq	09041.00	1
Alpha- and Photodetector	09099.00	1
Pre-amplifier for alpha detector	09100.10	1
Base plate for radioactivity	09200.00	1
Source holder on fixing magnet	09202.00	1
Counter tube holder on fixing magnet	09201.00	1
Screened cable, BNC, l = 750 mm	07542.11	1
Screened cable, BNC, l = 250 mm	07542.10	1
PC, Windows® XP or higher		

Complete Equipment Set, Manual on CD-ROM included
Alpha-Energies of different sources with Multi Channel Analyzer P2522015



Alpha-spectrum of the ^{226}Ra.

Tasks:

1. The Alpha-spectrum of the ^{226}Ra is recorded with Multi Channal Analyzer
2. The calibration spectrum of the open ^{241}Am Alpha-emitter is recorded at the same settings.
3. The Alpha-energies corresponding to the individual peaks of the Alpha-spectrum of the radium are calculated and compared to the values in the literature.

Rutherford experiment 5.2.21-01/11/15

Set-up of experiment P2522115 with MCA

What you can learn about ...

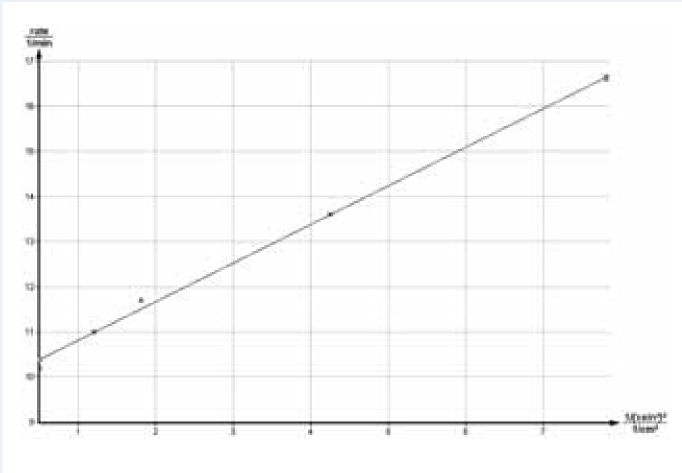
- Scattering
- Angle of scattering
- Impact parameter
- Central force
- Coulomb field
- Coulomb forces
- Rutherford atomic model
- Identity of atomic number and charge on the nucleus

Principle:

The relationship between the angle of scattering and the rate of scattering of α-particles by gold foil is examined with a semiconductor detector. This detector has a detection probability of 1 for α-particles and virtually no zero effect, so that the number of pulses agrees exactly with the number of α-particles striking the detector.

In order to obtain maximum possible counting rates, a measurement geometry is used which dates back to Chadwick. It is also possible in this case to shift the foil and source in an axial direction (thus deviating from Chadwick's original apparatus), so that the angle of scattering can be varied over a wide range.

In addition to the annular diaphragm with gold foil, a second diaphragm with aluminium foil is provided in order to study the influence of the scattering material on the scattering rate.



Counting rate for gold as a function of $\frac{1}{\left(\frac{f}{2}\right)^2 \sin^4\left(\frac{\theta}{2}\right)}$.

What you need:

		Experiment P2522101 with digital counter	Experiment P2522111 with Cobra3	Experiment P2522115 with MCA
Multi-Channel-Analyzer, Extended version	13727.99			1
Software Multi-Channel-Analyzer	14452.61			1
Alpha detector*	09100.00	1	1	1
Annular diaphragm with gold foil	09103.02	1	1	1
Annular diaphragm with aluminium foil	09103.03	1	1	1
U-magnet, large	06320.00	1	1	1
Americium-241 source, 370 kBq	09090.11	1	1	1
Container for nuclear physics experiments	09103.00	1	1	1
Pre-amplifier for alpha detector	09100.10	1	1	1
Pulse height analyser	13725.93	1	1	
Universal counter	13601.99	1		
Vakuum gauge DVR 2	34171.00			1
Vakuum tube, NBR, 6/15 mm	39289.00			2
Diaphragm pump, two stage, 220 V	08163.93	1	1	1
Tubing connect., Y-shape, d = 8-9 mm	47518.03	1	1	1
Oscilloscope 30 MHz, 2 channels	11459.95	1		
Pinchcock, width 20 mm	43631.20	1	1	1
Screened cable, BNC, l = 750 mm	07542.11	4	4	3
Adapter BNC socket/4 mm plug pair	07542.27	1	1	
Connecting cable, 4 mm plug, 32 A, red, l = 75 cm	07362.01	2	2	
Connecting cable, 4 mm plug, 32 A, blue, l = 75 cm	07362.04	2	2	
Screened cable, BNC, l = 250 mm	07542.10			1
Cobra3 Basic-Unit, USB	12150.50		1	
Software Cobra3 Radioactivity	14506.61		1	
Power supply 12V/2A	12151.99		1	
PC, Windows® XP or higher				
** Alternatively:*				
Alpha- and Photodetector	09099.00	1	1	1

Complete Equipment Set, Manual on CD-ROM included
Rutherford experiment P25221 01/11/15

Tasks:

1. The particle rates are measured at different angles of scattering between about 20° and 90°. The measurements are compared with the particle rates calculated by means of the Rutherford theory for the measurement geometry used.
2. The particle rates are measured in the case of scattering by aluminium and gold with identical angles of scattering in each case. The ratio of the two particle rates is compared with the particle rate calculated from Rutherford's scattering equation.

5.2.22-11/15 Fine structure of the α-spectrum of ^{241}Am

Set-up of experiment P2522215 with MCA

What you can learn about …

- ➔ Energy level diagram (decay diagram)
- ➔ Transition probability
- ➔ Excited nuclear states
- ➔ γ-emission
- ➔ Connection between the fine structure of the α-spectrum and the accompanying γ-spectrum

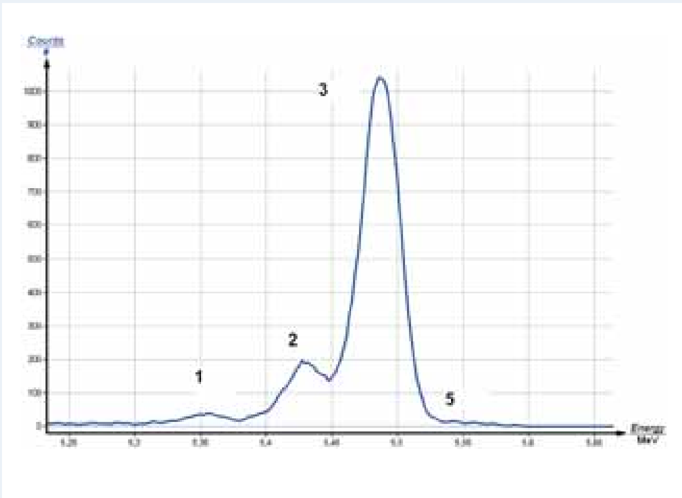
Principle:

The α-spectrum of an open ^{241}Am-emitter is measured with a semiconductor α-detector, maximum use being made in this case of the resolution capacity of the pulse height analyzer. Use is made for this purpose of the "Zoom" function, which is an additional amplification stage having in the effect that only that proportion of the pulses exceeding the threshold voltage of 5 V undergoes further processing. The pulse peaks above this threshold are amplified 5 times and restricted to a maximum of 10 V.

What you need:

		Experiment P2522211 with Cobra3	Experiment P2522215 with MCA
Multi-Channel-Analyzer, Extended version	13727.99		1
Software Multi-Channel-Analyzer	14452.61		1
Alpha- and Photodetector*	09099.00	1	1
Americium-241 source, 3.7 kBq	09090.03	1	
Container for nuclear physics experiments	09103.00	1	1
Pre-amplifier for alpha detector	09100.10	1	1
Pulse height analyser	13725.93	1	
Vakuum gauge DVR 2	34171.00		1
Vakuum tube, NBR, 6/15 mm	39289.00		1
Diaphragm pump, two stage, 220 V	08163.93	1	1
Rubber tubing/vacuum, d = 6 mm	39289.00	3	3
Tubing connect.,Y-shape, d = 8-9 mm	47518.03	1	1
Oscilloscope 30 MHz, 2 channels	11459.95	1	
Pinchcock, width 20 mm	43631.20	3	3
Screened cable, BNC, l = 750 mm	07542.11	4	3
Connecting cable, 4 mm plug, 32 A, red, l = 75 cm	07362.01	2	
Connecting cable, 4 mm plug, 32 A, blue, l = 75 cm	07362.04	2	
Data cable 2 x SUB-D, plug/socket, 9 pole	14602.00	1	
Cobra3 Basic-Unit, USB	12150.50	1	
Software Cobra3 Universal recorder	14504.61	1	
Power supply 12V/2A	12151.99	1	
PC, Windows® XP or higher			
** Alternatively:*			
Alpha detector	09100.0	1	

Complete Equipment Set, Manual on CD-ROM included
Fine structure of the α-spectrum of ^{241}Am P25222 11/15



Measured Alpha-spectrum of Am-241.

Tasks:

1. The spectrum of an open ^{241}Am-emitter is recorded with the xyt-recorder at the maximum resolution capacity of the measurement layout, using automatic window movement. The energy of the two peaks preceding the principal peak is calculated. The principal peak, corresponding to a particle energy of 5.486 MeV, is used for calibration purposes.
2. The resolution capacity of the measurement layout is measured from the half-life width of the principal peak.

Study of the α-energies of ^{226}Ra 5.2.23-11/15

Set-up of experiment P2522311 with Cobra3

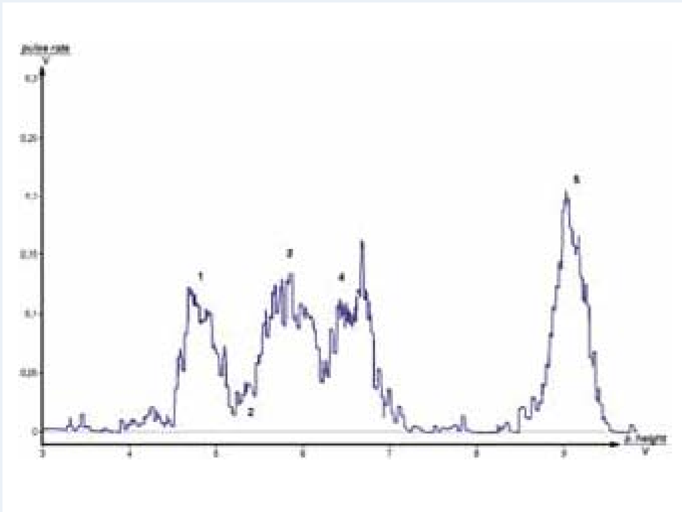
What you can learn about ...

- Decay series
- Radioactive equilibrium
- Isotopic properties
- Decay energy
- Particle energy
- Potential well model of the atomic nucleus
- Tunnel effect
- Geiger-Nuttal law
- Semiconductor
- Barrier layer

Principle:

An α-spectrometer, consisting of a silicon surface barrier layer detector, a preamplifier, a pulse height analyzer and a recording device for registration of the spectra is calibrated by means of an open α-emitter of known α-energy (^{241}Am).

The energy spectrum of a radium source which is in equilibrium with its decay products, is recorded and evaluated. The α-energies found in this way are allocated to the corresponding nuclides of the radium decay series.



^{226}Ra pulse rate dependence of pulse height.

What you need:

		Experiment P2522311 with Cobra3	Experiment P2522315 with MCA
Multi-Channel-Analyzer, Extended version	13727.99		1
Software Multi-Channel-Analyzer	14452.61		1
Alpha- and Photodetector*	09099.00	1	1
Americium-241 source, 3.7 kBq	09090.03	1	1
Radioactive Source Ra-226, 4 kBq	09041.00	1	1
Container for nuclear physics experiments	09103.00	1	1
Pre-amplifier for alpha detector	09100.10	1	1
Pulse height analyser	13725.93	1	
Vakuum gauge DVR 2	34171.00		1
Vakuum tube, NBR, 6/15 mm	39289.00		1
Diaphragm pump, two stage, 220 V	08163.93	1	1
Rubber tubing/vacuum, d = 6 mm	39289.00	2	2
Tubing connect., Y-shape, d = 8-9 mm	47518.03	1	1
Oscilloscope 30 MHz, 2 channels	11459.95	1	
Pinchcock, width 20 mm	43631.20	1	1
Screened cable, BNC, l = 750 mm	07542.11	4	3
Connecting cable, 4 mm plug, 32 A, red, l = 75 cm	07362.01	2	
Connecting cable, 4 mm plug, 32 A, blue, l = 75 cm	07362.04	2	
Data cable 2 x SUB-D, plug/socket, 9 pole	14602.00		1
Cobra3 Basic-Unit, USB	12150.50	1	
Software Cobra3 Universal recorder	14504.61	1	
Power supply 12V/2A	12151.99	1	
PC, Windows® XP or higher			

** Alternatively:*

Alpha detector	09100.00	1	

Complete Equipment Set, Manual on CD-ROM included
Study of the α-energies of ^{226}Ra P25223 11/15

Tasks:

1. The α-spectrum of the ^{226}Ra is recorded, the settings of the pulse analyzer (amplification) and recorder (x and y input sensitivity) being selected so as to make best possible use of the recording width.
2. The calibration spectrum of the open ^{241}Am-emitter is recorded at the same settings.
3. The α-energies corresponding to the individual peaks of the α-spectrum of the radium are calculated and, on the assumption of a constant energy loss in the source covering, the α-active nuclides of the radium decay series corresponding to the individual peaks are determined on the basis of the values in the literature.

5.2.24-11/15 Energy loss of α-particles in gases

Set-up of experiment P2522411 with Cobra3

What you can learn about …

- ➔ Range
- ➔ Range dispersion
- ➔ Mean free path length
- ➔ Mean ionization energy of gas atoms
- ➔ Mean energy loss of α-particles per collision
- ➔ Differencial energy loss
- ➔ Bethe formula
- ➔ Electron concentration in gases

Principle:

A study is made of the connection between the energy E of α-particles and the path x travelled by them in air at standard pressure. The measurements recorded enable the differencial energy loss dE/dx to be calculated as a function of x.

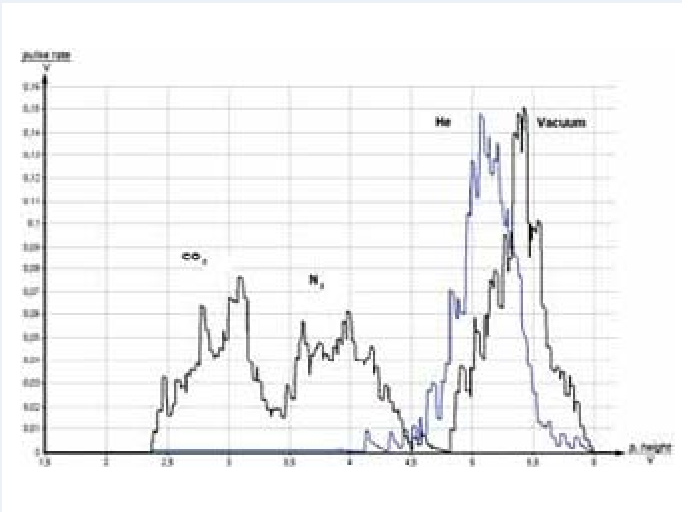
What you need:

		Experiment P2522411 with Cobra3	Experiment P2522415 with MCA
Multi-Channel-Analyzer, Extended version	13727.99		1
Software Multi-Channel-Analyzer	14452.61		1
Alpha- and Photodetector*	09099.00	1	1
Americium-241 source, 3.7 kBq	09090.03	1	1
Americium-241 source, 370 kBq	09090.11	1	1
Container for nuclear physics experiments	09103.00	1	1
Pre-amplifier for alpha detector	09100.10	1	1
Pulse height analyser	13725.93	1	
Vakuum gauge DVR 2	34171.00	1	1
Vakuum tube, NBR, 6/15 mm	39289.00	3	3
Hose clamp	40998.00	9	9
Diaphragm pump, two stage, 220 V	08163.93	1	1
Rubber tubing/vacuum, d = 6 mm	39289.00	3	3
Tubing connect.,Y-shape, d = 8-9 mm	47518.03	1	1
Oscilloscope 30 MHz, 2 channels	11459.95	1	
Pinchcock, width 20 mm	43631.20	3	3
Glass stopcocks, 3 way, T-shaped	36731.00	1	1
Fine control valve for pressure bottles	33499.00	1	1
Compressed gas, helium, 12 l	41772.03	1	1
Compressed gas, nitrogen, 12 l	41772.04	1	1
Compressed gas, CO_2, 21 g	41772.06	1	1
Screened cable, BNC, l = 750 mm	07542.11	4	3
Connecting cable, 4 mm plug, 32 A, red, l = 75 cm	07362.01	2	
Connecting cable, 4 mm plug, 32 A, blue, l = 75 cm	07362.04	2	
Cobra3 Basic-Unit, USB	12150.50	1	
Software Cobra3 Universal recorder	14504.61	1	
Power supply 12V/2A	12151.99	1	

* *Alternatively:*

Alpha detector	09100.00	1	

Complete Equipment Set, Manual on CD-ROM included
Energy loss of α-particles in gases P25224 01/11/15

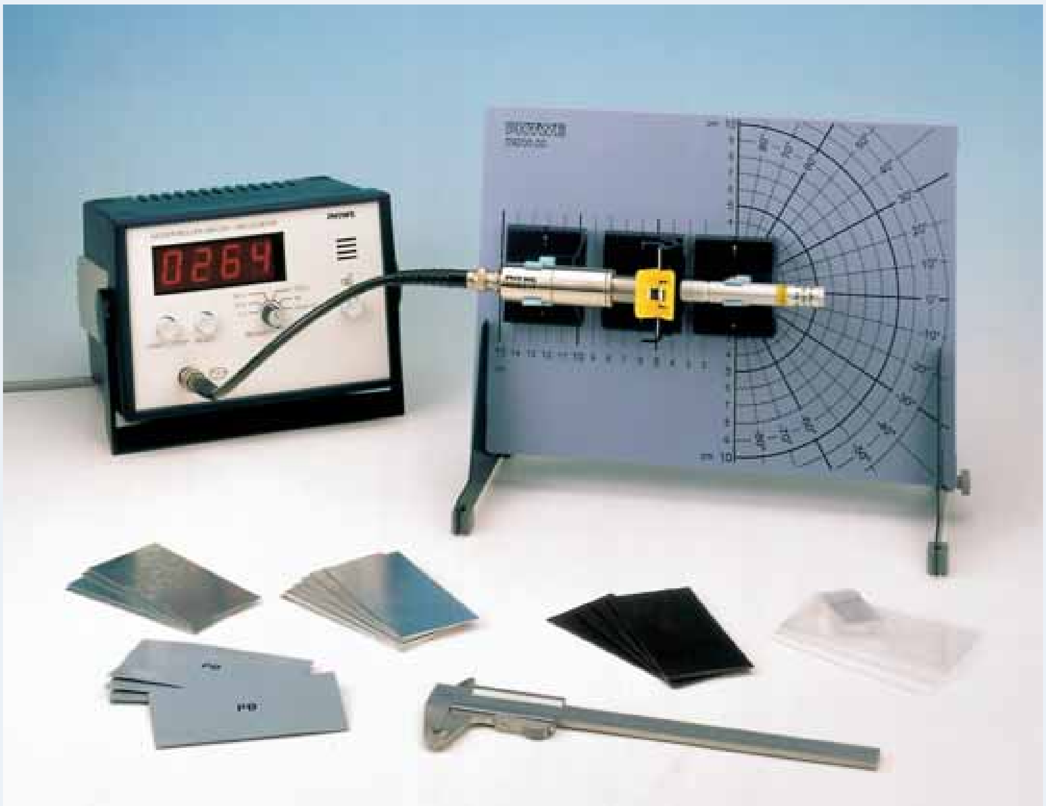


Influence of the type of gas on the energy loss of α-particles.

Tasks:

1. The spectrum of a covered ^{241}Am source is measured at a fixed distance s as a function of the pressure p. The distance s is selected in such a way as to correspond to the maximum range at the highest pressure measurable with the manometer used. The energy corresponding to the central points of the individual spectra are determined (after calibration of the measurement layout with an open ^{241}Am-emitter, see 3.) and plotted as a function of the distance x converted to a 1013 hPa basis. Using this function, the differential energy loss ($-dE/dx$) is then calculated as a function of x and again plotted on the graph.
2. The spectrum of the source used in 1. is measured initially under the same geometric conditions under vacuum and subsequently with the vessel filled with helium, nitrogen or carbon dioxide, in each case under identical pressures. The different energy loss values are compared with the electron concentration in the particular gas.
3. The mean energy with which the α-particles leave the covered americium source is determined by calibration against the open americium emitter (E = 5.485 MeV). (This value is required for the evaluation in 1.)

Electron absorption 5.2.31-00



What you can learn about …

- → Density
- → Counter tube
- → Radioactive decay
- → Attenuation coefficient
- → Mass coverage

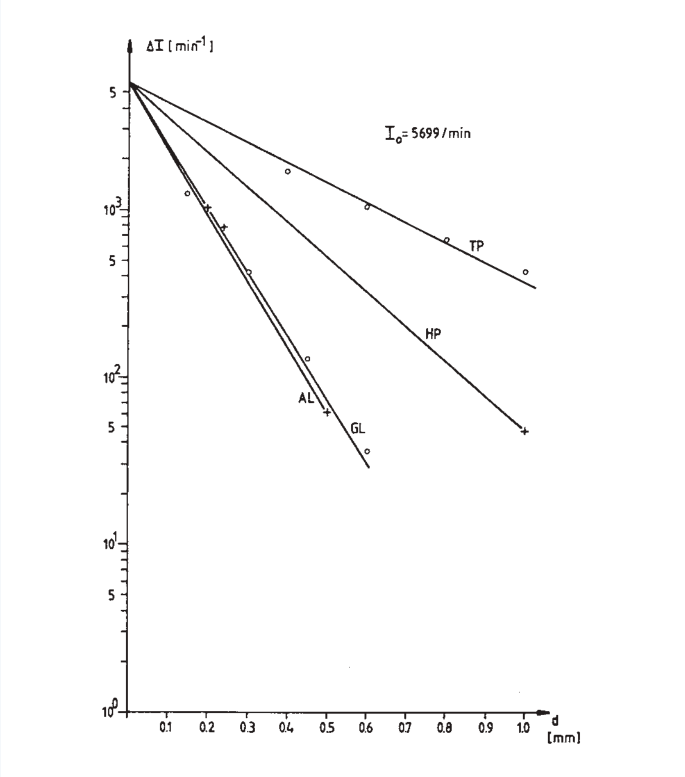
Principle:

The attenuation of an electron particle stream passing through a material layer depends both on the thickness of the layer and on the mass coverage, resp. the "mass per unit area". It will be shown that the particle flux consisting of electrons of a particular energy distribution decreases with the "mass per unit area". As electron source, a radioactive sample of Sr^{90} is used.

What you need:

Radioactive source, Sr-90, 74kBq	09047.53	1
Geiger-Müller Counter	13606.99	1
Counter tube, type A, BNC	09025.11	1
Screened cable, BNC, l = 750 mm	07542.11	1
Stopwatch, digital, 1/100 s	03071.01	1
Base plate for radioactivity	09200.00	1
Supports for base 09200.00, 2 pcs.	09200.01	1
Counter tube holder on fixing magnet	09201.00	1
Plate holder on fixing magnet	09203.00	1
Source holder on fixing magnet	09202.00	1
Vernier calipers, stainless steel	03010.00	1
Absorption plates for beta-rays	09024.00	1
Cover glasses, 40 x 22 mm, 50 pcs.	64688.00	1

Complete Equipment Set, Manual on CD-ROM included
Electron absorption P2523100



Counting rate ΔI as a function of absorber thickness.

Tasks:

1. The β-counting rates are measured as a function of the absorber thickness using different absorbing materials such as aluminium (AL), glass (GL), hard paper (HP), and typing paper (TP).
2. The attenuation coefficients are evaluated for the four absorbing materials and plotted as a function of the density.

5.2.32-00 β-spectroscopy

What you can learn about ...

- → β^--decay
- → β^+-decay
- → Electron capture
- → Neutrino
- → Positron
- → Decay diagram
- → Decay energy
- → Resting energy
- → Relativistic Lorentz equation

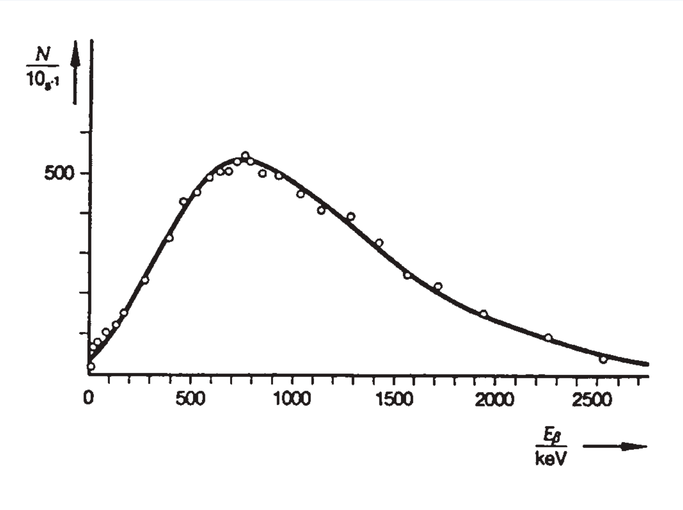
Principle:

The radiation of β-unstable atomic nuclei is selected on the basis of its pulses in a magnetic transverse field, using a diaphragm system. The relationship between coil current and particle energy is determined for calibration of the spectrometer and the decay energy of the β-transition is obtained in each case from the β^--spectra.

What you need:

Beta-spectroscope	09104.00	1
Iron core, solid, 25 mm long	06490.01	1
Iron core, rod shaped, laminated	06500.00	1
Iron core, U-shaped, laminated	06501.00	1
Clamping device	06506.00	1
Coil, 600 turns	06514.01	1
Radioactive source, Na-22, 74kBq	09047.52	1
Radioactive source, Sr-90, 74kBq	09047.53	1
Counter tube, type A, BNC	09025.11	1
Geiger-Müller Counter	13606.99	1
Power supply, universal	13500.93	1
Digital multimeter 2010	07128.00	1
Teslameter, digital	13610.93	1
Hall probe, tangential, with protective cap	13610.02	1
Screened cable, BNC, l = 750 mm	07542.11	1
Connecting cable, 4 mm plug, 32 A, red, l = 50 cm	07361.01	1
Connecting cable, 4 mm plug, 32 A, blue, l = 50 cm	07361.04	2

Complete Equipment Set, Manual on CD-ROM included
β-spectroscopy P2523200



β-spectrum of ^{90}Sr.

Tasks:

1. Energy calibration of the magnetic spectrometer.
2. Measurement of the β-spectra of ^{90}Sr and ^{22}Na.
3. Determination of the decay energy of the two isotopes.

Law of distance and absorption of gamma or beta rays 5.2.41-01/11

Set-up of experiment P2524111 with Cobra3

What you can learn about …

- ➔ Radioactive radiation
- ➔ Beta-decay
- ➔ Conservation of parity
- ➔ Antineutrino
- ➔ Gamma quanta
- ➔ Half-value thickness
- ➔ Absorption coefficient
- ➔ Term diagram
- ➔ Pair formation
- ➔ Compton effect
- ➔ Photoelectric effect
- ➔ Conservation of angular momentum
- ➔ Forbidden transition
- ➔ Weak interaction
- ➔ Dead time

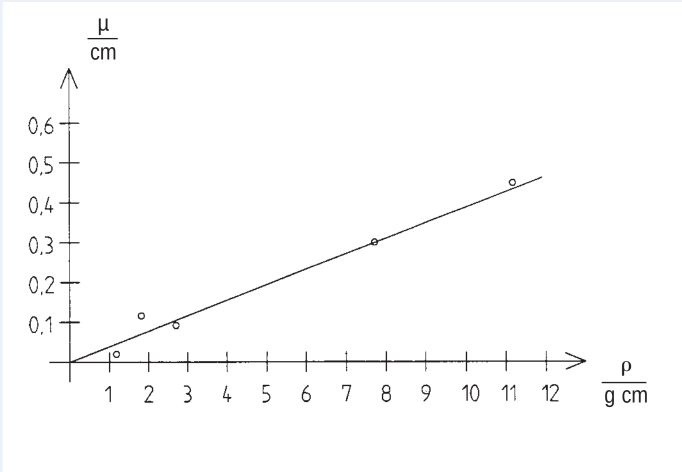
Principle:

The inverse square law of distance is demonstrated with the gamma radiation from a ^{60}Co preparation, the half-value thickness and absorption coefficient of various materials determined with the narrow beam system and the corresponding mass attenuation coefficient calculated.

What you need:

		Experiment P2524101 with GM Counter	Experiment P2524111 with Cobra3
Radioactive sources, set	09047.50	1	1
Absorption plates for beta-rays	09024.00	1	1
Base plate for radioactivity	09200.00	1	1
Counter tube holder on fixing magnet	09201.00	1	1
Source holder on fixing magnet	09202.00	1	1
Plate holder on fixing magnet	09204.00	1	1
Counter tube, type A, BNC	09025.11	1	1
Screened cable, BNC, l = 300 mm	07542.10	1	1
Vernier caliper	03010.00	1	1
Geiger-Mueller-Counter	13606.99	1	
Absorption material, lead	09029.01	1	1
Absorption material, iron	09029.02	1	1
Absorption material, aluminium	09029.03	1	1
Absorption material, Plexiglas	09029.04	1	1
Absorption material, concrete	09029.05	1	1
Cobra3 Basic-Unit, USB	12150.50		1
Power supply 12V/2A	12151.99		1
Software Cobra3 Radioactivity	14506.61		1
Counter tube module	12106.00		1
PC, Windows® XP or higher			

Complete Equipment Set, Manual on CD-ROM included
Law of distance and absorption of gamma or beta rays P25241 01/11



Attenuation coefficient μ of different materials as a function of the material density ρ (from left to right: Plexiglas®, concrete, aluminium, iron, lead).

Tasks:

1. To measure the impulse counting rate as a function of the distance between the source and the counter tube.
2. To determine the half-value thickness $d_{1/2}$ and the absorption coefficient μ of a number of materials by measuring the impulse counting rate as a function of the thickness of the irradiated material. Lead, iron, aluminium, concrete and Plexiglas are used as absorbers.
3. To calculate the mass attenuation coefficient from the measured values.

5.2.42-11/15 Energy Dependence of the γ-absorption Coefficient

Set-up of experiment P2524215 with MCA

What you can learn about ...

- → Compton scattering
- → Photo effect
- → Pair production
- → Absorption coefficient
- → Radioactive decay
- → γ-spectroscopy

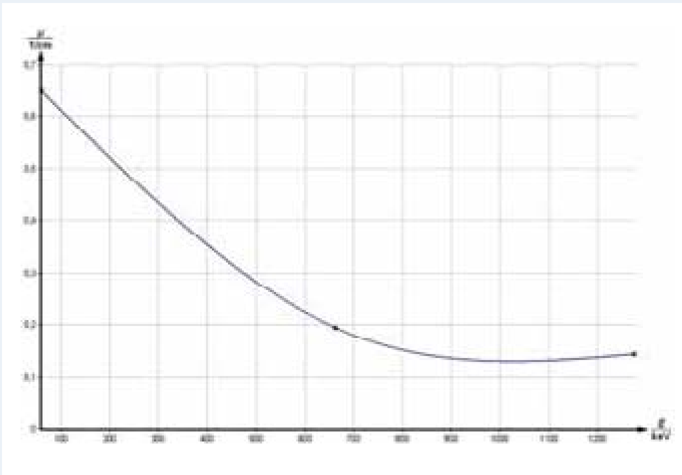
Principle:

The intensity of γ-radiation decreases when it passes through solid matter. The attenuation can be the result of Compton scattering, the photo effect or the pair production. An absorption coefficient can be attributed to each of the three phenomena. These absorption coefficients, as well as the total absorption, are highly energy-dependent. The energy dependence of the total absorption coefficient for aluminium in the range below 1.3 MeV is verified.

What you need:

		Experiment P2524211 with Cobra3	Experiment P2524215 with MCA
Multi-Channel-Analyzer, Extended version	13727.99		1
Software for Multi-Channel-Analyzer	14452.61		1
Americium-241 source, 370 kBq	09090.11	1	1
Radioactive Source Cs-137, 37 kBq	09096.01	1	1
Radioactive Source Na-22, 74 kBq	09096.01	1	1
Gamma detector	09101.00	1	1
Operating unit for gamma detector	09101.93	1	1
High voltage connecting cable	09101.10	1	1
Pulse height analyser	13725.93	1	
Oscilloscope 30 MHz, 2 channels	11459.95	1	
Base plate for radioactivity	09200.00	1	1
Plate holder on fixing magnet	09203.00	1	1
Lab jack, 160 x 130 mm	02074.00	1	1
Vernier calipers, stainless steel	03010.00	1	1
Source holder on fixing magnet	09202.00	1	1
Absorption material, aluminium	09029.03	1	1
Adapter BNC socket/4 mm plug pair	07542.27	1	
Screened cable, BNC, l = 750 mm	07542.11	2	1
Connecting cable, 4 mm plug, 32 A, red, l = 75 cm	07362.01	2	
Connecting cable, 4 mm plug, 32 A, blue, l = 75 cm	07362.04	2	
Cobra3 Basic-Unit, USB	12150.50	1	
Power supply 12V/2A	12151.99	1	
Software Cobra3 Universal recorder	14504.61	1	
Software Cobra3 Radioactivity	14506.61	1	
PC, Windows® XP or higher			

Complete Equipment Set, Manual on CD-ROM included
Energy Dependence of the γ-absorption Coefficient 25242 11/15


Total gamma-absorption coefficient as a function of the energy.

Tasks:

1. For each of the emitting isotopes Na^{22}, Cs^{137} and Am^{241} the γ-spectrum is traced and a treshold energy, $E_{thres,}$ just below the photo-peak in the high energy range determined.
2. Using the scintillation counter in conjunction with the pulse height analyser as a monochromator, the γ-intensity is measured as a function of the thickness of different aluminium layers. The three γ-emitting isotopes are used successively as the source, assuming that the energy of the emitted γ-radiation is known.

Compton effect 5.2.44-11/15

Set-up of experiment P2524411 with Cobra3

What you can learn about …

- ➔ Corpuscle
- ➔ Scattering
- ➔ Compton wavelength
- ➔ γ-quanta
- ➔ De Broglie wavelength
- ➔ Klein-Nishina formula

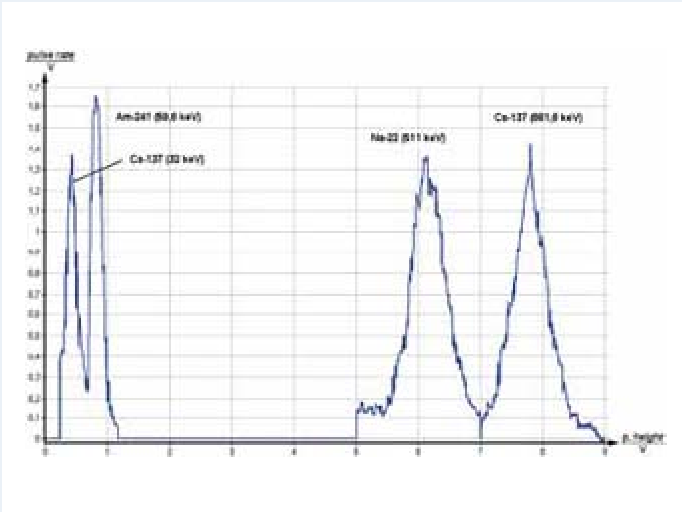
Principle:

The energy of scattered γ-radiation is measured as a function of the angle of scatter. The Compton wavelength is determined from the measured values.

What you need:

		Experiment P2524415 with MCA	Experiment P2524411 with Cobra3
Multi-Channel-Analyzer, Extended version	13727.99		1
Software for Multi-Channel-Analyzer	14452.61		1
Radioactive source, Na-22, 74kBq	09047.52	1	1
Americium-241 source, 370 kBq	09090.11	1	1
Radioactive Source Cs-137, 37kBq	09096.01	1	1
Radioactive source Cs-137,18.5 MBq	09096.20	1	1
Gamma detector	09101.00	1	1
Operating unit for gamma detector	09101.93	1	1
High voltage connecting cable	09101.10	1	1
Pulse height analyser	13725.93	1	
Oscilloscope 30 MHz, 2 channels	11459.95	1	
Shielding cylinder for gamma-detector	09101.11	1	1
Rod, iron, d = 25 mm, l = 200 mm	09101.13	1	1
Lead block, 200 x 100 x 50 mm	09029.11	1	1
Lead brick with hole	09021.00	1	1
Source holder on fixing magnet	09202.00	1	1
Adapter BNC socket/4 mm plug pair	07542.27	1	
Screened cable, BNC, l = 750 mm	07542.11	3	1
Connecting cable, 4 mm plug, 32 A, red, l = 75 cm	07362.01	2	
Connecting cable, 4 mm plug, 32 A, blue, l = 75 cm	07362.04	2	
Cobra3 Basic-Unit, USB	12150.50	1	
Power supply 12V/2A	12151.99	1	
Software Cobra3 Universal recorder	14504.61	1	
PC, Windows® XP or higher			

Complete Equipment Set, Manual on CD-ROM included
Compton effect P25244 11/15



Energy of known peaks as a function of the pulse height.

Tasks:

1. Calibrate the measuring set-up with the aid of a Cs-137 calibrating source (37 kBq), an Am-241 source (370 kBq) and a Na-22 source (74 kBq).
2. Measure the energy of the Cs-137 661.6 keV peaks scattered at different angles and calculate the Compton wavelength from the readings taken.

5.2.45-11/15 Internal conversion in ^{137m}Ba

Set-up of experiment P2524501 with Cobra3

What you can learn about …

- → γ-radiation
- → Nuclear transitions
- → Transition probability
- → Duration
- → Metastable states
- → Isotopic spin quantum numbers
- → Rules governing selection
- → Multipole radiation
- → Isomeric nuclei
- → Photonuclear reaction
- → Conversion electron
- → Characteristic X-ray radiation
- → Scintillation detectors

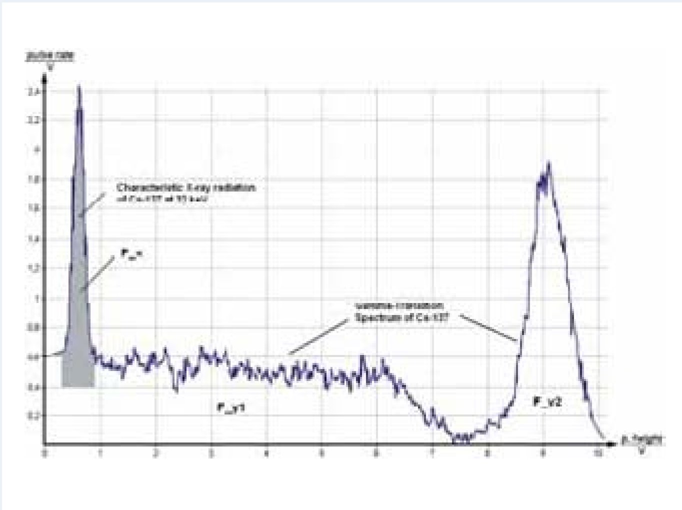
Principle:

The radiation emitted during the decay of the ^{137}Cs isotope is measured with a scintillation detector and the energy spectrum determined with a pulse height analyzer. The spectrum contains fractions due to a γ-transition and fractions originating from a characteristic X-ray radiation. The areas of the fractions in question are determined and the conversion factor obtained from them.

What you need:

		Experiment P2524511 with Cobra3	Experiment P2524515 with MCA
Multi-Channel-Analyzer, Extended version	13727.99		1
Software Multi-Channel-Analyzer	14452.61		1
Radioactive Source Cs-137, 37kBq	09096.01	1	1
Gamma detector	09101.00	1	1
Operating unit for gamma detector	09101.93	1	1
High voltage connecting cable	09101.10	1	1
Pulse height analyzer	13725.93	1	
Oscilloscope 30 MHz, 2 channels	11459.95	1	
Support rod -PASS-, square, l = 400 mm	02026.55	1	1
Right angle clamp -PASS-	02040.55	1	1
Tripod base -PASS-	02002.55	1	1
Adapter BNC socket/4 mm plug pair	07542.27	1	
Screened cable, BNC, l = 750 mm	07542.11	3	1
Connecting cable, 4 mm plug, 32 A, red, l = 75 cm	07362.01	2	
Connecting cable, 4 mm plug, 32 A, blue, l = 75 cm	07362.04	2	
Cobra3 Basic-Unit, USB	12150.50	1	
Power supply 12V/2A	12151.99	1	
Software Cobra3 Universal recorder	14504.61	1	
PC, Windows® XP or higher			

PComplete Equipment Set, Manual on CD-ROM included
Internal conversion in ^{137m}Ba P25245 11/15



γ-spectrum of ^{137}Cs. F_x corresponds to characteristic X-ray radiation caused by internal conversion in Ba-137. F_y1 and F_y2 corresponds to the transition radiation.

Tasks:

1. Measurement of the g-spectrum of ^{137}Cs using a scintillation detector.
2. Determination of the conversion factor of the ^{137m}Ba excited nucleus.

Photonuclear cross-section / Compton scattering cross-section 5.2.46-11/15

Set-up of experiment P2524615 with MCA

What you can learn about …

- → γ-radiation
- → Interaction with material
- → Photoelectric effect
- → Compton effect
- → Pair formation
- → Detection probability
- → Scintillation detectors

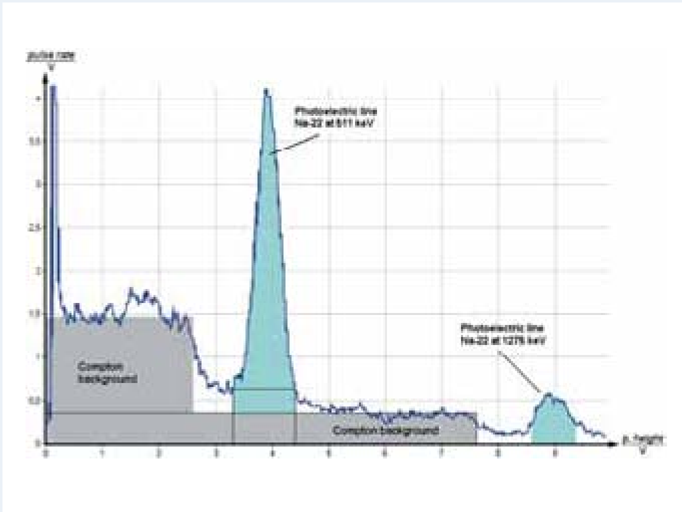
Principle:

The radiation of ^{137}Cs and ^{22}Na is measured with a scintillation detector and the energy spectrum determined with a pulse height analyzer. The fractions of the spectra caused by Compton scattering and those caused by the photoelectric effect are determined on the basis of their areas. The results are used for determining the ratio of the effective cross-sections and examining its energy dependence.

What you need:

		Experiment P2524611 with Cobra3	Experiment P2524615 with MCA
Multi-Channel-Analyzer, Extended version	13727.99		1
Software Multi-Channel-Analyzer	14452.61		1
Radioactive source, Na-22, 74kBq	09047.52	1	1
Radioactive Source Cs-137, 37kBq	09096.01	1	1
Gamma detector	09101.00	1	1
Operating unit for gamma detector	09101.93	1	1
High voltage connecting cable	09101.10	1	1
Pulse height analyser	13725.93	1	
Oscilloscope 30 MHz, 2 channels	11459.95	1	
Support rod -PASS-, square, l = 400 mm	02026.55	1	1
Universal clamp	37718.00	1	1
Right angle clamp -PASS-	02040.55	2	2
Tripod base -PASS-	02002.55	1	1
Screened cable, BNC, l = 750 mm	07542.11	1	1
Connecting cable, 4 mm plug, 32 A, red, l = 75 cm	07362.01	2	
Connecting cable, 4 mm plug, 32 A, blue, l = 75 cm	07362.04	2	
Cobra3 Basic-Unit, USB	12150.50	1	
Power supply 12V/2A	12151.99	1	
Software Cobra3 Universal recorder	14504.61	1	
PC, Windows® XP or higher			

Complete Equipment Set, Manual on CD-ROM included
Photonuclear cross-section / Compton scattering cross-section P25246 11/15



γ-spectrum of ^{22}Na.

Tasks:

1. Measurement of the g-spectra of ^{22}Na and ^{137}Cs, using a scintillation detector.
2. Determination of the ratio of the specific effective cross-sections due to the Compton effect and the photoelectric effect in photons having energy values of 511, 662 and 1275 keV.

5.2.47-11/15 X-ray fluorescence and Moseley's law

Set-up of experiment P2524711 with Cobra3

What you can learn about ...

- Binding energy
- Photoelectric effect
- Shell structure of electron shells
- Characteristic X-ray radiation
- γ-spectrometry
- X-ray spectral analysis

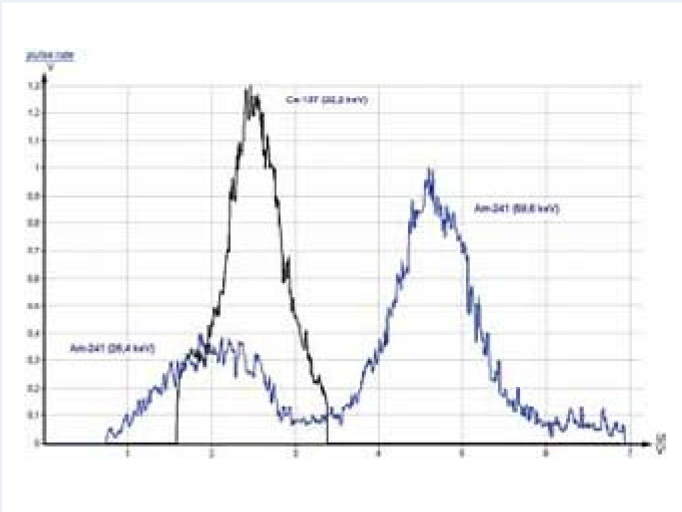
Principle:

The irradiation of strontinum (sulphate), cadmium, indium, iodine and barium (chloride) with soft γ-radiations gives rise to K_a radiations characteristics of these elements. The X-ray spectra are recorded with a γ-spectrometer consisting of a scintillation counter, a pulse height analyser and a recorder. After calibration of the spectrometer, the Rydberg constant is determined from the energies of the X-ray lines, using Moseley's law.

What you need:

		Experiment P2524711 with Cobra3	Experiment P2524715 with MCA
Multi-Channel-Analyzer, Extended version	13727.99		1
Software Multi-Channel-Analyzer	14452.61		1
Americium-241 source, 370 kBq	09090.11	1	1
Radioactive Source Cs-137, 37kBq	09096.01	1	1
Pulse height analyser	13725.93	1	
Gamma detector	09101.00	1	1
Operating unit for gamma detector	09101.93	1	1
High voltage connecting cable	09101.10	1	1
Oscilloscope 30 MHz, 2 channels	11459.95	1	
Adapter BNC socket/4 mm plug pair	07542.27	1	
Tin-II chloride 250 g	31991.25	1	1
Silver foil sheet, 150 x 150 x 0.1 mm, 25 g	31839.04	1	1
Absorption material, lead	09029.01	1	1
Plastic bags, DIN A5, pack of 100	46444.01	1	1
Crocodile clips, bare, 10 pcs	07274.03	1	1
Support rod -PASS-, square, l = 250 mm	02025.55	3	3
Support base -PASS-	02005.55	1	1
Universal clamp	37718.00	1	1
Right angle clamp -PASS-	02040.55	3	3
Support rod with hole, stainless steel, l = 10 cm	02036.01	1	1
Spring balance holder	03065.20	1	1
Barium chloride, 250 g	30033.25	1	1
Iodine resublimed, 25 g	30093.04	1	1
Screened cable, BNC, l = 750 mm	07542.11	3	1
Connecting cable, 4 mm plug, 32 A, red, l = 75 cm	07362.01	2	
Connecting cable, 4 mm plug, 32 A, blue, l = 75 cm	07362.04	2	
Cobra3 Basic-Unit, USB	12150.50	1	
Power supply 12V/2A	12151.99	1	
Software Cobra3 Universal recorder	14504.61	1	
PC, Windows® XP or higher			

Complete Equipment Set, Manual on CD-ROM included
X-ray fluorescence and Moseley's law P25247 11/15



Calibration lines of Cs-137 and Am-241

Tasks:

1. Calibration of the γ-spectrometer in the low energy range, using the Ba-resonance line of a ^{137}Cs emitter (32 keV) and the γ-line of ^{241}Am at 59.6 keV.
2. Recording of the X-ray fluorescence spectra (K_a-lines) of different elements and determination of the corresponding energies.
3. Plotting of the measured X-ray energies according to Moseley's law against $(Z\text{-}1)^2$ and determination of the Rydberg constant R_∞ from the slope of the resulting lines.

Hall effect in p-germanium 5.3.01-01

What you can learn about …

- ➔ Semiconductor
- ➔ Band theory
- ➔ Forbidden zone
- ➔ Intrinsic conductivity
- ➔ Extrinsic conductivity
- ➔ Valence band
- ➔ Conduction band
- ➔ Lorentz force
- ➔ Magnetic resistance
- ➔ Mobility
- ➔ Conductivity
- ➔ Band spacing
- ➔ Hall coefficient

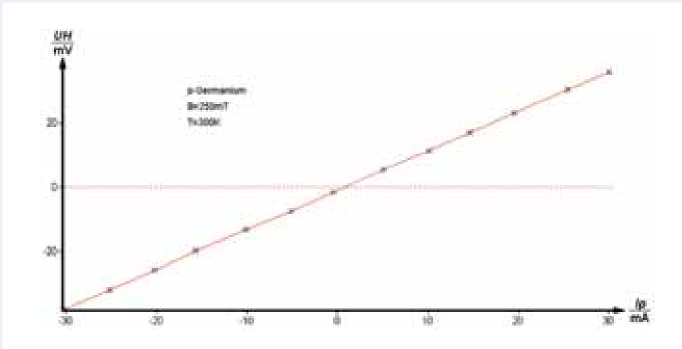
Principle:

The resistivity and Hall voltage of a rectangular germanium sample are measured as a function of temperature and magnetic field. The band spacing, the specific conductivity, the type of charge carrier and the mobility of the charge carriers are determined from the measurements.

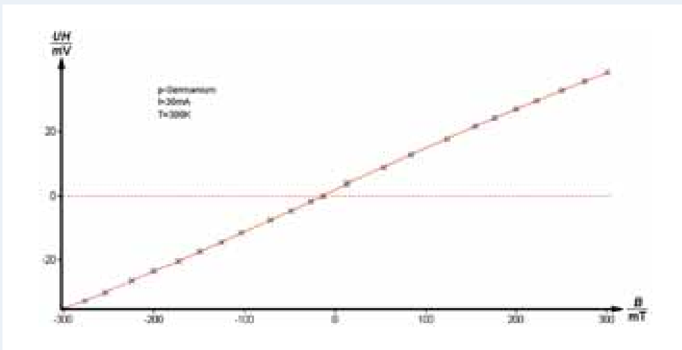
What you need:

Hall effect module	11801.00	1
Hall effect, p-Ge, carrier board	11805.01	1
Coil, 600 turns	06514.01	2
Iron core, U-shaped, laminated	06501.00	1
Pole pieces, plane, 30 x 30 x 48 mm, 1 pair	06489.00	1
Hall probe, tangential, with protective cap	13610.02	1
Power supply 0-12 V DC/ 6 V, 12 V AC	13505.93	1
Tripod base -PASS-	02002.55	1
Support rod -PASS-, square, l = 250 mm	02025.55	1
Right angle clamp -PASS-	02040.55	1
Connecting cable, 4 mm plug, 32 A, red, l = 50 cm	07361.01	3
Connecting cable, 4 mm plug, 32 A, blue, l = 50 cm	07361.04	2
Connecting cable, 4 mm plug, 32 A, black, l = 75 cm	07362.05	2
Teslameter, digital	13610.93	1
Digital multimeter 2010	07128.00	1

Complete Equipment Set, Manual on CD-ROM included
Hall effect in p-germanium P2530101



Hall voltage as a function of current.



Hall voltage as a function of magnetic induction.

Tasks:

1. The Hall voltage is measured at room temperature and constant magnetic field as a function of the control current and plotted on a graph (measurement without compensation for defect voltage).
2. The voltage across the sample is measured at room temperature and constant control current as a function of the magnetic induction B.
3. The voltage across the sample is measured at constant control current as a function of the temperature. The band spacing of germanium is calculated from the measurements.
4. The Hall voltage U_H is measured as a function of the magnetic induction B, at room temperature. The sign of the charge carriers and the Hall constant R_H together with the Hall mobility μ_H and the carrier concentration p are calculated from the measurements.
5. The Hall voltage U_H is measured as a function of temperature at constant magnetic induction B and the values are plotted on a graph.

5.3.01-11 Hall effect in p-germanium with Cobra3

What you can learn about ...

- ➔ Semiconductor
- ➔ Band theory
- ➔ Forbidden zone
- ➔ Intrinsic conductivity
- ➔ Extrinsic conductivity
- ➔ Valence band
- ➔ Conduction band
- ➔ Lorentz force
- ➔ Magnetic resistance
- ➔ Mobility
- ➔ Conductivity
- ➔ Band spacing
- ➔ Hall coefficient

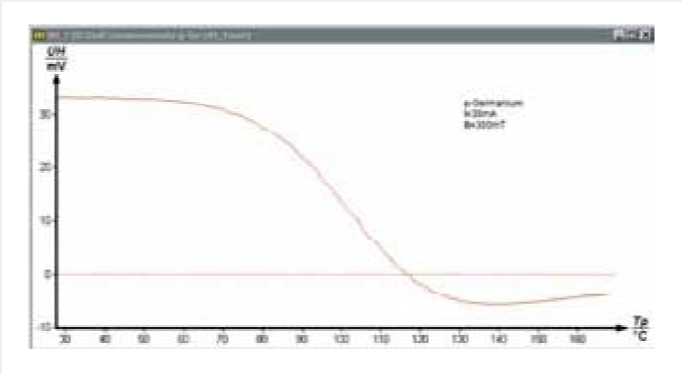
Principle:

The resistivity and Hall voltage of a rectangular germanium sample are measured as a function of temperature and magnetic field. The band spacing, the specific conductivity, the type of charge carrier and the mobility of the charge carriers are determined from the measurements.

What you need:

Hall effect module	11801.00	1
Hall effect, p-Ge, carrier board	11805.01	1
Coil, 600 turns	06514.01	2
Iron core, U-shaped, laminated	06501.00	1
Pole pieces, plane, 30 x 30 x 48 mm, 1 pair	06489.00	1
Hall probe, tangential, with protective cap	13610.02	1
Power supply 0-12 V DC/ 6 V, 12 V AC	13505.93	1
Tripod base -PASS-	02002.55	1
Support rod -PASS-, square, l = 250 mm	02025.55	1
Right angle clamp -PASS-	02040.55	1
Connecting cable, 4 mm plug, 32 A, red, l = 50 cm	07361.01	2
Connecting cable, 4 mm plug, 32 A, blue, l = 50 cm	07361.04	1
Connecting cable, 4 mm plug, 32 A, black, l = 75 cm	07362.05	2
Cobra3 Basic-Unit, USB	12150.50	1
Power supply 12V/2A	12151.99	1
Cobra3 measuring module Tesla	12109.00	1
Software Cobra3 Hall effect	14521.61	1
Data cable 2 x SUB-D, plug/socket, 9 pole	14602.00	1
PC, Windows® XP or higher		

Complete Equipment Set, Manual on CD-ROM included
Hall effect in p-germanium with Cobra3 P2530111



Hall voltage as a function of temperature.

Tasks:

1. The Hall voltage is measured at room temperature and constant magnetic field as a function of the control current and plotted on a graph (measurement without compensation for defect voltage).
2. The voltage across the sample is measured at room temperature and constant control current as a function of the magnetic induction B.
3. The voltage across the sample is measured at constant control current as a function of the temperature. The band spacing of germanium is calculated from the measurements.
4. The Hall voltage U_H is measured as a function of the magnetic induction B, at room temperature. The sign of the charge carriers and the Hall constant R_H together with the Hall mobility μ_H and the carrier concentration p are calculated from the measurements.
5. The Hall voltage U_H is measured as a function of temperature at constant magnetic induction B and the values are plotted on a graph.

Hall effect in n-germanium 5.3.02-01/11

Set-up of experiment P2530211 with Cobra3

What you can learn about …

- → Semiconductor
- → Band theory
- → Forbidden zone
- → Intrinsic conduction
- → Extrinsic conduction
- → Valence band
- → Conduction band
- → Lorentz force
- → Magneto resistance
- → Neyer-Neldel Rule

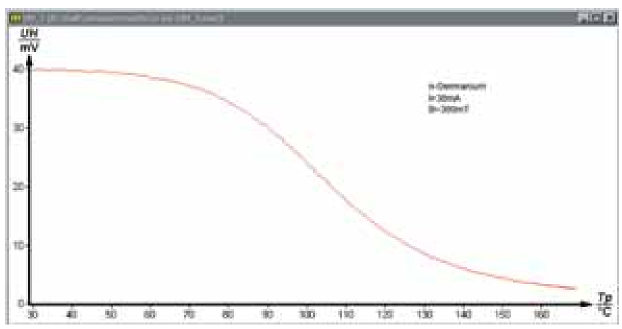
Principle:

The resistance and Hall voltage are measured on a rectangular strip of germanium as a function of the temperature and of the magnetic field. From the results obtained the energy gap, specific conductivity, type of charge carrier and the carrier mobility are determined.

What you need:

		Experiment P2530211 with Cobra3	Experiment P2530201 with teslameter
Hall effect module	11801.00	1	1
Hall effect, n-Ge, carrier board	11802.01	1	1
Coil, 600 turns	06514.01	2	2
Iron core, U-shaped, laminated	06501.00	1	1
Pole pieces, plane, 30 x 30 x 48 mm, 1 pair	06489.00	1	1
Hall probe, tangential, with protective cap	13610.02	1	1
Power supply 0-12 V DC/ 6 V, 12 V AC	13505.93	1	1
Tripod base -PASS-	02002.55	1	1
Support rod -PASS-, square, l = 250 mm	02025.55	1	1
Right angle clamp -PASS-	02040.55	1	1
Connecting cable, 4 mm plug, 32 A, red, l = 50 cm	07361.01	3	2
Connecting cable, 4 mm plug, 32 A, blue, l = 50 cm	07361.04	2	1
Connecting cable, 4 mm plug, 32 A, black, l = 75 cm	07362.05	2	2
Teslameter, digital	13610.93	1	
Digital multimeter 2010	07128.00	1	
Cobra3 Basic-Unit, USB	12150.50		1
Power supply 12V/2A	12151.99		1
Cobra3 measuring module Tesla	12109.00		1
Software Cobra3 Hall effect	14521.61		1
Data cable 2 x SUB-D, plug/socket, 9 pole	14602.00		1
PC, Windows® XP or higher			

Complete Equipment Set, Manual on CD-ROM included
Hall effect in n-germanium P25302 01/11



Hall voltage as a function of temperature.

Tasks:

1. At constant room temperature and with a uniform magnetic field measure the Hall voltage as a function of the control current and plot the values on a graph (measurement without compensation for error voltage).
2. At room temperature and with a constant control current, measure the voltage across the specimen as a function of the magnetic flux density B.
3. Keeping the control current constant measure the voltage across the specimen as a function of temperature. From the readings taken, calculate the energy gap of germanium.
4. At room temperature measure the Hall Voltage U_H as a function of the magnetic flux density B. From the readings taken, determine the Hall coefficient R_H and the sign of the charge carriers. Also calculate the Hall mobility μ_H and the carrier density n.
5. Measure the Hall voltage U_H as a function of temperature at uniform magnetic flux density B, and plot the readings on a graph.

5.3.03-00 Hall effect in metals

What you can learn about ...

- → Normal Hall effect
- → Anomalous Hall effect
- → Charge carriers
- → Hall mobility
- → Electrons
- → Defect electrons

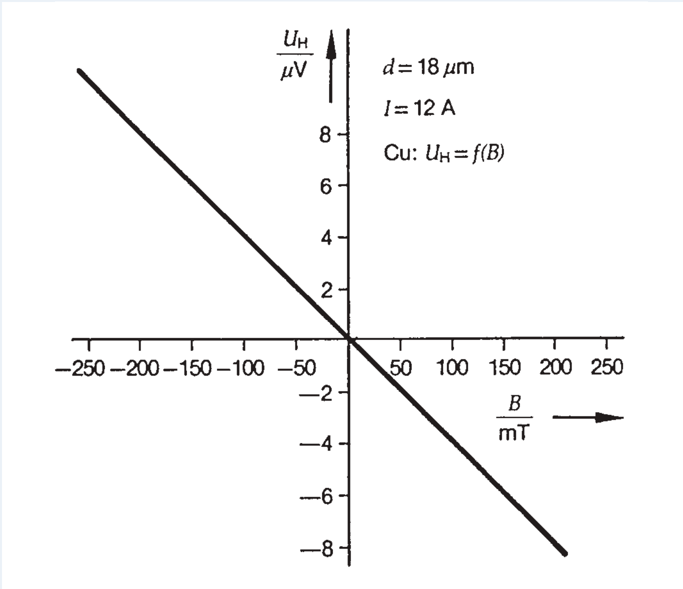
Principle:

The Hall effect in thin zinc and copper foils is studied and the Hall coefficient determined. The effect of temperature on the Hall voltage is investigated.

What you need:

Hall effect, Cu, carrier board	11803.00	1
Hall effect, Zn, carrier board	11804.01	1
Coil, 300 turns	06513.01	2
Iron core, U-shaped, laminated	06501.00	1
Pole pieces, plane, 30 x 30 x 48 mm, 1 pair	06489.00	1
Power supply, stabilised, 0...30 V- / 20 A	13536.93	1
Power supply, universal	13500.93	1
Universal measuring amplifier	13626.93	1
Teslameter, digital	13610.93	1
Hall probe, tangential, with protective cap	13610.02	1
Digital multimeter 2010	07128.00	1
Meter 10/30 mV, 200°C	07019.00	1
Universal clamp with joint	37716.00	1
Tripod base -PASS-	02002.55	1
Support rod -PASS-, square, l = 250 mm	02025.55	1
Right angle clamp -PASS-	02040.55	2
Connecting cable, 4 mm plug, 32 A, red, l = 75 cm	07362.01	6
Connecting cable, 4 mm plug, 32 A, blue, l = 75 cm	07362.04	5
Connecting cable, 4 mm plug, 32 A, black, l = 75 cm	07362.05	2

Complete Equipment Set, Manual on CD-ROM included
Hall effect in metals P2530300



Hall voltage as a function of magnetic induction B, using a copper sample.

Tasks:

1. The Hall voltage is measured in thin copper and zinc foils.
2. The Hall coefficient is determined from measurements of the current and the magnetic induction.
3. The temperature dependence of the Hall voltage is investigated on the copper sample.

Band gap of germanium 5.3.04-01/11

Set-up of experiment P2530401 with digital multimeter

What you can learn about …

- → Semiconductor
- → Band theory
- → Forbidden band
- → Intrinsic conduction
- → Extrinsic conduction
- → Impurity depletion
- → Valence band
- → Conduction band

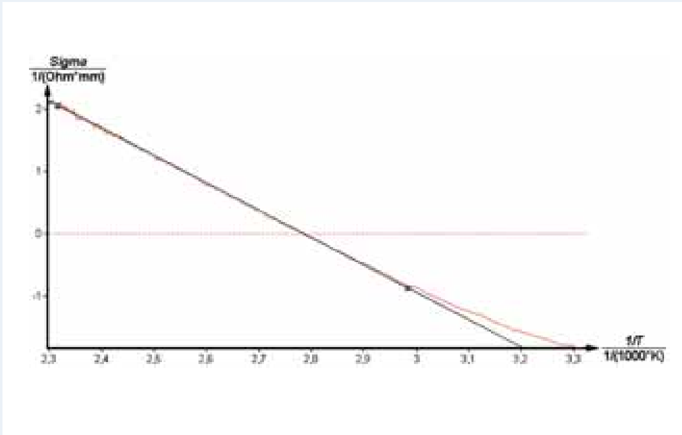
Principle:

The conductivity of a germanium testpiece is measured as a function of temperature. The energy gap is determined from the measured values.

What you need:

		Experiment P2530411 with Cobra3	Experiment P2530401 with Multimeter
Hall effect module	11801.00	1	1
Intrinsic conductor, Ge, carrier board	11807.01	1	1
Power supply 0-12 V DC/ 6 V, 12 V AC	13505.93	1	1
Tripod base -PASS-	02002.55	1	1
Support rod -PASS-, square, l = 250 mm	02025.55	1	1
Right angle clamp -PASS-	02040.55	1	1
Digital multimeter 2010	07128.00		2
Connecting cable, 4 mm plug, 32 A, black, l = 50 cm	07361.05	2	2
Connecting cable, 4 mm plug, 32 A, red, l = 10 cm	07359.01		1
Connecting cable, 4 mm plug, 32 A, blue, l = 10 cm	07359.04	1	
Cobra3 Basic-Unit, USB	12150.50	1	
Power supply 12V/2A	12151.99	1	
Software Cobra3 Hall effect	14521.61	1	
Data cable 2 x SUB-D, plug/socket, 9 pole	14602.00	1	
PC, Windows® XP or higher			

Complete Equipment Set, Manual on CD-ROM included
Band gap of germanium P2530401/11



Regression of the conductivity versus the reciprocal of the absolute temperature.

Tasks:

1. The current and voltage are to be measured across a germanium test-piece as a function of temperature.
2. From the measurements, the conductivity σ is to be calculated and plotted against the reciprocal of the temperature T. A linear plot is obtained, from whose slope the energy gap of germanium can be determined.

5.3.10-00 Surface treatment / Plasma Physics

What you can learn about ...

- ➔ Arc discharge
- ➔ Glow discharge
- ➔ Electron avalanches
- ➔ Townsend breakthrough mechanism
- ➔ Streamers
- ➔ Microdischarges
- ➔ Dielectric barrier discharge (DBD)
- ➔ Surface energy
- ➔ Contact angle (CA)
- ➔ Contact angle measurement

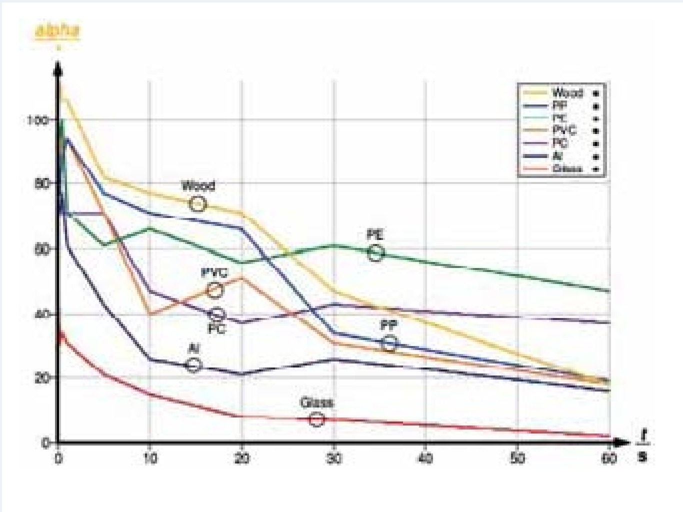
Principle:

Different samples are exposed to a dielectric barrier discharge in air at atmospheric pressure. The plasma induces both chemical and physical reactions on the sample surface altering the surface structure and thus the surface energy. The contact angle of water on the sample surface is observed in the exposed and in the unexposed region to analyse the effect of the plasma treatment on the surface energy.

What you need:

Plasma Physics Operating Unit	09108.99	1
Plasma Physics Experimental Set	09108.10	1
Plasma Physics Sample Set	09108.30	1
Microliterpipette dig. 2-20 µl	47141.01	1
Pipette tips, 2-200 µl, 1000pcs	47148.01	1
Denatured alcohol (Spirit f.burning), 1000 ml	31150.70	1
Vernier caliper	03010.00	1
Water, distilled, 5 l	31246.81	1
Contact angle measurement equipment		
Housing for experiment lamp	08129.01	1
Halogen lamp, 12 V/50 W	08129.06	1
Power supply 0-12V DC/6V,12V AC	13505.93	1
Lab jack, 160 x 130 mm	02074.00	1
Tripod base -PASS-	02002.55	1
Universal clamp with joint	37716.00	1
Support rod -PASS-, square, l = 400 mm	02026.55	1
Right angle clamp -PASS-	02040.55	2
Web-Cam CCD USB VGA PC Philips SPC900NC	88040.00	1
Software "Measure Dynamics", single user license	14440.62	1
PC, Windows® XP or higher		

Complete Equipment Set, Manual on CD-ROM included
Surface treatment / Plasma Physics P2531000



Measurement results for the contact angle of water on different sample surfaces after plasma exposure of duration *t*.

Tasks:

Various samples are to be treated with a plasma for different periods of time. The effect of the treatment on the contact angle of water on the surface is to be observed by drop size measurement or by web cam photography.

Paschen curve / Plasma Physics 5.3.11-00

What you can learn about ...

- Glow discharge
- Electron avalanches
- Free path length
- Townsend breakdown theory
- Paschen curve

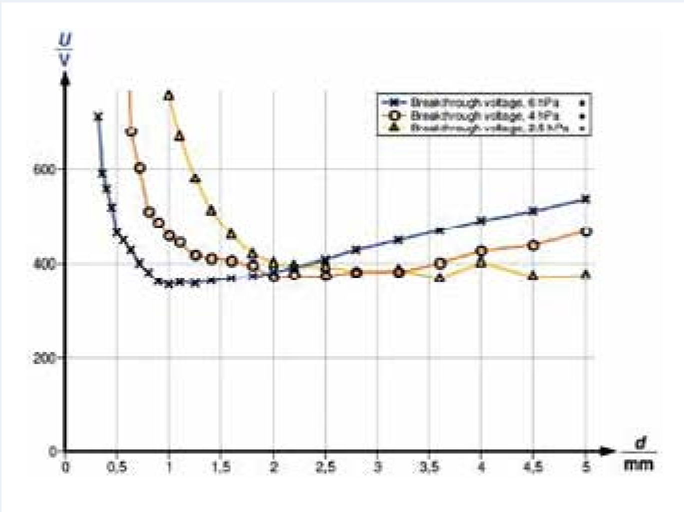
Principle:

The electric breakthrough voltage in air is measured in dependence on electrode distance and gas pressure. The results are compared to the Paschen curve which is a result of Townsend electric breakdown theory which assumes the product *pd* of electrode distance *d* and gas pressure *p* to be the similarity parameter describing the electric breakdown behavior of a gas.

What you need:

Plasma Physics Operating Unit	09108.99	1
Plasma Physics Experimental Set	09108.10	1
Digital multimeter 2010	07128.00	1
Vacuum pump, one stage	02750.93	1
Oil mist filter	02752.00	1
Rubber tubing, vacuum, i.d. 6 mm	39289.00	2
Fine control valve	33499.00	1
Vacuum gauge DVR 2	34171.00	1
Tubing connect., T-shape, ID 8-9 mm	47519.03	1
Connecting cord, safety, 32 A, l = 100 cm, red	07337.01	1
Connecting cord, safety, 32A, l = 100 cm, blue	07337.04	1

Complete Equipment Set, Manual on CD-ROM included
Paschen curve / Plasma Physics P2531100



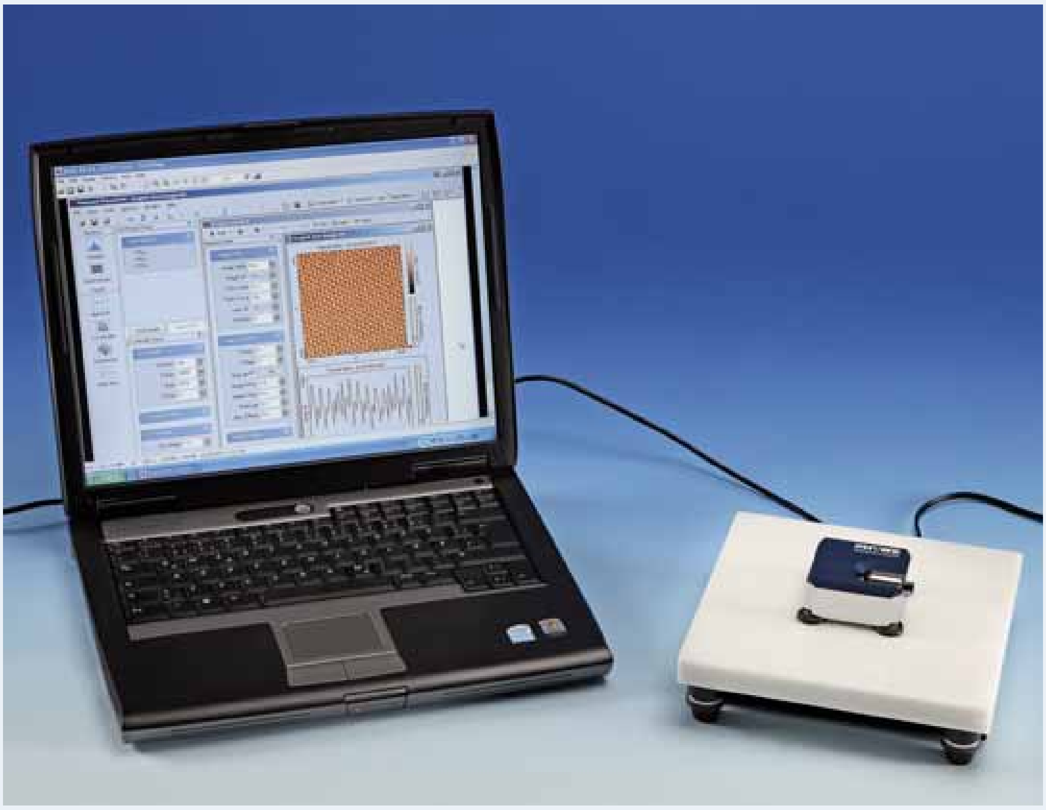
Breakdown voltage in dependence on electrode distance for different gas pressures.

Tasks:

Measure the voltage between plane parallel electrodes at which electric breakthrough occurs in dependence on electrode distance *d* at different gas pressures *p* in the hPa range.

Create plots of the breakthrough voltage over electrode distance *d* and over product of electrode distance and pressure *pd* (Paschen curve).

5.3.20-00 Atomic resolution of the graphite surface by STM (Scanning Tunneling Microscopy)



What you can learn about ...

- ➔ Tunneling effect
- ➔ Hexagonal Structures
- ➔ Scanning Tunneling Microscopy (STM)
- ➔ Imaging on the sub nanometer scale
- ➔ Piezo-electric devices
- ➔ Local Density of States (LDOS)
- ➔ Constant-Height and Constant-Current-Mode

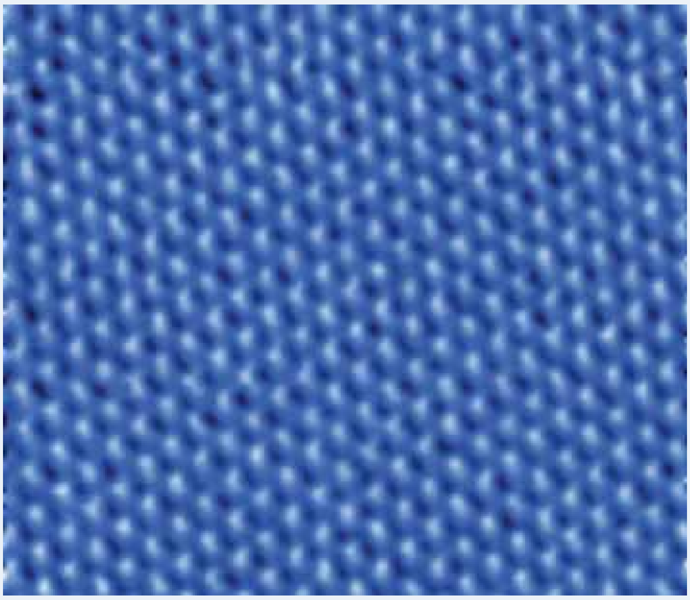
Principle:

Approaching a very sharp metal tip to a electrically conductive sample by applying a electrical field leads to a current between tip and sample without any mechanical contact. This so-called tunneling current is used to investigate the electronic topography on the sub nanometer scale of a fresh prepared graphite (HOPG) surface. By scanning the tip line-by-line across the surface graphite atoms and the hexagonal structure are imaged.

What you need:

Compact-Scanning Tunneling Microscope, complete set incl. tools, sample kit and consumables, in aluminium case	09600.99	1
Graphite model, 2D	09620.00	1
Crystal lattice kit: graphite	39840.00	1
PC, Windows® XP or higher		

Complete Equipment Set, Manual on CD-ROM included
Atomic resolution of the graphite surface by STM (Scanning Tunneling Microscopy) P2532000



Atomic resolved image of the graphite surface (5nm x 5nm).

Tasks:

1. Prepare a Pt-Ir tip and the graphite (HOPG) sample and approach the tip to the sample.
2. Investigate the topography of clean terraces and the step height between neighboring terraces in constant-height mode.
3. Image the arrangement of graphite atoms on a clean terrace by optimize tunneling and scanning parameters. Interpret the structure by analyzing angles and distances between atoms and atomic rows and by using the 2D and 3D graphite model.
4. Measure and compare images in the constant-height and constant-current mode.

Characteristic X-rays of copper 5.4.01-00

What you can learn about …

- ➔ Bremsstrahlung
- ➔ Characteristic radiation
- ➔ Energy levels
- ➔ Crystal structures
- ➔ Lattice constant
- ➔ Absorption
- ➔ Absorption edges
- ➔ Interference
- ➔ **The** Bragg equation
- ➔ Order of diffraction

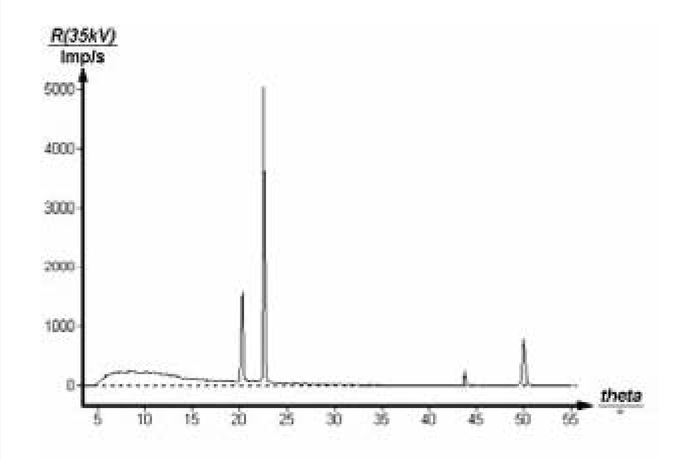
Principle:

Spectra of X-rays from a copper anode are to be analyzed by means of different monocrystals and the results plotted graphically. The energies of the characteristic lines are then to be determined from the positions of the glancing angles for the various orders of diffraction.

What you need:

X-ray basic unit, 35 kV	09058.99	1
Goniometer for X-ray Unit 35 kV	09058.10	1
Plug-in module with Cu-X-ray tube	09058.50	1
Counter tube type B, BNC cable, l = 50 cm	09005.00	1
Lithium fluorid crystal, mounted	09056.05	1
Potassium bromide crystal, mounted	09056.01	1
Software X-ray unit, 35 kV	14407.61	1
Data cable 2 x SUB-D, plug/socket, 9 pole	14602.00	1
PC, Windows® XP or higher		

Complete Equipment Set, Manual on CD-ROM included
Characteristic X-rays of copper P2540100



X-ray intensity of copper as a function of the glancing angle; LiF (100) monocrystal as Bragg analyzer.

Tasks:

1. The intensity of the X-rays emitted by the copper anode at maximum anode voltage and anode current is to be recorded as a function of the Bragg angle, using an LiF monocrystal as analyzer.
2. Step 1 is to be repeated using the KBr monocrystal as analyzer.
3. The energy values of the characteristic copper lines are to be calculated and compared with the energy differences of the copper energy terms.

5.4.02-00 Characteristic X-rays of molybdenum

What you can learn about …

- ➔ X-ray tube
- ➔ Bremsstrahlung
- ➔ Characteristic radiation
- ➔ Energy levels
- ➔ Crystal structures
- ➔ Lattice constant
- ➔ Absorption
- ➔ Absorption edges
- ➔ Interference
- ➔ **The** Bragg equation
- ➔ Order of diffraction

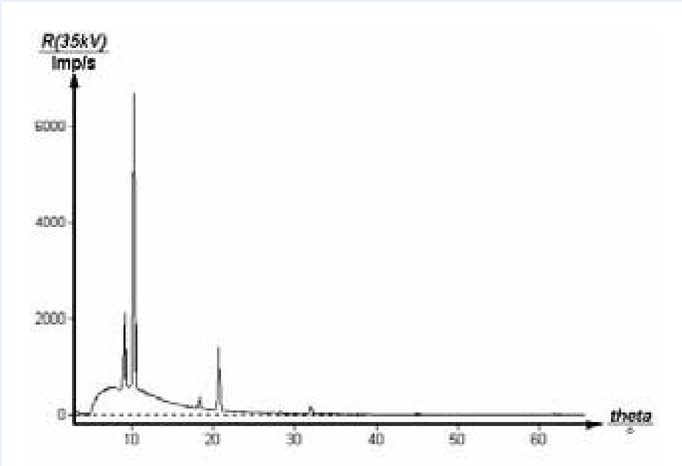
Principle:

Spectra of X-rays from a molybdenum anode are to be analyzed by means of different monocrystals and the results plotted graphically. The energies of the characteristic lines are then to be determined from the positions of the glancing angles for the various orders of diffraction.

What you need:

X-ray basic unit, 35 kV	09058.99	1
Goniometer for X-ray Unit 35 kV	09058.10	1
Plug-in module with Mo-X-ray tube	09058.60	1
Counter tube type B, BNC cable, l = 50 cm	09005.00	1
Lithium fluorid crystal, mounted	09056.05	1
Potassium bromide crystal, mounted	09056.01	1
Software x-ray unit, 35 kV	14407.61	1
Data cable 2 x SUB-D, plug/socket, 9 pole	14602.00	1
PC, Windows® XP or higher		

Complete Equipment Set, Manual on CD-ROM included
Characteristik X-rays of molybdenum P2540200



X-ray intensity of molybdenum as a function of the glancing angle; LiF (100) monocrystal as Bragg analyzer.

Tasks:

1. The intensity of the X-rays emitted by the molybdenum anode at maximum anode voltage and anode current is to be recorded as a function of the Bragg angle, using an LiF monocrystal as analyzer.
2. Step 1 is to be repeated using the KBr monocrystal as analyzer.
3. The energy values of the characteristic molybdenum lines are to be calculated and compared with the energy differences of the molybdenum energy terms.

Characteristic X-rays of iron 5.4.03-00

What you can learn about …

- X-ray tube
- Bremsstrahlung
- Characteristic radiation
- Energy levels
- Crystal structures
- Lattice constant
- Absorption
- Absorption edges
- Interference
- **The** Bragg equation
- Order of diffraction

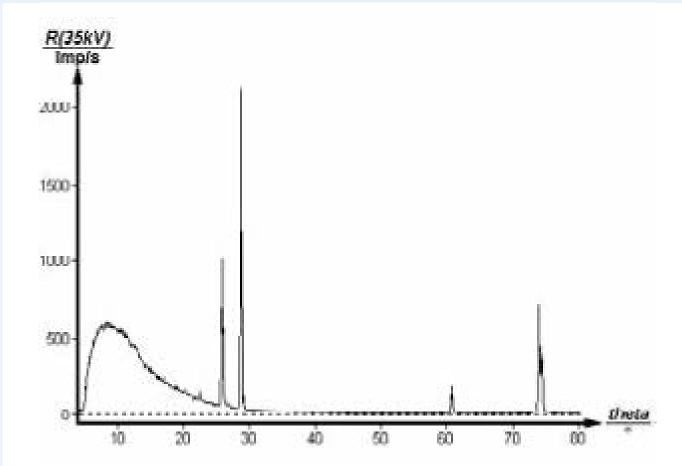
Principle:

Spectra of X-rays from a iron anode are to be analyzed by means of different monocrystals and the results plotted graphically. The energies of the characteristic lines are then to be determined from the positions of the glancing angles for the various orders of diffraction.

What you need:

X-ray basic unit, 35 kV	09058.99	1
Goniometer for X-ray Unit 35 kV	09058.10	1
Plug-in module with Fe-X-ray tube	09058.70	1
Counter tube type B, BNC cable, l = 50 cm	09005.00	1
Lithium fluorid crystal, mounted	09056.05	1
Potassium bromide crystal, mounted	09056.01	1
Software X-ray unit, 35 kV	14407.61	1
Data cable 2 x SUB-D, plug/socket, 9 pole	14602.00	1
PC, Windows® XP or higher		

Complete Equipment Set, Manual on CD-ROM included
Characteristik X-rays of iron P2540300



X-ray intensity of iron as a function of the glancing angle; LiF (100) monocrystal as Bragg analyzer.

Tasks:

1. The intensity of the X-rays emitted by the iron anode at maximum anode voltage and anode current is to be recorded as a function of the Bragg angle, using an LiF monocrystal as analyzer.
2. Step 1 is to be repeated using the KBr monocrystal as analyzer.
3. The energy values of the characteristic iron lines are to be calculated and compared with the energy differences of the iron energy terms.

5.4.04-00 The intensity of characteristic X-rays as a function of anode current and anode voltage

What you can learn about …

- ➔ Characteristic X-ray radiation
- ➔ Energy levels
- ➔ **The** Bragg equation
- ➔ Intensity of characteristic X-rays

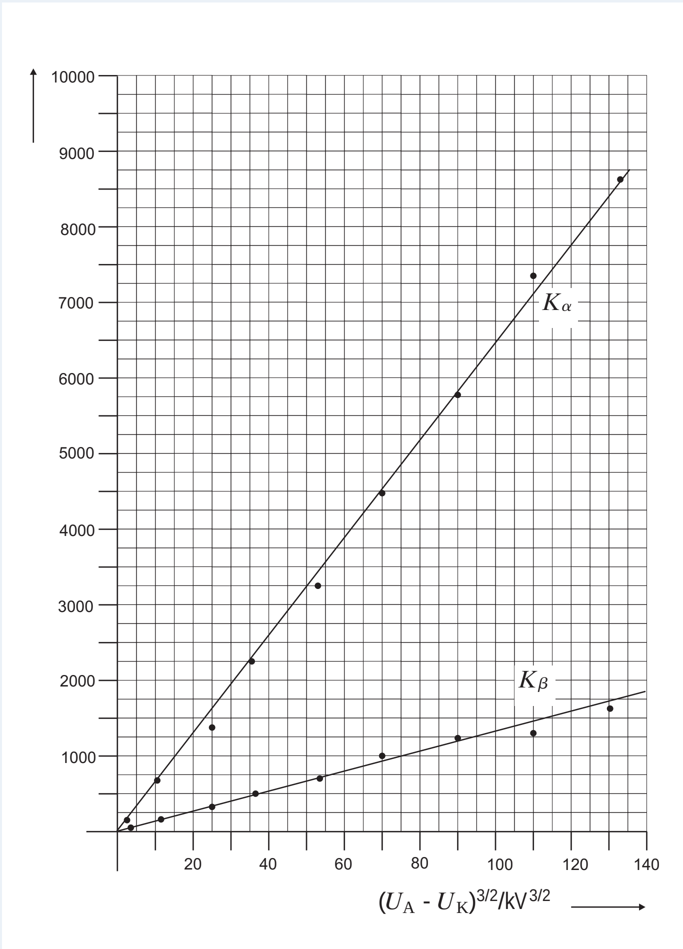
Principle:

Polychromatic X-radiation from a copper anode is to be directed against an LiF monocrystal so that the wavelengths can be analyzed according to Bragg. The dependency of the characteristic K_α and K_β radiation on the anode current and anode voltage are to be determined.

What you need:

X-ray basic unit, 35 kV	09058.99	1
Goniometer for X-ray Unit 35 kV	09058.10	1
Plug-in module with Cu-X-ray tube	09058.50	1
Counter tube type B, BNC cable, l = 50 cm	09005.00	1
Lithium fluorid crystal, mounted	09056.05	1
Software X-ray unit, 35 kV	14407.61	1
Data cable 2 x SUB-D, plug/socket, 9 pole	14602.00	1
PC, Windows® XP or higher		

Complete Equipment Set, Manual on CD-ROM included
The intensity of characteristic X-rays as a function of anode current and anode voltage P2540400



K_α and K_β intensities as a function of $(U_A - U_K)1.5$ (I_A = const.).

Tasks:

1. The intensity spectrum of polychromatic radiation from an X-ray tube is to be recorded with the help of an LiF monocrystal.
2. The intensities of the characteristic K_α and K_β radiations are to be determined as a function of both the anode current and the anode voltage, and be plotted graphically.
3. The results of the measurement are to be compared with the theoretical intensity formula.

Monochromatization of molybdenum X-rays 5.4.05-00

What you can learn about …

- Bremsstrahlung
- Characteristic radiation
- Energy levels
- Absorption
- Absorption edges
- Interference
- Diffraction
- Bragg scattering

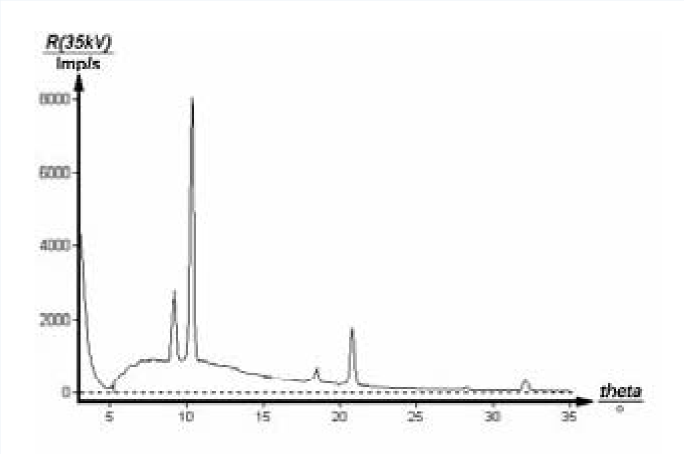
Principle:

Polychromatic X-rays are to be energy analyzed using various monocrystals and a suitably selected thin metal foil having an absorption edge which drastically reduces the intensity of an unwanted line.

What you need:

X-ray basic unit, 35 kV	09058.99	1
Goniometer for X-ray Unit 35 kV	09058.10	1
Plug-in module with Mo-X-ray tube	09058.60	1
Counter tube type B, BNC cable, l = 50 cm	09005.00	1
Lithium fluorid crystal, mounted	09056.05	1
Potassium bromide crystal, mounted	09056.01	1
Diaphragm tube with Zr- foil	09058.03	1
Software X-ray unit, 35 kV	14407.61	1
Data cable 2 x SUB-D, plug/socket, 9 pole	14602.00	1
PC, Windows® XP or higher		

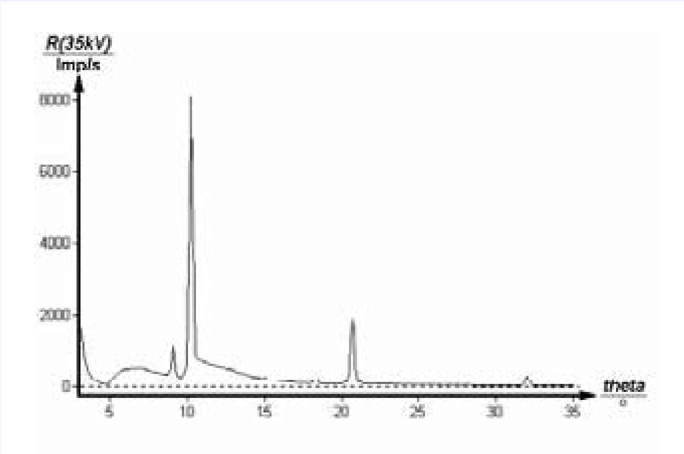
Complete Equipment Set, Manual on CD-ROM included
Monochromatization of molybdenum X-rays P2540500



Molybdenum X-ray intensity as a function of the glancing angle ϑ; LiF (100) monocrystal as analyzer.

Tasks:

1. The intensity of the X-rays emitted by the molybdenum anode is to be graphically recorded as a function of the Bragg angle, using LiF and KBr monocrystals successively as analyzers.
2. The energy values of the characteristic molybdenum lines are to be calculated.
3. The LiF monocrystal is to be used to filter out a characteristic line and the appertaining monochromatization graphically recorded.
4. Step 1 is to be repeated, using a zirconium filter.



Molybdenum X-ray monochromatization with Zr filter; LiF (100) monocrystal as analyzer.

5.4.06-00 Monochromatization of copper X-rays

What you can learn about ...

- ➔ Bremsstrahlung
- ➔ Characteristic radiation
- ➔ Energy levels
- ➔ Absorption
- ➔ Absorption edges
- ➔ Interference
- ➔ Diffraction
- ➔ Bragg scattering

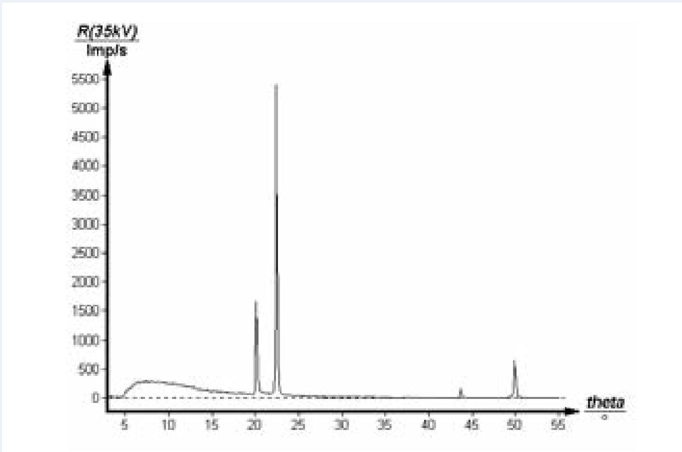
Principle:

Polychromatic X-rays are to be energy analyzed using various monocrystals and a suitably selected thin metal foil having an absorption edge which drastically reduces the intensity of an unwanted line.

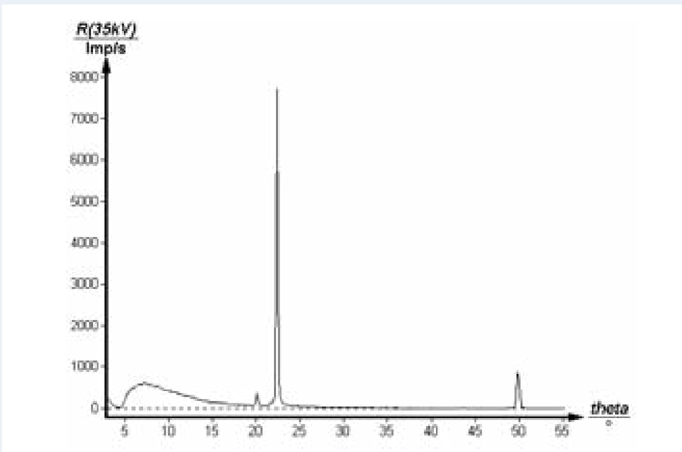
What you need:

X-ray basic unit, 35 kV	09058.99	1
Goniometer for X-ray Unit 35 kV	09058.10	1
Plug-in module with Cu-X-ray tube	09058.50	1
Counter tube type B, BNC cable, l = 50 cm	09005.00	1
Lithium fluorid crystal, mounted	09056.05	1
Potassium bromide crystal, mounted	09056.01	1
Diaphragm tube with Ni- foil	09056.03	1
Software X-ray unit, 35 kV	14407.61	1
Data cable 2 x SUB-D, plug/socket, 9 pole	14602.00	1
PC, Windows® XP or higher		

Complete Equipment Set, Manual on CD-ROM included
Monochromatization of copper X-rays P2540600



Copper X-ray intensity as a function of the glancing angle ϑ; LiF (100) monocrystal as analyzer (Diameter of diaphragm tube d = 1 mm).



Copper X-ray monochromatization with Ni filter; LiF (100) monocrystal as analyzer (Diameter of diaphragm tube d = 2 mm).

Tasks:

1. The intensity of the X-rays emitted by the copper anode is to be graphically recorded as a function of the Bragg angle, using LiF and KBr monocrystals successively as analyzers.
2. The energy values of the characteristic copper lines are to be calculated.
3. The LiF monocrystal is to be used to filter out a characteristic line and the appertaining monochromatization graphically recorded.
4. Step 1 is to be repeated, using a nickel filter.

K_α doublet splitting of molybdenum X-rays / fine structure 5.4.07-00

What you can learn about ...

- ➔ Characteristic X-ray radiation
- ➔ Energy levels
- ➔ Selection rules
- ➔ The Bragg equation
- ➔ Energy term symbols

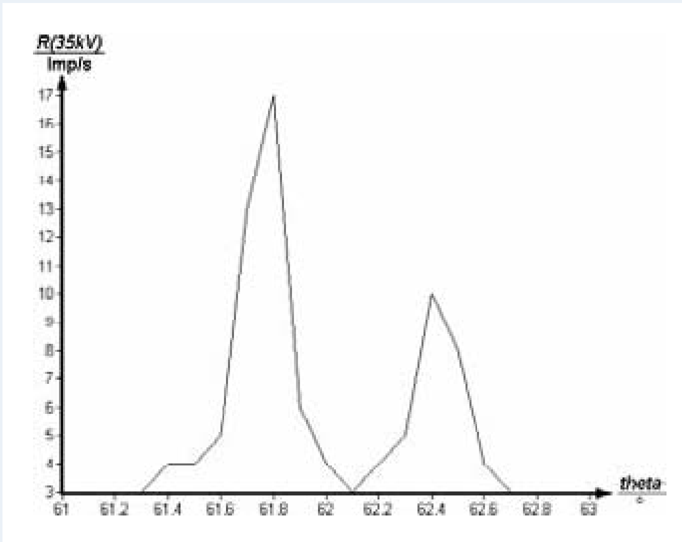
Principle:

The polychromatic molybdenum X-ray spectrum is to analyzed by means of a monocrystal. The energy of the characteristic lines is to be determined from the positions of the glancing angles at various orders of diffraction. The separation of the K_α doublet in higher order diffraction is to be examined.

What you need:

X-ray basic unit, 35 kV	09058.99	1
Goniometer for X-ray Unit 35 kV	09058.10	1
Plug-in module with Mo-X-ray tube	09058.60	1
Counter tube type B, BNC cable, l = 50 cm	09005.00	1
Lithium fluorid crystal, mounted	09056.05	1
Software X-ray unit, 35 kV	14407.61	1
Data cable 2 x SUB-D, plug/socket, 9 pole	14602.00	1
PC, Windows® XP or higher		

Complete Equipment Set, Manual on CD-ROM included
K_α doublet splitting of molybdenum X-rays / fine structure P2540700



X-ray spectrum of molybdenum; separation of the $K_{\alpha 1}$ and $K_{\alpha 2}$ lines in 5^{th} order diffraction.

Tasks:

1. The intensity of the X-rays emitted by the molybdenum anode at maximum anode voltage is to be recorded as a function of the Bragg angle, using an LiF monocrystal as analyzer.
2. The wavelengths and ratio of the intensities of the two K_α lines are to be determined in high order diffraction, and a comparison made with the theoretical predictions.

5.4.08-00 K_α doublet splitting of iron X-rays / fine structure

What you can learn about …

- ➔ Characteristic X-ray radiation
- ➔ Energy levels
- ➔ Selection rules
- ➔ **The** Bragg equation
- ➔ Energy term symbols

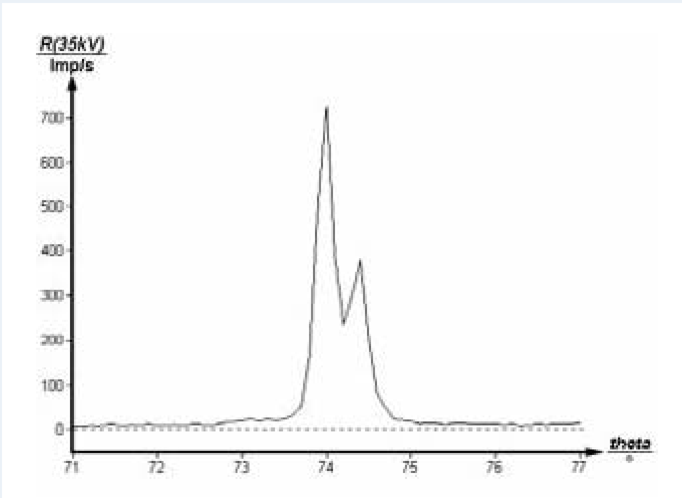
Principle:

The polychromatic iron X-ray spectrum is to analyzed by means of a monocrystal. The energy of the characteristic lines is to be determined from the positions of the glancing angles for various orders of diffraction. The separation of the K_α doublet in higher order diffraction is to be examined.

What you need:

X-ray basic unit, 35 kV	09058.99	1
Goniometer for X-ray Unit 35 kV	09058.10	1
Plug-in module with Fe-X-ray tube	09058.70	1
Counter tube type B, BNC cable, l = 50 cm	09005.00	1
Lithium fluorid crystal, mounted	09056.05	1
Software X-ray unit, 35 kV	14407.61	1
Data cable 2 x SUB-D, plug/socket, 9 pole	14602.00	1
PC, Windows® XP or higher		

Complete Equipment Set, Manual on CD-ROM included
K_α doublet splitting of iron X-rays / fine structure P2540800



X-ray spectrum of iron; separation of the $K_{\alpha 1}$ and $K_{\alpha 2}$ lines in 2^{nd} order diffraction.

Tasks:

1. The intensity of the X-rays emitted by the iron anode at maximum anode voltage is to be recorded as a function of the Bragg angle using an LiF monocrystal as analyzer.
2. The wavelengths and ratio of the intensities of the two K_α lines are to be determined in high order diffraction, and a comparison made with the theoretical predictions.

Duane-Hunt displacement law and Planck's "quantum of action" 5.4.09-00

What you can learn about …

- → X-ray tube
- → Bremsstrahlung
- → Characteristic X-ray radiation
- → Energy levels
- → Crystal structures
- → Lattice constant
- → Interference
- → **The** Bragg equation

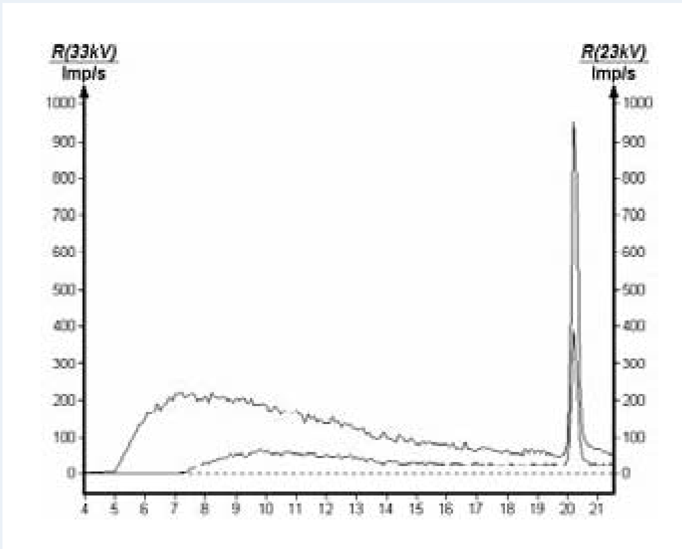
Principle:

X-ray spectra are to be recorded as a function of the anode voltage. The short wavelength limit of the bremsspectrum is to be used to determine the agreement with the Duane-Hunt displacement law, and to determine Planck's "quantum of action".

What you need:

X-ray basic unit, 35 kV	09058.99	1
Goniometer for X-ray unit, 35 kV	09058.10	1
Plug-in module with Cu X-ray tube	09058.50	1
Counter tube, type B, BNC cable, l = 50 cm	09005.00	1
Lithium fluoride crystal, mounted	09056.05	1
Software X-ray unit, 35 kV	14407.61	1
Data cable 2 x SUB-D, plug/socket, 9 pole	14602.00	1
PC, Windows® XP or higher		

Complete Equipment Set, Manual on CD-ROM included
Duane-Hunt displacement law and Planck's "quantum of action" P2540900



Bremsstrahlung as function of two anode voltages; Glancing angle ϑ as x-axis in degree.

Tasks:

1. The intensity of the X-rays emitted by the copper anode at various anode voltages is to be recorded as a function of the Bragg angle, using an LiF monocrystal.
2. The short wavelength limit (= maximum energy) of the bremsspectrum is to be determined for the spectra obtained in (1).
3. The results are to be used to verify the Duane-Hunt displacement law, and to determine Planck's "quantum of action".

5.4.10-00 Characteristic X-ray lines of different anode materials/Moseley's Law;
Rydberg frequency and screening constant

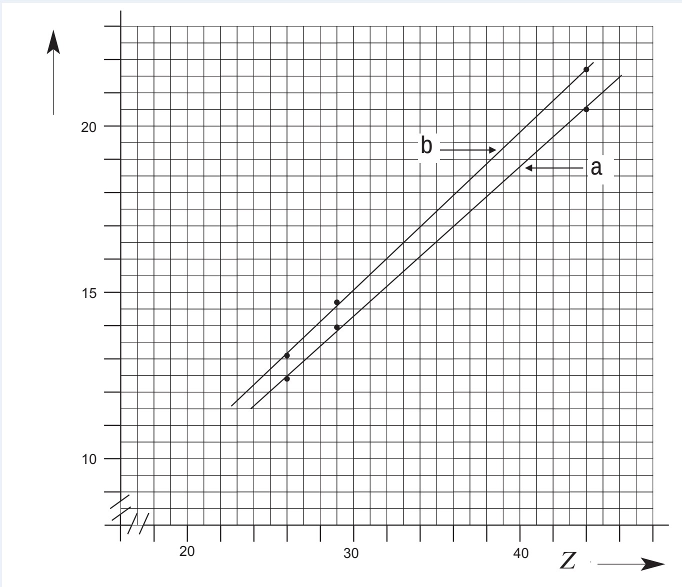
What you can learn about …
- → Characteristic X-ray radiation
- → Bohr's atomic model
- → Energy levels
- → Binding energy
- → Bragg scattering
- → Moseley's law; Rydberg frequency and screening constant

Principle:
The X-rays emanating from three X-ray tubes, each with a different anode material, are to be analyzed and the wavelengths of the characteristic X-ray lines from each are to be determined, so that Moseley's Law can be verified.

What you need:

X-ray basic unit, 35 kV	09058.99	1
Goniometer for X-ray Unit 35 kV	09058.10	1
Plug-in module with Cu-X-ray tube	09058.50	1
Plug-in module with Mo-X-ray tube	09058.60	1
Plug-in module with Fe-X-ray tube	09058.70	1
Counter tube type B, BNC cable, l = 50 cm	09005.00	1
Lithium fluorid crystal, mounted	09056.05	1
Software x-ray unit, 35 kV	14407.61	1
Data cable 2 x SUB-D, plug/socket, 9 pole	14602.00	1
PC, Windows® XP or higher		

Complete Equipment Set, Manual on CD-ROM included
Characteristik X-ray lines of different anode materials / Moseley's Law;
Rydberg frequency and screening constant P2541000



Moseley straight lines
Curve a: Transition $n_2 \rightarrow n_1$ (K_α line)
Curve b: Transition $n_3 \rightarrow n_1$ (K_β line)

Tasks:
1. The X-ray spectra emanated from Fe, Cu and Mo X-ray tubes are to be recorded.
2. The Bragg angles of the characteristic lines are to be determined from the spectra, and then be used to determine their wavelengths and frequencies.
3. The Rydberg constants and the screening constants are to be determined from the Moseley straight lines.

Absorption of X-rays 5.4.11-00

What you can learn about …

- ➔ Bremsstrahlung
- ➔ Characteristic radiation
- ➔ Bragg scattering
- ➔ Law of absorption
- ➔ Mass absorption coefficient
- ➔ Absorption edges
- ➔ Half-value thickness
- ➔ Photoelectric effect
- ➔ Compton scattering
- ➔ Pair production

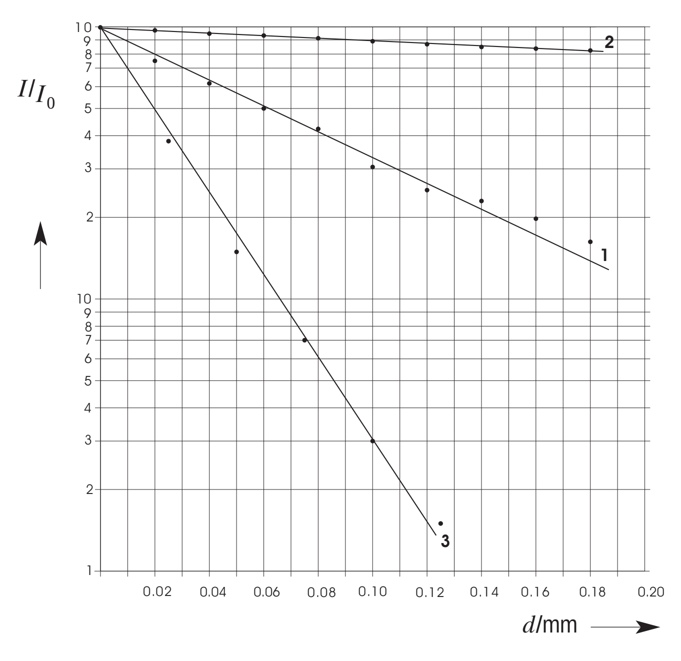
Principle:

Polychromatic X-rays are to be energy selected using a monocrystal analyzer. The monochromatic radiation obtained is to serve as the primary radiation source for examination of the absorption behaviour of various metals as a function of the absorber thickness and the wavelength of the primary radiation.

What you need:

X-ray basic unit, 35 kV	09058.99	1
Goniometer for X-ray Unit 35 kV	09058.10	1
Plug-in module with Cu-X-ray tube	09058.50	1
Counter tube type B, BNC cable, l = 50 cm	09005.00	1
Lithium fluorid crystal, mounted	09056.05	1
Absorption set for x-rays	09056.02	1
Software for X-ray Unit 35 kV	14407.61	1
Data cable 2 x SUB-D, plug/socket, 9 pole	14602.00	1
PC, Windows® XP or higher		

Complete Equipment Set, Manual on CD-ROM included
Absorption of X-rays P2541100



Semi-logarithmic representation of the pulse rates as a function of the absorber thickness.
U_a = 35 kV, I_a = 1 mA.
Curve 1: Al (Z = 13); λ = 139 pm
Curve 2: Al (Z = 13); λ = 70 pm
Curve 3: Zn (Z = 30); λ = 139 pm.

Tasks:

1. The intensity attenuation of the primary radiation is to be measured for aluminium and zinc as a function of the material thickness and at two different wavelengths. The mass absorption coefficients are to be determined from the graphical representation of the measured values.
2. The mass absorption coefficients for aluminium, zinc and tin foils of constant thickness are to be determined as a function of the wavelength. It is to be shown from the graphical representation that $\mu/\rho = f(\lambda^3)$.
3. The absorption coefficients for copper and nickel are to be determined as a function of the wavelength and the measured values plotted. The energies of the K levels are to be calculated.
4. The validity of $\mu/\rho = f(Z^3)$ is to be proved.

5.4.12-00 K- and L-absorption edges of X-rays / Moseley's Law and the Rydberg constant

What you can learn about …

- → X-ray bremsstrahlung
- → Characteristic radiation
- → Bragg equation
- → Bohr's atomic model
- → Atomic energy level scheme
- → Moseley's law
- → Rydberg constant
- → Screening constant

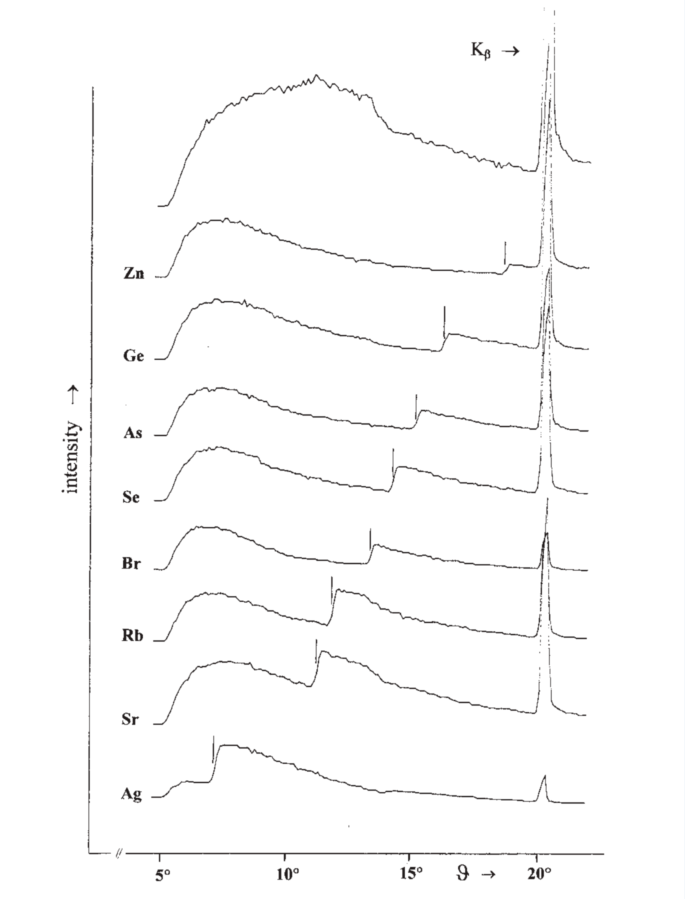
Principle:

Samples of various elements of different atomic numbers are to be irradiated with X-rays of a known spectral distribution, and the energy of the transmitted intensities analyzed using a monocrystal analyzer. The Rydberg constant and screening constants are to be found by determining the energy at which absorption edges occur.

What you need:

X-ray basic unit, 35 kV	09058.99	1
Goniometer for X-ray Unit 35 kV	09058.10	1
Plug-in module with Cu-X-ray tube	09058.50	1
Counter tube type B, BNC cable, l = 50 cm	09005.00	1
Lithium fluorid crystal, mounted	09056.05	1
Set of chemicals for edge absorption	09056.04	1
Silver nitrate, cryst. 15 g	30222.00	1
Mortar with pestle, 70 ml, porcelain	32603.00	1
Spoon with spatula end, l = 150 mm, steel, micro	33393.00	1
Software x-ray unit, 35 kV	14407.61	1
Data cable 2 x SUB-D, plug/socket, 9 pole	14602.00	1
PC, Windows® XP or higher		

Complete Equipment Set, Manual on CD-ROM included
K- and L-absorption edges of X-rays / Moseley's Law and Rydberg constant P2541200



X-ray spectra of copper without absorber and with K absorption edges for various absorbers.

Tasks:

1. The intensity of the X-rays emitted from the copper anode is to be recorded as a function of the Bragg angle using an LiF monocrystal as analyzer.
2. The K absorption edges of different absorber materials are to be found.
3. The Rydberg and screening constants are to be calculated from the energy values of the K absorption edges.
4. The L absorption edges of different absorber materials are to be found.
5. The Rydberg constant is to be calculated from the energy values of the L absorption edges.

Examination of the structure of NaCl monocrystals with different orientations 5.4.13-00

What you can learn about ...

- ➔ Characteristic X-ray radiation
- ➔ Energy levels
- ➔ Crystal structures
- ➔ Reciprocal lattice
- ➔ Miller indices
- ➔ Bragg scattering
- ➔ Atomic form factor
- ➔ Structure factor

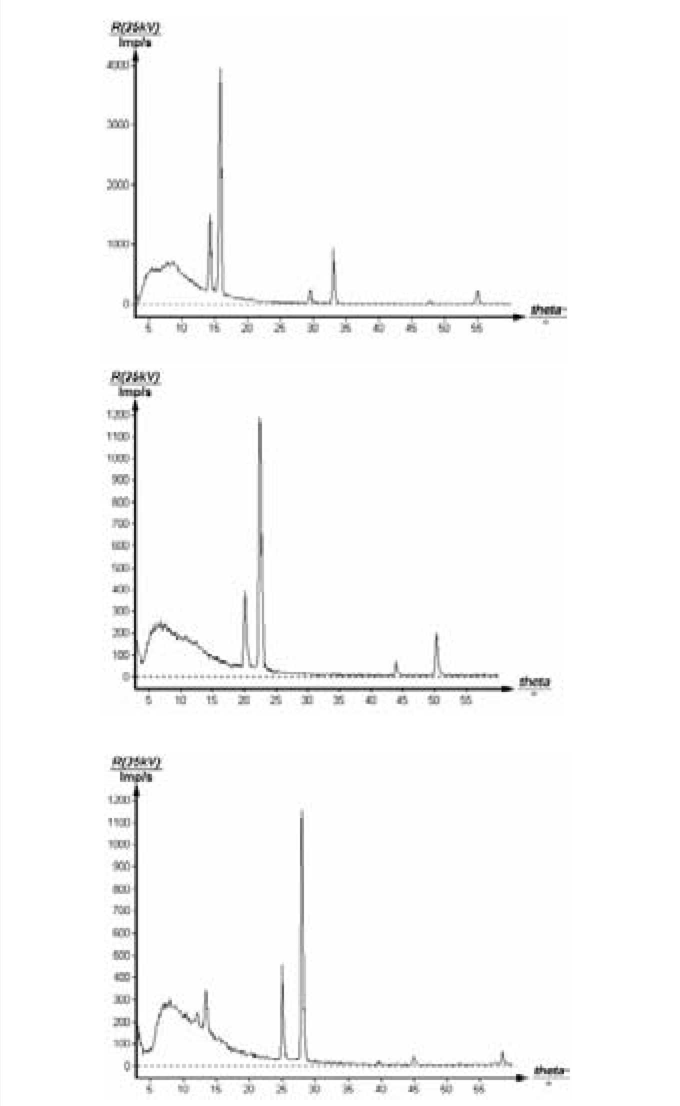
Principle:

Polychromatic X-rays are to be directed against NaCl monocrystals with different orientations. The spacing between the lattice planes of each monocrystals then to be determined by analyzing the wavelength-dependent intensity of the reflected radiation.

What you need:

X-ray basic unit, 35 kV	09058.99	1
Goniometer for X-ray Unit 35 kV	09058.10	1
Plug-in module with Cu-X-ray tube	09058.50	1
Counter tube type B, BNC cable, l = 50 cm	09005.00	1
Universal crystal holder for X-Ray Unit	09058.02	1
NaCl-monocrystals, set of 3	09058.01	1
Software X-ray unit, 35 kV	14407.61	1
Data cable 2 x SUB-D, plug/socket, 9 pole	14602.00	1
PC, Windows® XP or higher		

Complete Equipment Set, Manual on CD-ROM included
Examination of the structure of NaCl monocrystals with different orientations P2541300



X-ray intensity of copper as a function of the glancing angle: NaCl monocrystal with different orientations as Bragg-analyzer: 1-(100); 2-(110); 3-(111)

Tasks:

1. NaCl monocrystals with the orientations (100), (110) and (111) are each to be separately used to record an intensity spectrum of the polychromatic radiation emanated by the X-ray tube.
2. The Bragg angles of the characteristic radiations are to be determined from the spectra, and the distances between lattice planes calculated for each orientation.
3. The planes of reflection and their Miller indices are to be found.

5.4.14/15-00 X-ray investigation of different crystal structures / Debye-Scherrer powder method

Set-up of experiment P2541400

What you can learn about …

- → Crystal lattices
- → Crystal systems
- → Reciprocal lattice
- → Miller indices
- → Structure amplitude
- → Atomic form factor
- → Bragg scattering

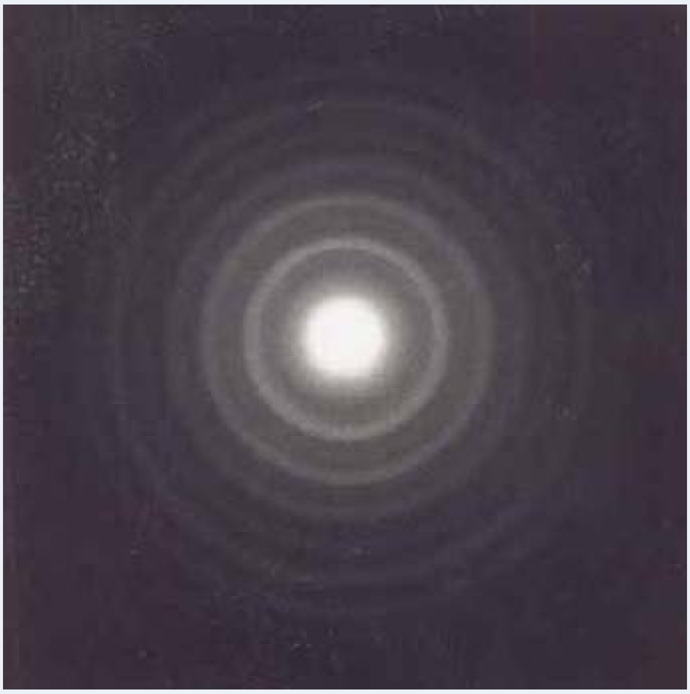
Principle:

Polycrystalline samples are to be irradiated by an X-ray beam and the resulting diffraction patterns recorded on film and evaluated.

What you need:

Item	Order No.	Exp. P2541400 with cubic structures	Exp. P2541500 with hexagonal structures
X-ray basic unit, 35 kV	09058.99	1	1
Plug-in module with Mo-X-ray tube	09058.60	1	1
Mortar with pestle, 70 ml, porcelain	32603.00	1	
Spoon with spatula end, l = 150 mm, steel, micro	33393.00	1	
Sodium chloride, 250 g	30155.25	1	
Caesium chloride 5 g	31171.02	1	
Diaphragm tube with Zr- foil	09058.03		1
Vernier caliper, plastic	03011.00	1	1
Film holder	09058.08	1	1
X-ray films, wet chemical, 100 x 100 mm, 100 pieces	09058.23	1	1
Bag for x-ray films, 10 pieces	09058.22	1	1
X-ray film developer, for 4.5 l solution	06696.20	1	1
X-ray film fixing, for 4.5 l solution	06696.30	1	1
Tray (PP), 180 x 240 mm, white	47481.00	3	3

Complete Equipment Set, Manual on CD-ROM included
X-ray investigation of different crystal structures / Debye-Scherrer powder method
… of cubic crystal structures P2541400
… of hexagonal crystal structures P2541500



Debye-Scherrer pattern of a powdered sample of CsCl. Thickness of the sample, 0.4 mm. Exposure time, 2.0 h. Mo X-ray tube: U_A = 35 kV; I_A = 1 mA.

Tasks:

1. Debye-Scherrer photographs are to be taken of powdered samples of sodium chloride and caesium chloride.
2. The Debye-Scherrer rings are to be evaluated and assigned to the corresponding lattice planes.
3. The lattice constants of the sample materials are to be determined.
4. The number of atoms in the unit cells of each sample are to be determined.

X-ray investigation of crystal structures / Laue method 5.4.16-00

What you can learn about …

- → Crystal lattices
- → Crystal systems
- → Crystal classes
- → Bravais lattice
- → Reciprocal lattice
- → Miller indices
- → Structure amplitude
- → Atomic form factor
- → The Bragg equation

Principle:

A monocrystal is to be irradiated by a polychromatic X-ray beam and the resulting diffraction patterns recorded on film and evaluated.

What you need:

X-ray basic unit, 35 kV	09058.99	1
Plug-in module with Mo-X-ray tube	09058.60	1
Lithium fluorid crystal, mounted	09056.05	1
Crystal holder for lane diffraction	09058.11	1
Film holder	09058.08	1
Vernier caliper, plastic	03011.00	1
X-ray films, wet chemical, 100 x 100 mm, 100 pieces	09058.23	1
Bag for x-ray films, 10 pieces	09058.22	1
X-ray film developer, for 4.5 l solution	06696.20	1
X-ray film fixing, for 4.5 l solution	06696.30	1
Tray (PP), 180 x 240 mm, white	47481.00	3

Complete Equipment Set, Manual on CD-ROM included
X-ray investigation of crystal structures / Laue method P2541600

Laue pattern of an LiF (100) crystal.
Cu X-ray tube: U_A = 35 kV; I_A = 1 mA
Distance between sample and film: D = 19 mm
Exposure time: t = 120 min

Tasks:

1. The Laue diffraction of an LiF monocrystal is to be recorded on a film.
2. The Miller indices of the corresponding crystal surfaces are to be assigned to the Laue reflections.

5.4.17-00 Compton scattering of X-rays

What you can learn about ...

- → Compton effect
- → Compton wavelength
- → Rest energy
- → Absorption
- → Transmission
- → Conservation of energy and momentum
- → X-rays
- → The Bragg equation

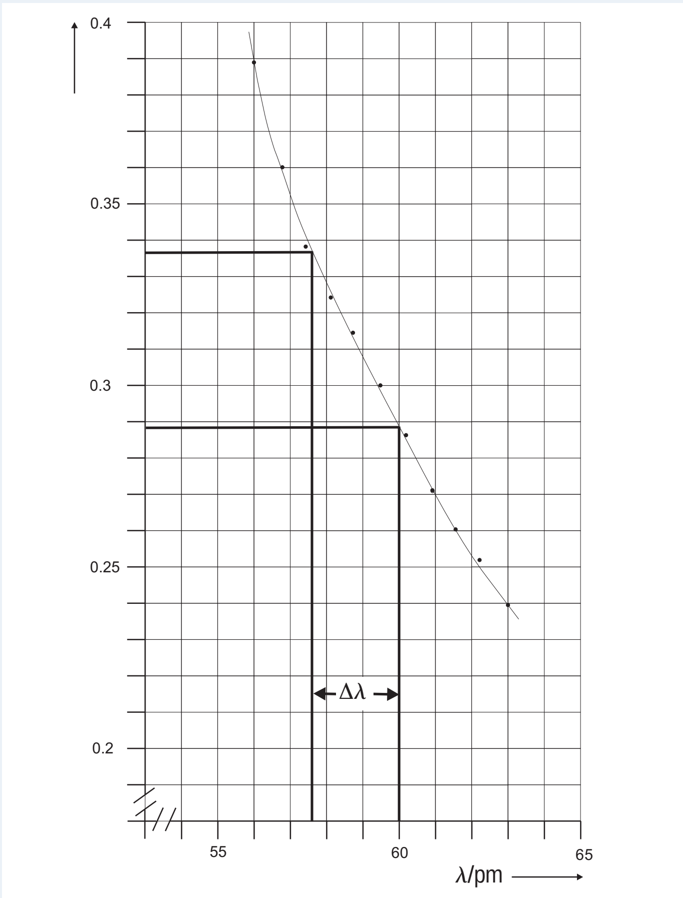
Principle:

Compton scattering is to be achieved by directing an X-ray beam against a piece of plastic. The portions of the scattered X-rays at various angles is to be measured with a counter tube. Measurements are to be made with an absorber positioned in front of and behind the scatterer, so that the Compton wavelength can be determined from the varying intensity attenuation of the X-rays at different wavelengths, using a premeasured transmission curve.

What you need:

X-ray basic unit, 35 kV	09058.99	1
Goniometer for X-ray Unit 35 kV	09058.10	1
Plug-in module with Cu-X-ray tube	09058.50	1
Counter tube type B, BNC cable, l = 50 cm	09005.00	1
Lithium fluorid crystal, mounted	09056.05	1
Compton attachment for X-ray Unit 35 kV	09058.04	1
Software for X-ray Unit 35 kV	14407.61	1
Data cable 2 x SUB-D, plug/socket, 9 pole	14602.00	1
PC, Windows® XP or higher		

Complete Equipment Set, Manual on CD-ROM included
Compton scattering of X-rays P2541700



Transmission curve of aluminium.
Experimental set-up for 90° Compton scattering.

Tasks:

1. The transmission of an aluminium absorber is to be determined as a function of the wavelength of the X-rays by means of Bragg scattering and the measured values plotted graphically.
2. A scatterer is to be used and the intensity of the X-rays scattered at different angles determined. The intensity attenuation which occurs on placing an aluminium absorber in front of, and behind, the scatterer is to be determined for the same angles as previously, and the different transmission coefficients then calculated.
3. The different transmission coefficients and the transmission curve are to be used to determine the changes in wavelengths.
4. The Compton wavelength for 90° scattering is to be determined and compared with the theoretical value.

X-ray dosimetry 5.4.18-00

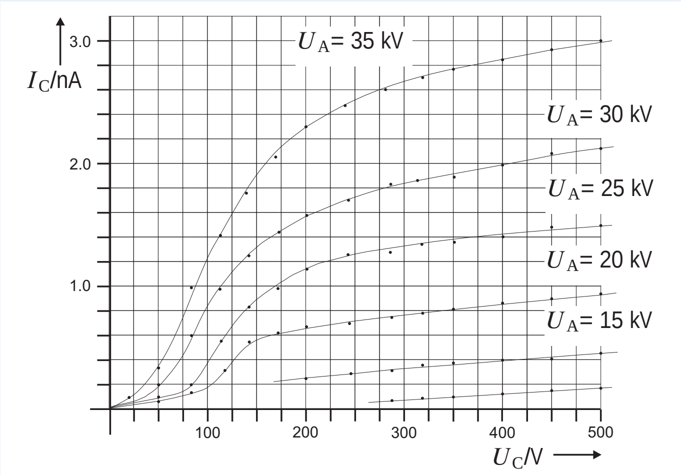
What you can learn about …
- → X-rays
- → Absorption inverse square law
- → Ionizing energy
- → Energy dose
- → Equivalent dose and ion dose and their rates
- → Q factor
- → Local ion dose rate
- → Dosimeter

Principle:
The molecules of air within a plate capacitor are to be ionized by X-rays. The ion dose, ion dose rate and local ion dose rate are to be calculated from the ionization current and the radiated mass of air.

What you need:

X-ray basic unit, 35 kV	09058.99	1
Plug-in module with Cu-X-ray tube	09058.50	1
Capacitor plates for X-ray Unit 35 kV	09058.05	1
Power supply, regulated, 0...600 V-	13672.93	1
Direct current measuring amplifier	13620.93	1
Digital multimeter 2010	07128.00	2
High value resistors, 50 MΩ	07159.00	1
Adapter, BNC socket - 4 mm plug	07542.20	1
Screened cable, BNC, l = 30 cm	07542.10	1
Connecting cable, 4 mm plug, 32 A, blue, l = 10 cm	07359.04	2
Connecting cable, 4 mm plug, 32 A, red, l = 50 cm	07361.01	2
Connecting cable, 4 mm plug, 32 A, blue, l = 50 cm	07361.04	2
Connecting cable, 4 mm plug, 32 A, red, l = 75 cm	07362.01	2

Complete Equipment Set, Manual on CD-ROM included
X-ray dosimetry P2541800



Ionization current I_C as a function of capacitor voltage U_C for various anode voltages U_A. Diaphragm tube d = 5 mm; I_A = 1 mA.

Tasks:
1. The ion current at maximum anode voltage is to be measured and graphically recorded as a function of the capacitor voltage by using two different beam limiting apertures.
2. The ion dose rate is to be determined from the saturation current values and the air masses penetrated by radiation are to be calculated.
3. The energy dose rate and various local ion dose rates are to be calculated.
4. Using the d = 5 mm aperture, the ion current is to be determined and graphically recorded at various anode currents but with maximum anode and capacitor voltages.
5. The saturation current is to be plotted as a function of the anode voltage.
6. Using the d = 5 mm aperture, the ion current is to be determined and graphically recorded at various anode currents but with maximum anode and capacitor voltages.
7. Using the two different diaphragm tubes and the fluorescent screen, the given distance between the aperture and the radiation source at maximum anode coltage and current is to be verified.

5.4.19-00 Contrast medium experiment with a blood vessel model

What you can learn about …

- ➔ X-ray radiation
- ➔ Bremsstrahlung
- ➔ Characteristic radiation
- ➔ Law of absorption
- ➔ Mass absorption coefficient
- ➔ Contrast medium

Principle:

A liquid contrast medium is to be injected into a model of a blood vessel, which is hidden from sight and exposed to X-ray radiation, to enable the inner structure of the model to be examined on a fluorescent screen.

What you need:

X-ray basic unit, 35 kV	09058.99	1
Plug-in module with W-X-ray tube	09058.80	1
Blood vessel, model for contrast fluid	09058.06	1
Potassium iodide, 50 g	30104.05	1
Beaker, DURAN®, short form, 250 ml	36013.00	1
Wide mouth bottle with screw cap, clear glass, 250 ml	46213.00	1
Stirring rods, BORO 3.3, l = 200 mm, d = 6 mm	40485.04	1

Complete Equipment Set, Manual on CD-ROM included
Contrast medium experiment with a bood vessel model P2541900

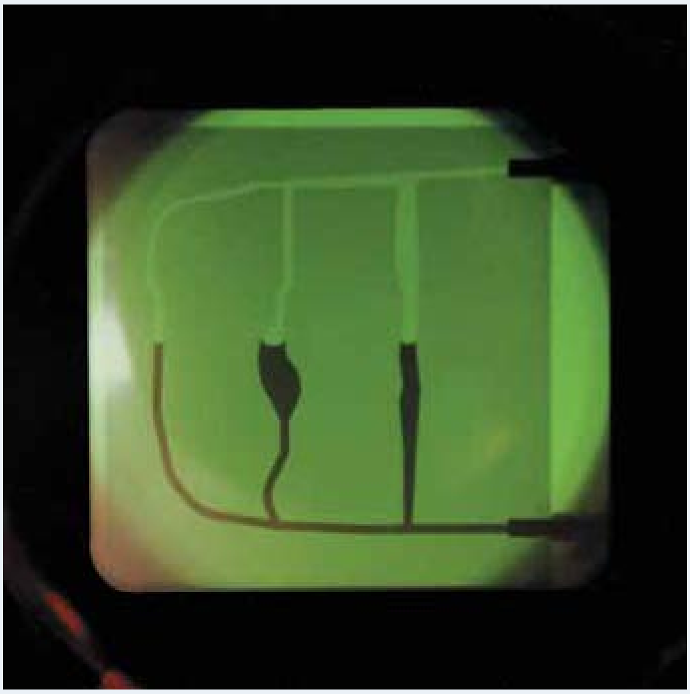


Figure shows the model filled to different extents with contrast medium.

Experimental steps:

1. A 50% potassium iodide solution is to be injected into the blood vessel model.
2. The fluorescent screen of the X-ray basic unit is to be observed to follow the course taken by the injected solution in the blood vessel model.

Determination of the length and position of an object which cannot be seen 5.4.20-00

BEST SELLER

MEDICINE

What you can learn about …

- X-ray radiation
- Bremsstrahlung
- Characteristic radiation
- Law of absorption
- Mass absorption coefficient
- Stereographic projection

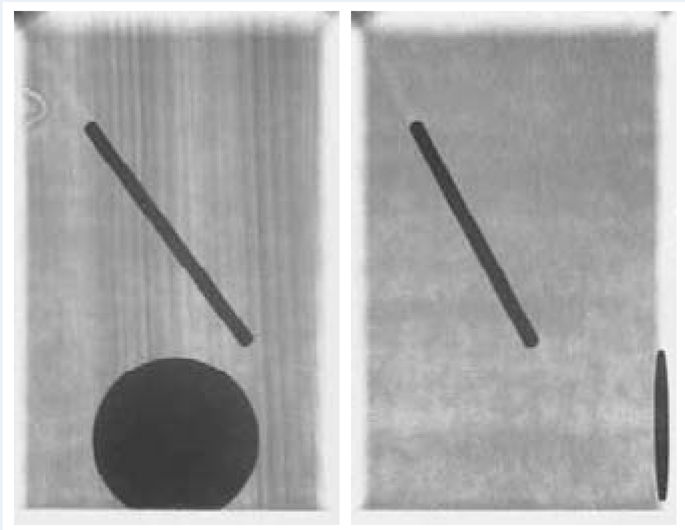
Principle:

The length and the spatial position of a metal pin which cannot be seen are to be determined from radiograms of two different planes which are at right angles to each other.

What you need:

X-ray basic unit, 35 kV	09058.99	1
Plug-in module with W-X-ray tube	09058.80	1
Film holder	09058.08	1
Implant model for X-ray photography	09058.07	1
Vernier caliper	03010.00	1
X-ray films, wet chemical, 100 x 100 mm, 100 pieces	09058.23	1
Bag for x-ray films, 10 pieces	09058.22	1
X-ray film developer, for 4.5 l solution	06696.20	1
X-ray film fixing, for 4.5 l solution	06696.30	1
Tray (PP), 180 x 240 mm, white	47481.00	3

Complete Equipment Set, Manual on CD-ROM included
Determination of the length and position of an object which cannot be seen P2542000



Projection fotos of the implant model in the xz-plane (left) and in the yz-plane (right).

Tasks:

1. The length of a metal pin which cannot be seen is to be determined from radiograms of two different planes which are at right angles to each other.
2. The true length of the pin is to be determined by taking the magnification which results from the divergence of the X-rays into account.
3. The spatial position of the pin is to be determined.

5.4.21/22/23/24/25-00 Diffractometric Debye-Scherrer patterns of different powder samples

What you can learn about …

- ➔ Wavelength
- ➔ Crystal lattices
- ➔ Crystal systems
- ➔ Bravais-lattice
- ➔ Reciprocal lattice
- ➔ Miller indices
- ➔ Structure factor
- ➔ Atomic scattering factor
- ➔ Bragg scattering
- ➔ Characteristic X-rays
- ➔ Monochromatization of X-rays

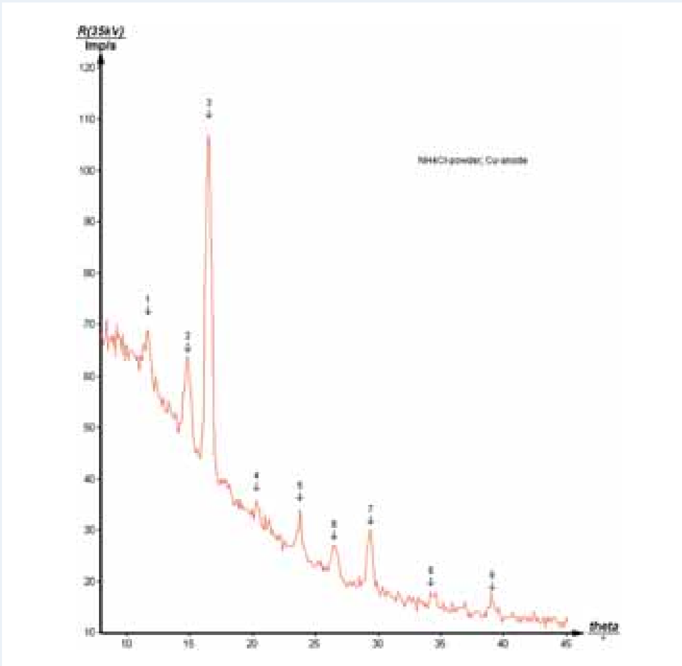
Principle:

Polycrystalline powder samples, which crystallize in the three cubic Bravais types, simple, face-centered and body-centered, are irradiated with the radiation from a Roentgen tube with a copper anode. A swivelling Geiger-Mueller counter tube detects the radiation that is constructively reflected from the various lattice planes of the crystallites. The Bragg diagrams are automatically recorded. Their evaluation gives the assignment of the Bragg lines to the individual lattice planes, their spacings as well as the lattice constants of the samples, and so also the corresponding Bravais lattice type.

What you need:

		Exp. P2542100 with the three cubic Bravais lattices	Exp. P2542200 with diamond structure	Exp. P2542300 with a hexagonal lattice structure	Exp. P2542400 with a tetragonal lattice structure	Exp. P2542500 with a cubic powder sample
X-ray basic unit, 35 kV	09058.99	1	1	1	1	1
Goniometer for X-ray Unit 35 kV	09058.10	1	1	1	1	1
Plug-in module with Cu-X-ray tube	09058.50	1	1	1	1	1
Counter tube type B, BNC cable, l = 50 cm	09005.00	1	1	1	1	1
Lithium fluorid crystal, mounted	09056.05	1	1	1	1	1
Universal crystal holder for X-Ray Unit	09058.02	1	1	1	1	1
Probe holder for powder probes (diffractometry)	09058.09	1	1	1	1	1
Diaphragm tube with Ni- foil	09056.03	1	1	1	1	1
Spoon with spatula end, l = 150 mm, steel, micro	33393.00	1	1	1	1	1
Vaseline, 100 g	30238.10	1	1	1	1	1
Mortar with pestle, 70 ml, porcelain	32603.00	1	1			1
Ammonium chloride, 250 g	30024.25	1				
Potassium chloride, 250 g	30098.25	1				
Potassium bromide 100 g	30258.10	1				
Molybdenum, Powder, 99,7%, 100 g	31767.10	1				
Germanium, Powder, 99%, 10 g	31768.03		1			
Silicium, Powder, 50 g	31155.05		1			
Zinc, powder 100 g	31978.10			1		
Lead-IV oxide, lead diox., 250 g	31122.25				1	
Sodium chloride, 250 g	30155.25					1
Software for X-ray Unit 35 kV*	14407.61	1	1	1	1	1
Data cable 2 x SUB-D, plug/socket, 9 pole*	14602.00	1	1	1	1	1
PC, Windows® XP or higher*						

Complete Equipment Set, Manual on CD-ROM included
Diffractometric Debye-Scherrer patterns of different powder samples P254 21/22/23/24/25-00



Bragg-Cu-K_{α} and Cu-K_{β}-lines of NH_4Cl.

Problems:

1. Record the intensity of the Cu X-rays back scattered by the four cubic crystal powder samples with various Bravais lattice types as a function of the scattering angle.
2. Calculate the lattice plane spacings appropriate to the angular positions of the individual Bragg lines.
3. Assign the Bragg reflections to the respective lattice planes. Determine the lattice constants of the samples and their Bravais lattice types.
4. Determine the number of atoms in the unit cell.

Diffractometric measurements to determine the intensity of Debye-Scherrer reflexes using a cubic lattice powder sample

5.4.26-00

What you can learn about ...

- → Crystal lattices
- → Crystal systems
- → Bravais-lattice
- → Reciprocal lattice
- → Miller indices
- → Structure factor
- → Atomic scattering factor
- → Lorentz-polarization factor
- → Multiplicity factor
- → Debye-Waller factor
- → Absorption factor
- → Bragg scattering
- → Characteristic X-rays
- → Monochromatization of X-rays

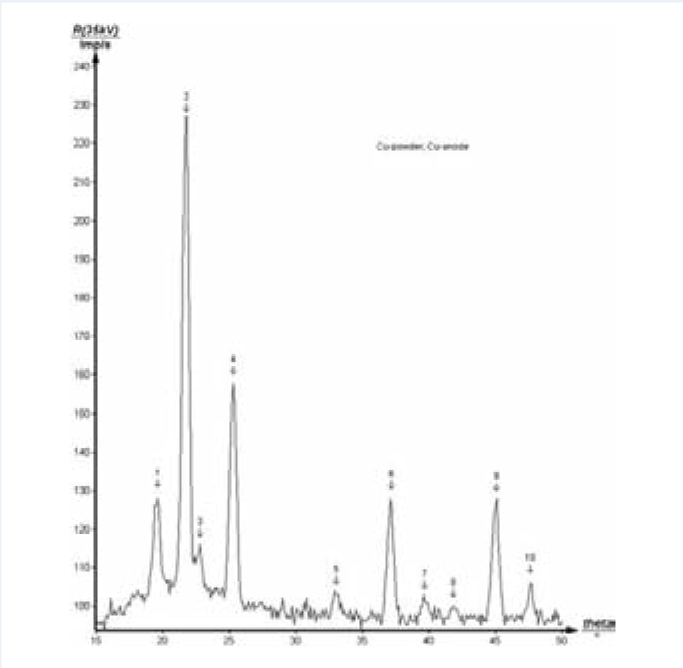
Principle:

A polycrystalline, cubic face-centered crystallizing powder sample is irradiated with the radiation from a X-ray tube with a copper anode. A Geiger-Mueller counter tube is automatically swivelled to detect the radiation that is constructively reflected from the various lattice planes of the crystallites. The Bragg diagram is automatically recorded. The intensities of the individual reflex lines are determined and compared with those theoretically expected. In addition, the evaluation allows the Bragg reflexes to be assigned to the individual lattice planes, and both their spacing and the corresponding Bravais lattice type to be determined.

What you need:

X-ray basic unit, 35 kV	09058.99	1
Goniometer for X-ray Unit 35 kV	09058.10	1
Plug-in module with Cu-X-ray tube	09058.50	1
Counter tube type B, BNC cable, l = 50 cm	09005.00	1
Lithium fluorid crystal, mounted	09056.05	1
Universal crystal holder for X-Ray Unit	09058.02	1
Probe holder for powder probes (diffractometry)	09058.09	1
Diaphragm tube with Ni- foil	09056.03	1
Spoon with spatula end, l = 150 mm, steel, micro	33393.00	1
Vaseline, 100 g	30238.10	1
Copper, powder, 100 g	30119.10	1
Software for X-ray Unit 35 kV*	14407.61	1
Data cable 2 x SUB-D, plug/socket, 9 pole*	14602.00	1
PC, Windows® XP or higher		

Complete Equipment Set, Manual on CD-ROM included
Diffractometric measurements to determine the intensity of Debye-Scherrer reflexes using a cubic lattice powder sample — P2542600



Debye-Scherrer pattern of a copper powder sample.

Tasks:

1. Record the intensity of the Cu X-rays back scattered by a cubic-crystallizing copper powder sample as a function of the scattering angle.
2. Calculate the lattice plane spacings from the angle positions of the individual Bragg lines.
3. Assign the Bragg reflexes to the respective lattice planes. Calculate the lattice constant of the substance and the Bravais lattice type.
4. Determine the intensity of the individual reflex lines and compare them with the theoretically expected intensities.
5. Determine the number of atoms in the unit cell.

5.4.27-00 Diffractometric Debye-Scherrer measurements for the examination of the texture of rolled sheets

What you can learn about ...

- → Wavelength
- → Crystal lattices
- → Crystal systems
- → Bravais-lattice
- → Reciprocal lattice
- → Miller indices
- → Structure factor
- → Atomic scattering factor
- → Bragg scattering
- → Characteristic X-rays
- → Monochromatization of X-rays
- → Fiber textures
- → Sheet textures
- → Annealing texture
- → Recrystallization

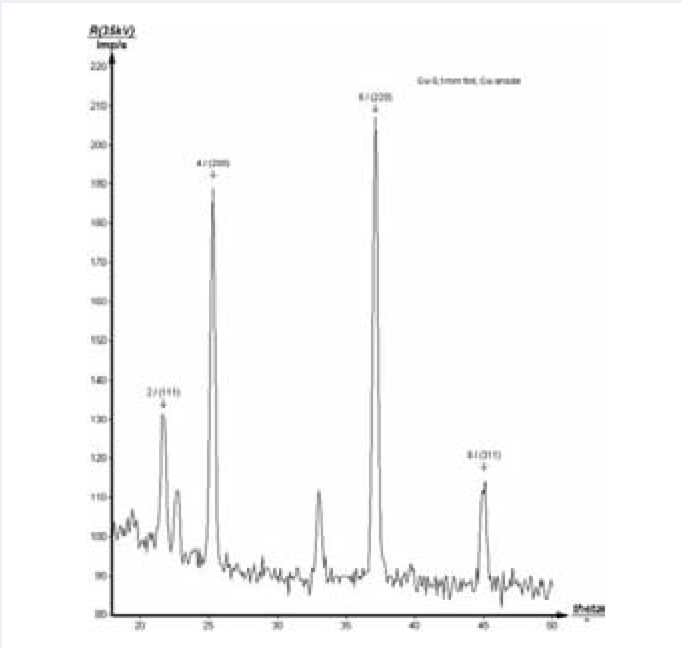
Principle:

A polycrystalline, cubic face-centered crystallizing copper powder sample and a thin copper sheet are separately irradiated with the radiation from a X-ray tube with a copper anode. A Geiger-Mueller counter tube is automatically swivelled to detect the radiation that is constructively reflected from the various lattice planes of the crystallites. The Bragg diagrams are automatically recorded. The evaluation allows the Bragg reflexes to be assigned to the individual lattice planes. In contrast to the powder sample, the rolled thin sheet gives a spectrum showing an alignment of the crystallites (rolled texture), that is made even more complete by heating the sheet.

What you need:

X-ray basic unit, 35 kV	09058.99	1
Goniometer for X-ray Unit 35 kV	09058.10	1
Plug-in module with Cu-X-ray tube	09058.50	1
Counter tube type B, BNC cable, l = 50 cm	09005.00	1
Lithium fluorid crystal, mounted	09056.05	1
Universal crystal holder for X-Ray Unit	09058.02	1
Probe holder for powder probes (diffractometry)	09058.09	1
Diaphragm tube with Ni- foil	09056.03	1
Spoon with spatula end, l = 150 mm, steel, micro	33393.00	1
Vaseline, 100 g	30238.10	1
Copper, powder, 100 g	30119.10	1
Copper foil, 0.1 mm, 100 g	30117.10	1
Crucible tongs, 200 mm, stainless steel	33600.00	1
Butane burner for cartridge 270 and 470	47536.00	1
Butane cartridge	47535.00	1
Software for X-ray Unit 35 kV*	14407.61	1
Data cable 2 x SUB-D, plug/socket, 9 pole*	14602.00	1
PC, Windows® XP or higher		

Complete Equipment Set, Manual on CD-ROM included
Diffractometric Debye-Scherrer measurements for the examination of the texture of rolled sheets P2542700



Debye-Scherrer diagram of a rolled copper sheet.

Tasks:

1. Record the intensity of the Cu X-rays back scattered by a cubic crystallizing copper powder sample as a function of the scattering angle.
2. Assign the Bragg reflexes to the individual lattice planes.
3. Record the Bragg spectrum of a thin sheet of copper.
4. Repeat the measurements made in Task 3 after the sheet of copper has been subjected to annealing.

Characteristic X-rays of tungsten 5.4.28-00

What you can learn about ...

- → Bremsstrahlung
- → Characteristic radiation
- → Energy levels
- → Crystal structures
- → Lattice constant
- → Absorption
- → Absorption edges
- → Interference
- → The Bragg equation
- → Order of diffraction
- → L-Transition

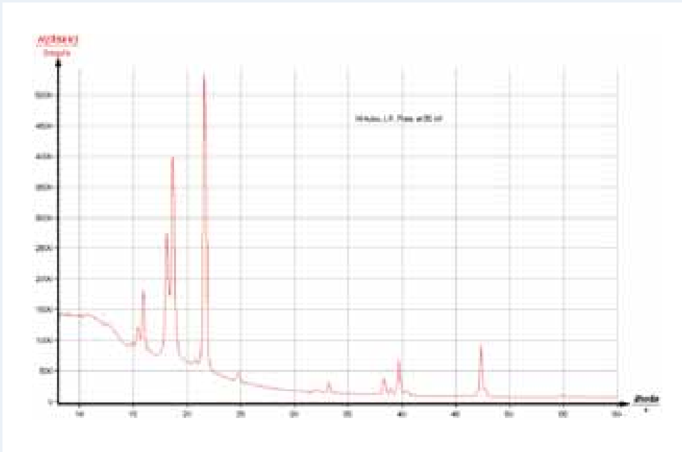
Principle:

Spectra of X-rays from a tungsten anode are to be analyzed by means of a LiF monocrystal and the results plotted graphically. The energies of the characteristic lines are then to be determined from the positions of the glancing angles for the various orders of diffraction. As the necessary energy for the k-transition (69,5 keV) is higher than the applied energy in this experiment, the transition takes place in lower level l, m and even o shell. The identification of the different transitions is a major task in this experiment.

What you need:

X-ray basic unit, 35 kV	09058.99	1
Goniometer for X-ray unit, 35 kV	09058.10	1
Plug-in module with W X-ray tube	09058.80	1
Counter tube, type B	09005.00	1
Lithium fluoride crystal, mounted	09056.05	1
Software X-ray unit, 35 kV	14407.61	1
RS232 data cable	14602.00	1
PC, Windows® XP or higher		

Complete Equipment Set, Manual on CD-ROM included
Characteristic X-rays of tungsten P2542800



X-ray intensity of tungsten as a function of the glancing angle; a LiF (100) monocrystal is used as a Bragg analyser..

Tasks:

1. The intensity of the X-rays emitted by the tungsten anode at maximum anode voltage and anode current is to be recorded as a function of the Bragg angle, using an LiF monocrystal as analyzer.
2. The energy values of the characteristic tungsten lines are to be calculated and compared with the energy differences of the copper energy terms
3. The identification of the various l-lines has to be carried out by applying the appropriate selection rules.

5.4.40-00 Spectroscopy with the X-ray energy detector

What you can learn about ...

- ➔ Energy levels
- ➔ Bremsstrahlung
- ➔ Characteristic radiation
- ➔ Bragg equation
- ➔ Selection rules

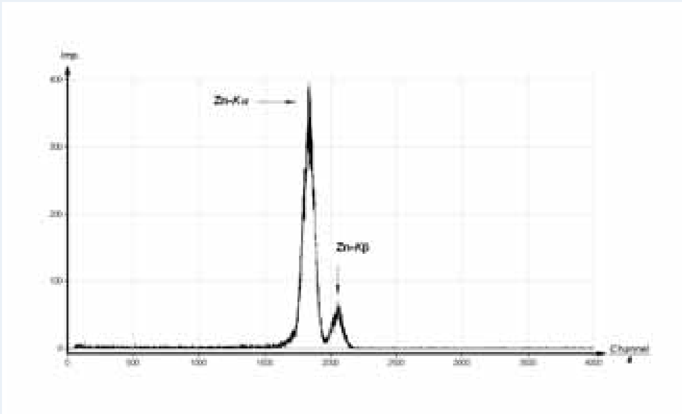
Principle:

The X-ray energy detector is used to gain information about the energy distribution of high energy gamma radiation in the range of 2 to 40 keV. The X-ray energy detector with a resolution of 380 keV in combination with a multi channel analyzer is used for direct measurement of the transition energies of *K* and *L* levels of metals and alloys.

What you need:

X-ray basic unit, 35 kV	09058.99	1
Goniometer for X-ray unit 35 kV	09058.10	1
Plug-in Cu tube for X-ray unit	09058.50	1
X-ray energy detector	09058.30	1
Multi-Channel-Analyzer	13727.99	1
Software Multi-Channel-Analyzer	14452.61	1
Specimen set X-ray energy detector	09058.31	1
Univ. crystal holder	09058.02	1
Probe holder for powder probes	09058.09	1
PC, Windows® XP or higher		

Complete Equipment Set, Manual on CD-ROM included
Spectroscopy with the X-ray energy detector P2544000



Fluorescence spectrum of zinc.

Tasks:

1. Calibration of the X-ray energy spectrum of copper
2. Determination of the resolution of the X-ray energy detector
3. X-ray fluorescence analysis of pure metals and alloys
4. Verification of the Bragg equation with the help of the X-ray energy detector

Energy resolution of the X-ray energy detector/multi-channel analyser system 5.4.41-00

What you can learn about …

- Bremsstrahlung
- Characteristic X-radiation
- Fluorescence radiation
- Conduction processes in semiconductors
- Doping of semiconductors
- Pin-diodes
- Resolution and resolving power
- Semiconductor energy
- Multi-channel analysers

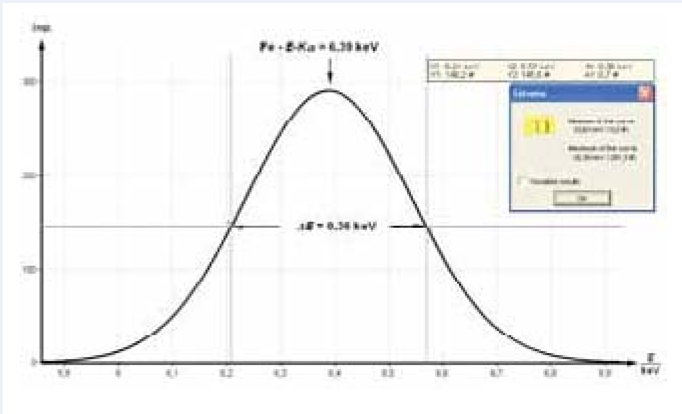
Principle:

Various metal samples are subjected to polychromatic X-rays. The resulting fluorescence radiation is analysed with the aid of a semiconductor detector and a multi-channel analyser. The energy of the characteristic X-ray lines and their full widths at half maximum are determined. In addition, the dependence of the full widths at half maximum and the shift of the line centroid as a function of the counting rate are examined.

What you need:

X-ray basic unit, 35 kV	09058.99	1
Goniometer for the 35 kV X-ray unit	09058.10	1
Plug-in molybdenum tube for the X-ray unit	09058.60	1
Multi-channel analyser	13727.99	1
X-ray energy detector	09058.30	1
Metal samples for X-ray fluorescence, set of 7	09058.31	1
Universal crystal holder for the X-ray unit	09058.02	1
Software for the multi-channel analyser	14452.61	1
Soldering tin		
PC, Windows® XP or higher		

Complete Equipment Set, Manual on CD-ROM included
Energy resolution of the X-ray energy detector/multi-channel analyser system P2544100



Normal distribution of the iron K_α-lines for determining the line energy and the full width at half maximum (the original measurement curve is hidden).

Tasks:

1. Calibration of the semiconductor detector with the aid of the characteristic radiation of the molybdenum X-ray tube.
2. Recording of the spectra of the fluorescence radiation that is generated by the metal samples.
3. Determination of the energy levels and full widths at half maximum of the characteristic K_α-lines and their graphical representation.
4. Determination and graphical representation of the full widths at half maximum as a function of the counting rate, with the K_α-line of zircon used as an example.
5. Determination and graphical representation of the shift of the line centroid as a function of the counting rate, with the K_α-line of zircon used as an example.

5.4.42-00 Inherent fluorescence radiation of the X-ray energy detector

What you can learn about ...

- → Bremsstrahlung
- → Characteristic X-radiation
- → Fluorescence radiation
- → Fluorescent yield
- → Interference of X-rays
- → Crystal structures
- → Bragg's law
- → Compton scattering
- → Escape peaks
- → Semiconductor energy detectors
- → Multi-channel analysers

Principle:

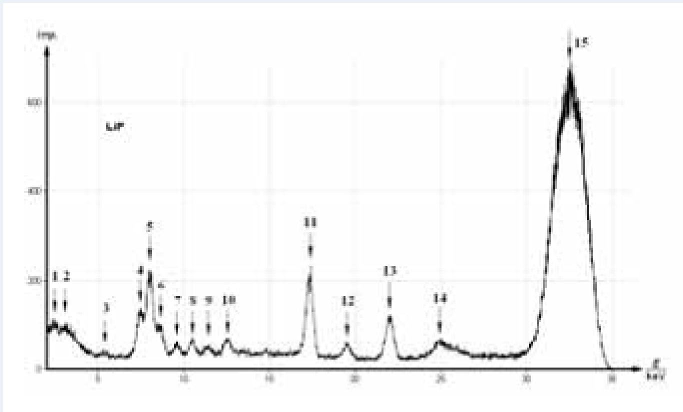
Fluorescence radiation of the elements of a sample can cause fluorescence radiation inside the detector and its housing if the energy is sufficiently high. As a result, the spectrum may include lines that are not caused by the sample.

For the detection of potential additional lines, the detector is subjected to monochromatic X-radiation with the aid of a monocrystal. For comparison, the fluorescence spectra of pure metal samples are measured.

What you need:

X-ray basic unit, 35 kV	09058.99	1
Goniometer for the 35 kV X-ray unit	09058.10	1
Plug-in molybdenum tube for the X-ray unit	09058.60	1
Multi-channel analyser	13727.99	1
X-ray energy detector	09058.30	1
Metal samples for X-ray fluorescence, set of 7	09058.31	1
LiF monocrystal with a holder	09056.05	1
Universal crystal holder for the X-ray unit	09058.02	1
Software for the multi-channel analyser	14452.61	1
PC, Windows® XP or higher		

Complete Equipment Set, Manual on CD-ROM included
Inherent fluorescence radiation of the X-ray energy detector P2544200



Characteristic fluorescence spectrum of the detector components (energy of the primary radiation E0 = 32.5 keV).

Tasks:

1. Calibration of the semiconductor energy detector with the aid of the characteristic fluorescence radiation of the calibration sample.
2. Irradiation of the X-ray energy detector with monoenergetic X-rays that are produced by the Bragg reflection on an LiF monocrystal. Measurement of the resulting fluorescence spectrum.
3. Determination of the energy of the spectrum lines.
4. Assignment of the lines to elements by comparing the measured values with table values.
5. Comparative measurement and evaluation of the fluorescence spectra of pure metal samples.

Qualitative X-ray fluorescence spectroscopy of metals 5.4.45-00

What you can learn about …

- → Bremsstrahlung
- → Characteristic X-radiation
- → Absorption of X-rays
- → Bohr's atomic model
- → Energy levels
- → Moseley's law
- → Rydberg frequency
- → Screening constant
- → Semiconductor energy detectors
- → Multi-channel analysers

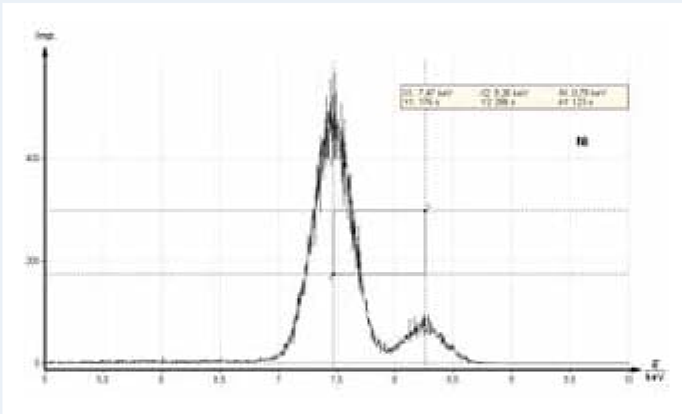
Principle:

Various metal samples are subjected to polychromatic X-rays. The energy of the resulting fluorescence radiation is analysed with the aid of a semiconductor detector and a multi-channel analyser. The energy of the corresponding characteristic X-ray lines is determined, and the resulting Moseley diagrams are used to determine the Rydberg frequency and the screening constants.

What you need:

X-ray basic unit, 35 kV	09058.99	1
Goniometer for the 35 kV X-ray unit	09058.10	1
Plug-in molybdenum tube for the X-ray unit	09058.60	1
Multi-channel analyser	13727.99	1
X-ray energy detector	09058.30	1
Metal samples for X-ray fluorescence, set of 7	09058.31	1
Universal crystal holder for the X-ray unit	09058.02	1
Software for the multi-channel analyser	14452.61	1
PC, Windows® XP or higher		

Complete Equipment Set, Manual on CD-ROM included
Qualitative X-ray fluorescence spectroscopy of metals P2544500



Fluorescence spectra of various metals: (The Mo spectrum was obtained through the analysis of the primary radiation of the Mo X-ray tube and is not caused, therefore, by any of the metal samples.)

Tasks:

1. Calibration of the semiconductor energy detector with the aid of the characteristic radiation of the molybdenum X-ray tube.
2. Recording of the spectra of the fluorescence radiation that is generated by the metal samples.
3. Determination of the energy values of the corresponding characteristic K_α- and K_β-lines.
4. Determination of the Rydberg frequency and screening constants with the aid of the resulting Moseley diagrams.

5.4.46-00 Qualitative X-ray fluorescence analysis of alloyed materials

What you can learn about …

- → Bremsstrahlung
- → Characteristic X-radiation
- → Energy levels
- → Fluorescent yield
- → Semiconductor energy detectors
- → Multi-channel analysers

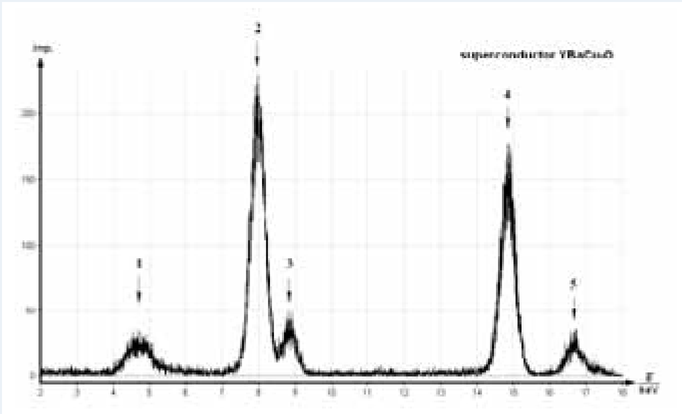
Principle:

Various alloyed materials are subjected to polychromatic Xrays. The energy of the resulting fluorescence radiation is analysed with the aid of a semiconductor detector and a multichannel analyser. The energy of the corresponding characteristic X-ray fluorescence lines is determined. The alloyed materials are identified by comparing the line energies with the corresponding table values.

What you need:

X-ray basic unit, 35 kV	09058.99 1
Goniometer for the 35 kV X-ray unit	09058.10 1
Plug-in molybdenum tube for the X-ray unit	09058.60 1
Multi-channel analyser	13727.99 1
X-ray energy detector	09058.30 1
Alloy samples for X-ray fluorescence, set of 5	09058.33 1
Wood's metal, 50 g	30242.05 1
Universal crystal holder for the X-ray unit	09058.02 1
Crucible tongs, steel, 200 mm	33600.00 1
Evaporating dish, porcelain, d = 51 mm	32514.00 1
Software for the multi-channel analyser	14452.61 1
Soldering tin	
PC, Windows® XP or higher	

Complete Equipment Set, Manual on CD-ROM included
Qualitative X-ray fluorescence analysis of alloyed materials P2544600

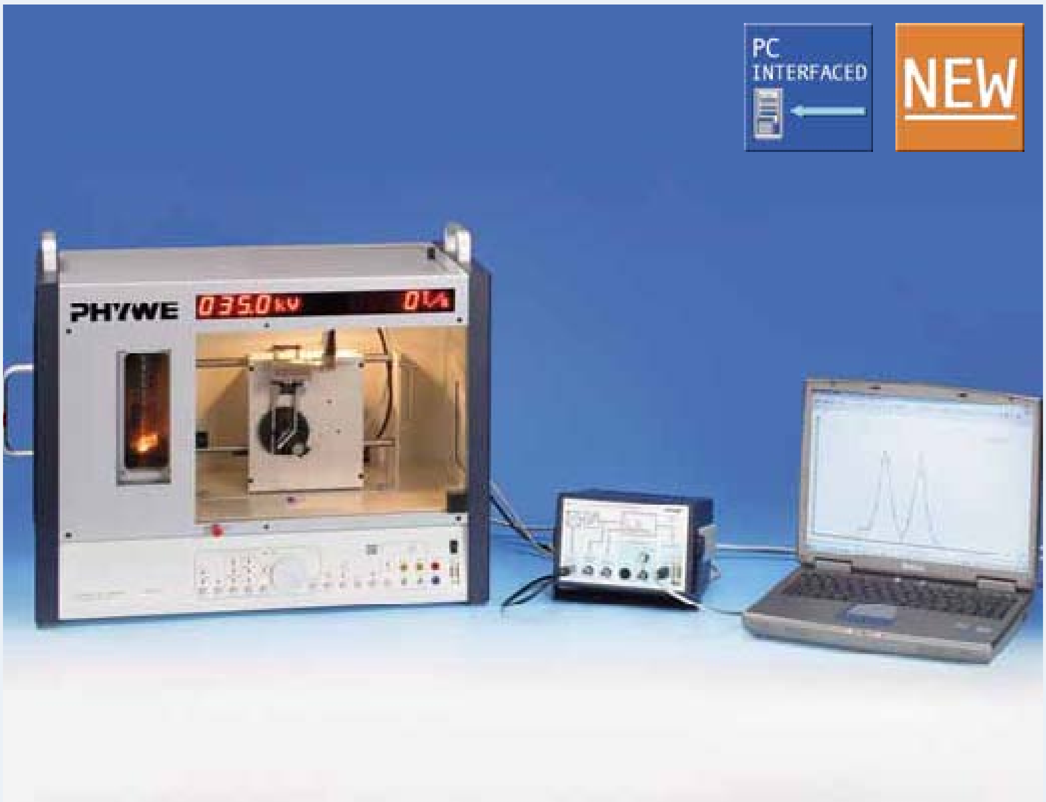


Fluorescence spectrum of a superconductor (YBaCu-O).

Tasks:

1. Calibration of the semiconductor energy detector with the aid of the characteristic radiation of the molybdenum X-ray tube.
2. Recording of the spectra of the fluorescence radiation that is generated by the samples.
3. Determination of the energy values of the corresponding fluorescence lines.
4. Comparison of the experimental energy values with table values in order to identify the alloy constituents.

Qualitative X-ray fluorescence analysis of powder samples 5.4.47-00



What you can learn about …

- → Bremsstrahlung
- → Characteristic X-radiation
- → Energy levels
- → Fluorescent yield
- → Semiconductor energy detectors
- → Multi-channel analysers

Principle:

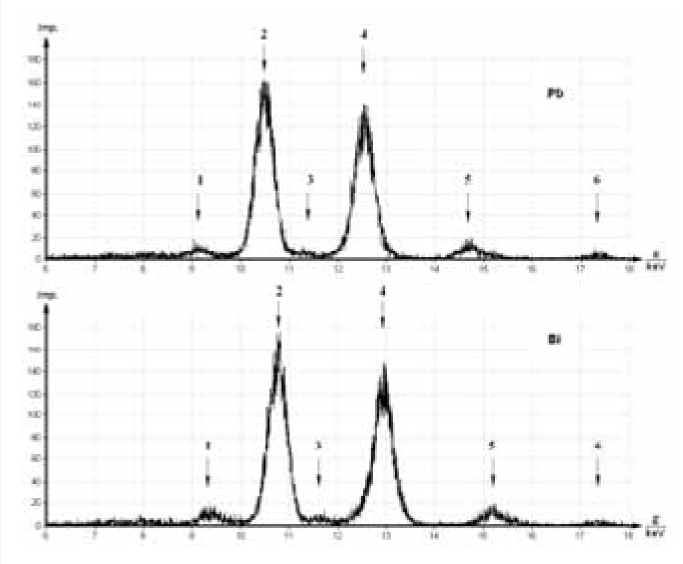
Various powder samples are subjected to polychromatic X-rays. The energy of the resulting fluorescence radiation is analysed with the aid of a semiconductor detector and a multichannel analyser. The energy of the corresponding characteristic X-ray fluorescence lines is determined.

The elements of the samples are identified by comparing the line energies with the corresponding table values.

What you need:

X-ray basic unit, 35 kV	09058.99	1
Goniometer for the 35 kV X-ray unit	09058.10	1
Plug-in molybdenum tube for the X-ray unit	09058.60	1
Multi-channel analyser	13727.99	1
X-ray energy detector	09058.30	1
Set of chemicals for the edge absorption	09056.04	1
Universal crystal holder for the X-ray unit	09058.02	1
Spatula for powder, steel, l = 150 mm	47560.00	1
Holder for powder samples	09058.09	1
Software for the multi-channel analyser	14452.61	1
PC, Windows® 98 or higher		

Complete Equipment Set, Manual on CD-ROM included
Qualitative X-ray fluorescence analysis of powder samples P2544700



L fluorescence lines of lead and bismuth.

Tasks:

1. Calibration of the semiconductor energy detector with the aid of the characteristic radiation of the molybdenum X-ray tube.
2. Recording of the fluorescence spectra that are produced by the samples.
3. Determination of the energy values of the corresponding fluorescence lines.
4. Comparison of the experimental energy values with the corresponding table values in order to identify the powder components.

5.4.48-00 Qualitative X-ray fluorescence analysis of liquids

What you can learn about …

- Bremsstrahlung
- Characteristic X-radiation
- Energy levels
- Fluorescent yield
- Solubility
- Solubility product
- Semiconductor energy detectors
- Multi-channel analysers

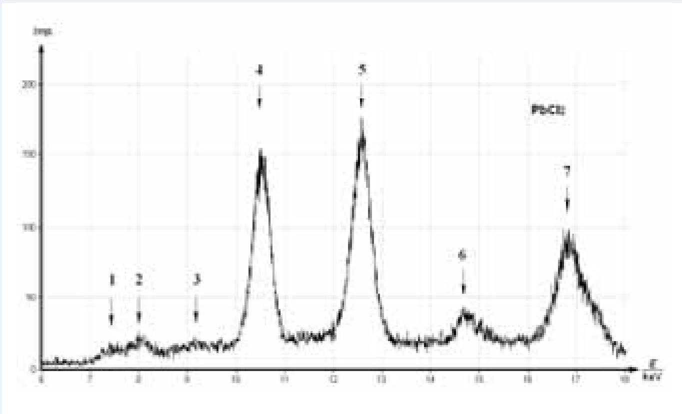
Principle:

Various saturated solutions are subjected to polychromatic X-rays. The energy of the resulting fluorescence radiation is analysed with the aid of a semiconductor detector and a multi-channel analyser. The energy of the corresponding characteristic X-ray fluorescence lines is determined. The elements of the samples are identified by comparing the line energies with the corresponding table values.

What you need:

X-ray basic unit, 35 kV	09058.99	1
Goniometer for the 35 kV X-ray unit	09058.10	1
Plug-in molybdenum tube for the X-ray unit	09058.60	1
Multi-channel analyser	13727.99	1
X-ray energy detector	09058.30	1
Universal crystal holder for the X-ray unit	09058.02	1
Balance, DENVER DLT-411, 400 g, 0.1g	49061.00	1
Beaker, polypropylene, 100 ml	36011.01	2
Spoon and spatula, steel, l = 120 mm	46949.00	1
Glass rod, BORO 3.3, l = 200 mm, d = 3 mm	40485.01	2
Macro-cuvettes, 4 ml, PS, 100 pieces	35663.10	1
Lead(II) chloride, 250 g	31117.25	1
Potassium bromide, 50 g	30258.05	1
Software for the multi-channel analyser	14452.61	1
PC, Windows® XP or higher		

Complete Equipment Set, Manual on CD-ROM included
Qualitative X-ray fluorescence analysis of liquids P2544800

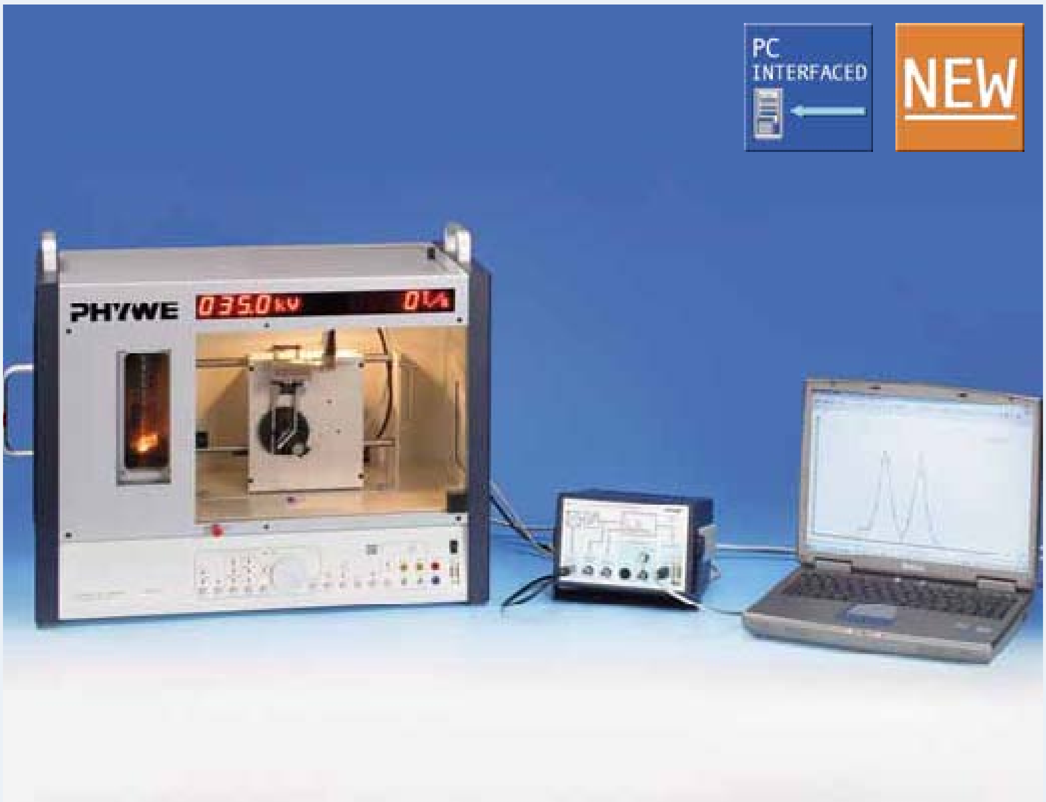


L-fluorescence lines of lead

Tasks:

1. Calibration of the semiconductor energy detector with the aid of the characteristic radiation of the molybdenum X-ray tube.
2. Recording of the fluorescence spectra of saturated potassium bromide and lead chloride solutions.
3. Determination of the energy values of the corresponding fluorescence lines and comparison with the corresponding table values.

Quantitative X-ray fluorescence analysis of alloyed materials 5.4.50-00



What you can learn about …

- Bremsstrahlung
- Characteristic X-radiation
- Energy levels
- Fluorescent yield
- Auger effect
- Coherent and incoherent photon scattering
- Absorption of X-rays
- Edge absorption
- Matrix effects
- Semiconductor energy detectors
- Multi-channel analysers

Principle:

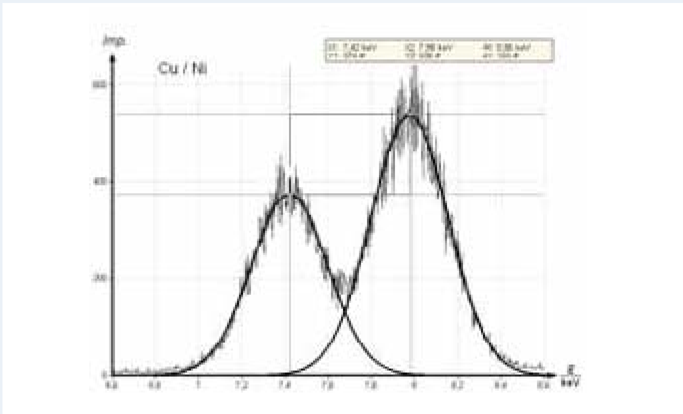
Various alloyed materials are subjected to polychromatic X-rays. The energy of the resulting fluorescence radiation is analysed with the aid of a semiconductor detector and a multi-channel analyser. The energy of the corresponding characteristic X-ray fluorescence lines is determined.

In order to determine the concentration of the alloy constituents, the intensity of their respective fluorescence signals is compared to that of the pure elements.

What you need:

X-ray basic unit, 35 kV	09058.99	1
Goniometer for the 35 kV X-ray unit	09058.10	1
Plug-in molybdenum tube for the X-ray unit	09058.60	1
Multi-channel analyser	13727.99	1
X-ray energy detector	09058.30	1
Universal crystal holder for the X-ray unit	09058.02	1
Set of samples for the quantitative X-ray fluorescence analysis, set of 4	09058.34	1
Set of metal samples for the X-ray fluorescence analysis, set of 7	09058.31	1
Software for the multi-channel analyser	14452.61	1
PC, Windows® XP or higher		

Complete Equipment Set, Manual on CD-ROM included
Quantitative X-ray fluorescence analysis of alloyed materials 2545000



Spectrum evaluation method: K_α-lines of constantan, copper, and nickel with a scaled normal distribution.

Tasks:

1. Calibration of the semiconductor energy detector with the aid of the characteristic radiation of the molybdenum X-ray tube.
2. Recording of the fluorescence spectra that are produced by the alloyed samples.
3. Recording of the fluorescence spectra that are produced by the pure metals.
4. Determination of the energy values of the corresponding fluorescence lines.
5. Calculation of the concentration levels of the alloy constituents.

5.4.51-00 Quantitative X-ray fluorescence analysis of liquids

What you can learn about ...

- ➔ Bremsstrahlung
- ➔ Characteristic X-radiation
- ➔ Energy levels
- ➔ Fluorescent yield
- ➔ Absorption of X-rays
- ➔ Auger effect
- ➔ Scattering of X-rays
- ➔ Matrix effects
- ➔ Solubility
- ➔ Solubility product
- ➔ Semiconductor energy detectors
- ➔ Multi-channel analysers

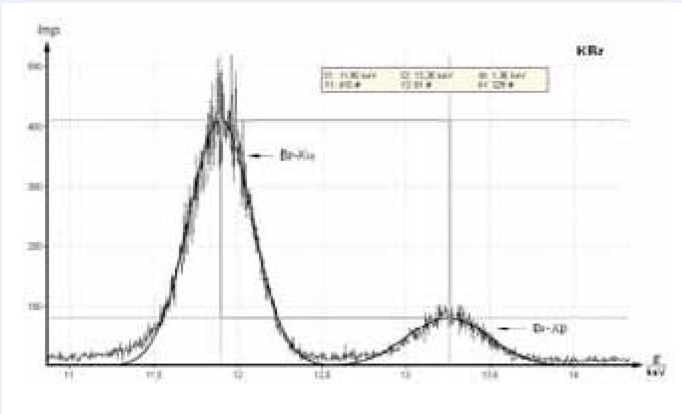
Principle:

Various solutions, with known element concentrations, are subjected to polychromatic X-rays. The energy and intensity of the resulting fluorescence radiation of the dissolved elements are analysed with the aid of a semiconductor detector and a multi-channel analyser. In order to determine the unknown element concentrations in the solutions, calibration is performed. For this purpose, the known element concentrations of the calibration solution are plotted against the corresponding fluorescence intensities of the dissolved elements.

What you need:

X-ray basic unit, 35 kV	09058.99	1
Goniometer for the 35 kV X-ray unit	09058.10	1
Plug-in molybdenum tube for the X-ray unit	09058.60	1
Multi-channel analyser	13727.99	1
X-ray energy detector	09058.30	1
Universal crystal holder for the X-ray unit	09058.02	1
Balance, DENVER DLT-411, 400g, 0.1g	49061.00	1
Pipette, 10 ml, graduated in steps of 0.1 ml	36600.00	3
Pipette ball	36592.00	1
Snap-cap vials, d = 30 mm, h = 75 mm, 10 pcs.	33622.03	1
Beaker, BORO 3.3, 250 ml	46054.00	3
Spoon and spatula, steel, l = 120 mm	46949.00	1
Glass rod, BORO 3.3, l = 200 mm, d = 3 mm	40485.01	2
Macro-cuvettes, 4 ml, PS, 100 pieces	35663.10	1
Potassium bromide, 50 g	30258.05	1
Water, distilled, 5 l	31246.81	1
Software for the multi-channel analyser	14452.61	1
PC, Windows® XP or higher		

Complete Equipment Set, Manual on CD-ROM included
Quantitative X-ray fluorescence analysis of liquids P2545100



Zoomed representation with a fitted normal distribution of the K_α- and K_β-lines of bromine.

Tasks:

1. Calibration of the semiconductor energy detector with the aid of the characteristic radiation of the molybdenum X-ray tube.
2. Recording of the fluorescence spectra of potassium bromide solutions with various concentration levels.
3. Determination of the intensity of the characteristic bromine radiation, based on the spectra.
4. Creation of a calibration function that is based on the concentration values as well as the intensity of the associated fluorescence radiation.

X-ray fluorescence spectroscopy – layer thickness determination 5.4.52-00

What you can learn about …

- Bremsstrahlung
- Characteristic X-radiation
- Fluorescent yield
- Auger effect
- Coherent and incoherent photon scattering
- Law of absorption
- Mass attenuation coefficient
- Saturation thickness
- Matrix effects
- Semiconductor energy detectors
- Multi-channel analysers

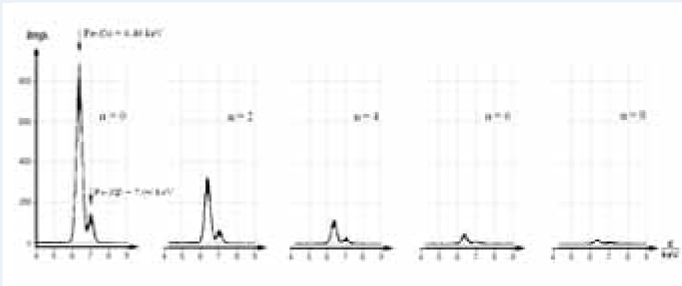
Principle:

X-ray fluorescence analysis (XRF) is suitable for the noncontact and non-destructive thickness measurement of thin layers as well as for determining their chemical composition. For this type of measurement, the X-ray source and detector are located on the same side of the sample.

What you need:

X-ray basic unit, 35 kV	09058.99	1
Goniometer for the 35 kV X-ray unit	09058.10	1
Plug-in molybdenum tube for the X-ray unit	09058.60	1
Multi-channel analyser	13727.99	1
X-ray energy detector	09058.30	1
Set of metal samples		
for the X-ray fluorescence analysis, set of 7	09058.31	1
Set of samples for the quantitative		
X-ray fluorescence analysis, set of 4	09058.34	1
Universal crystal holder for the X-ray unit	09058.02	1
Software for the multi-channel analyser	14452.61	1
Household aluminium foil		
PC, Windows® XP or higher		

Complete Equipment Set, Manual on CD-ROM included
X-ray fluorescence spectroscopy – layer thickness determination P2545200



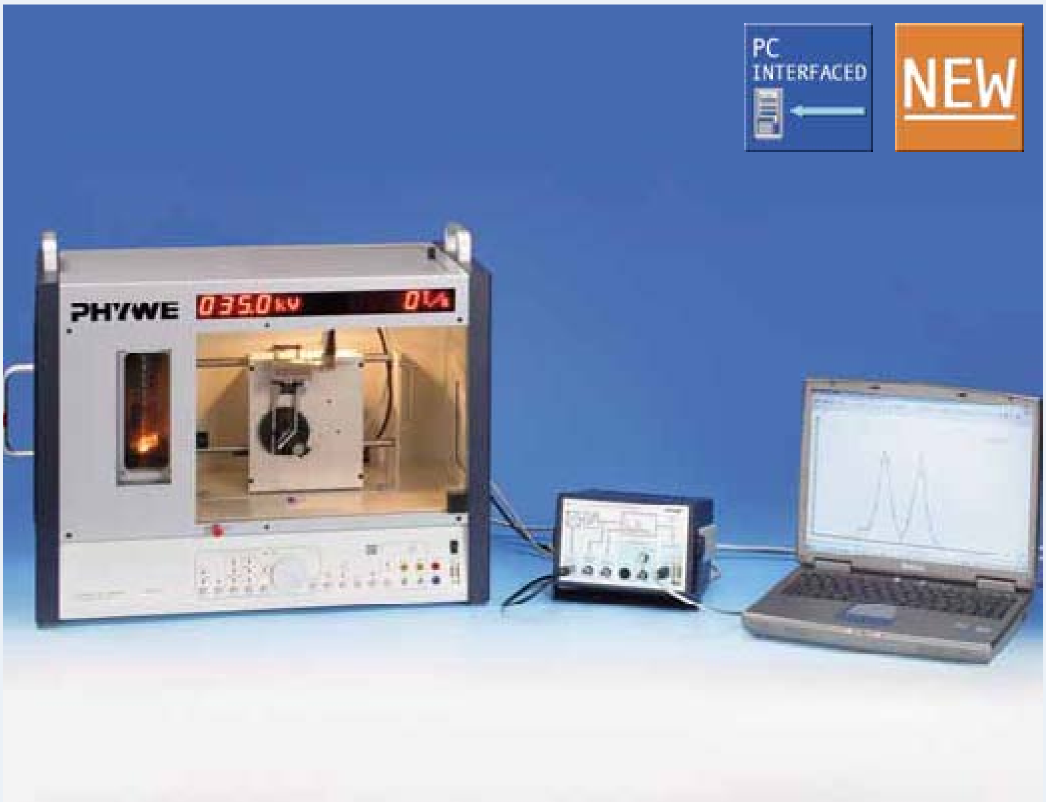
Fe-fluorescence lines as a function of the number n of the pieces of aluminium foils placed on the substrate.

When the layer on the substrate is subjected to X-rays, the radiation will penetrate the layer, if it is sufficiently thin, to a certain extent, depending on the thickness, and in turn cause characteristic fluorescence radiation in the material of the underlying substrate. On its way to the detector, this fluorescence radiation will be attenuated by absorption at the layer. The thickness of the layer can be determined based on the intensity attenuation of the fluorescence radiation of the substrate material.

Tasks:

1. Calibration of the semiconductor energy detector with the aid of the characteristic radiation of the molybdenum X-ray tube.
2. Determination of the fluorescence spectrum of an iron sample.
3. Measurement of the fluorescence spectrum of the iron substrate with different numbers of pieces of aluminium foil with the same thickness placed on the substrate. Determination of the intensity of the Fe-K_α fluorescence line.
4. Linear and semilogarithmic graphical representation of the intensity of the Fe-K_α fluorescence line as a function of the number of pieces of aluminium foil placed on the substrate.
5. Determination of the intensity of the Fe-K_α fluorescence line for various numbers of pieces of aluminium foil that are fastened in front of the outlet of the tube of the energy detector with some adhesive tape.
6. Calculation of the thickness of the aluminium foil.
7. Determination of the fluorescence spectrum of a molybdenum and copper sample.
8. Execution of tasks 3 to 6 for copper foil on a molybdenum substrate.

5.4.60-00 Compton effect – energy-dispersive direct measurement



What you can learn about …

- ➔ Bremsstrahlung
- ➔ Characteristic X-radiation
- ➔ Compton scattering
- ➔ Compton wavelength
- ➔ Conservation of energy and momentum
- ➔ Rest mass and rest energy of the electron
- ➔ Relativistic electron mass and energy
- ➔ Semiconductor energy detectors
- ➔ Multi-channel analysers

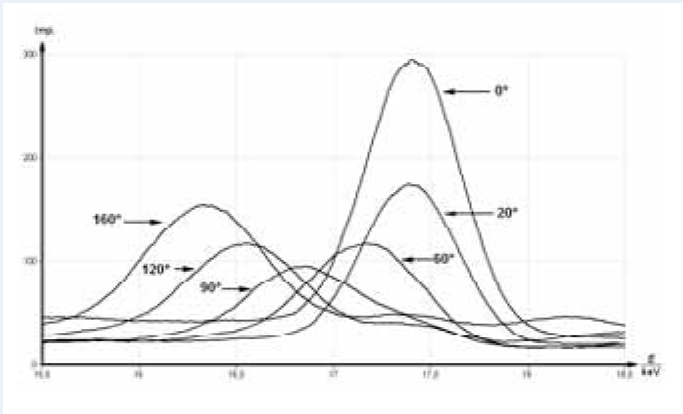
Principle:

Photons of the molybdenum K_α X-ray line are scattered at the quasi-free electrons of an acrylic glass cuboid. The energy of the scattered photons is determined in an angle-dependent manner with the aid of a swivelling semiconductor detector and a multi-channel analyser.

What you need:

X-ray basic unit, 35 kV	09058.99	1
Goniometer for the 35 kV X-ray unit	09058.10	1
Plug-in molybdenum tube for the X-ray unit	09058.60	1
Multi-channel analyser	13727.99	1
X-ray energy detector	09058.30	1
Compton attachment for the 35 kV X-ray unit	09058.04	1
Software for the multi-channel analyser	14452.61	1
PC, Windows® XP or higher		

Complete Equipment Set, Manual on CD-ROM included
Compton effect – energy-dispersive direct measurement P2546000



Molybdenum-K_α-Line of various scattering angles ϑ.

Tasks:

1. Energy calibration of the multi-channel analyser with the aid of the two characteristic molybdenum X-ray lines K_α and K_β.
2. Energy determination of the photons of the Mo-K_α-line that are scattered through an acrylic glass element as a function of the scattering angle.
3. Comparison of the measured energy values of the lines of scatter with the calculated energy values.
4. Calculation of the Compton wavelength of electrons and a comparison of this value with the corresponding value of the 90° scattering.

Energy-dispersive measurements of K- and L-absorption edges 5.4.61-00

What you can learn about ...

- Bremsstrahlung
- Characteristic X-radiation
- Absorption of X-rays
- Bohr's atomic model
- Energy levels
- Moseley's law
- Rydberg frequency
- Screening constant
- Semiconductor energy detectors
- Multi-channel analysers

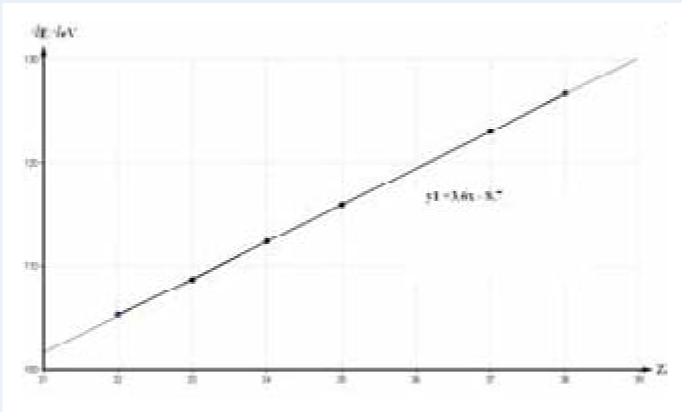
Principle:

Thin powder samples are subjected to polychromatic X-rays. The energy of the radiation that passes through the samples is analysed with the aid of a semiconductor detector and a multi-channel analyser. The energy of the corresponding absorption edges is determined, and the resulting Moseley diagrams are used to determine the Rydberg frequency, the screening constant, and the principal quantum numbers.

What you need:

X-ray basic unit, 35 kV	09058.99	1
Goniometer for the 35 kV X-ray unit	09058.10	1
Plug-in copper tube for the X-ray unit	09058.50	1
Multi-channel analyser	13727.99	1
X-ray energy detector	09058.30	1
Set of chemicals for edge absorption	09056.04	1
Universal crystal holder for the X-ray unit	09058.02	1
Microspoon, steel, l = 150 mm	33393.00	1
Software for the multi-channel analyser	14452.61	1
PC, Windows® XP or higher		

Complete Equipment Set, Manual on CD-ROM included
Energy-dispersive measurements of K- and L-absorption edges P2546100



Moseley diagram for the K-edge absorption.

Tasks:

1. Calibration of the semiconductor energy detector with the aid of the characteristic radiation of the calibration sample.
2. Recording of the energy spectra of the polychromatic X-rays that pass through the powder samples.
3. Determination of the energy of the corresponding K- and L-absorption edges.
4. Determination of the Rydberg frequency, screening constants, and principal quantum numbers with the aid of the resulting Moseley diagrams.

5.4.62-00 Determination of the lattice constants of a monocrystal with the aid of energy-dispersive X-ray spectroscopy

What you can learn about …

- ➔ Bremsstrahlung
- ➔ Characteristic X-radiation
- ➔ Energy levels
- ➔ Crystal structures
- ➔ Bravais lattice
- ➔ Reciprocal lattice
- ➔ Miller indices
- ➔ Bragg scattering
- ➔ Interference
- ➔ Semiconductor detectors
- ➔ Multi-channel analysers

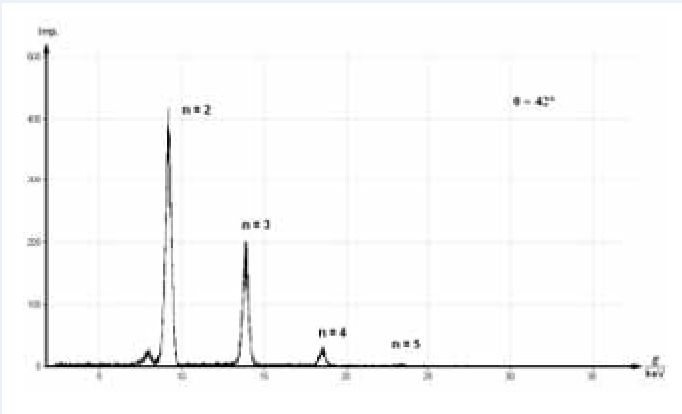
Principle:

Polychromatic X-rays impinge on a monocrystal under various glancing angles. The rays are reflected by the lattice planes of the monocrystal. An energy detector is only used to measure those radiation parts that interfere constructively. The lattice constant of the crystal is determined with the aid of the various orders of diffraction and the energy of the reflected rays.

What you need:

X-ray basic unit, 35 kV	09058.99	1
Goniometer for the 35 kV X-ray unit	09058.10	1
Plug-in copper tube for the X-ray unit	09058.50	1
LiF crystal, mounted in a holder	09056.05	1
Multi-channel analyser	13727.99	1
X-ray energy detector	09058.30	1
Software for the multi-channel analyser	14452.61	1
PC, Windows® XP or higher		

Complete Equipment Set, Manual on CD-ROM included
Determination of the lattice constants of a monocrystal with the aid of energy-dispersive X-ray spectroscopy P2546200



Bragg reflexes with an increasing order of diffraction and various glancing angles. $\vartheta = 42°$, the reflex with $n = 1$ cannot be observed.

Tasks:

1. Energy determination of the X-rays that are reflected at the lattice planes of the LiF-crystal for various glancing angles or diffraction orders.
2. Calculation of the lattice constant of the LiF-crystal based on the glancing angles and associated energy values.

Duane and Hunt's displacement law with an energy-dispersive measurement method 5.4.63-00

What you can learn about …

- ➔ Bremsstrahlung
- ➔ Characteristic X-radiation
- ➔ Energy levels
- ➔ Photon energy
- ➔ Semiconductor detectors
- ➔ Multi-channel analysers

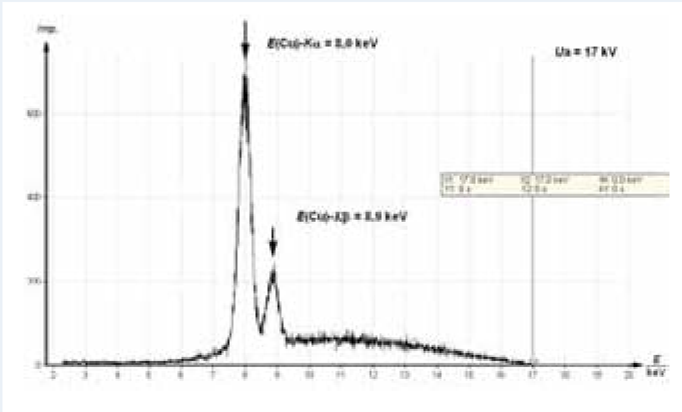
Principle:

X-ray spectra of an X-ray tube are measured in an energydispersive manner with a semiconductor detector and with various anode voltages. Duane and Hunt's law of displacement is verified with the aid of the maximum energy of the bremsspectrums.

What you need:

X-ray basic unit, 35 kV	09058.99	1
Goniometer for the 35 kV X-ray unit	09058.10	1
Plug-in copper tube for the X-ray unit	09058.50	1
Multi-channel analyser	13727.99	1
X-ray energy detector	09058.30	1
Software for the multi-channel analyser	14452.61	1
PC, Windows® XP or higher		

Complete Equipment Set, Manual on CD-ROM included
Duane and Hunt's displacement law with an energy-dispersive measurement method P2546300

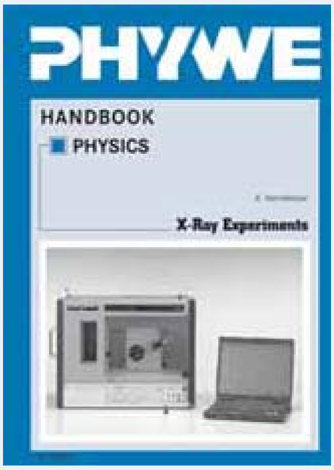


Cu-X-ray spectrum with accelerating voltages of U_a = 17 kV.

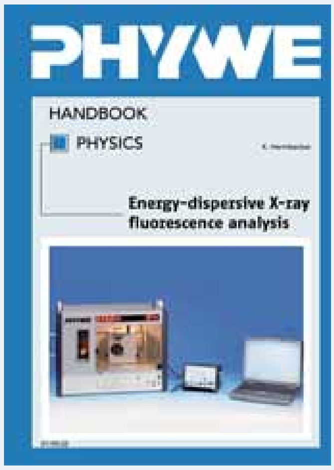
Tasks:

1. Recording of the X-ray spectrum that is emitted by the copper anode for various anode voltages U_a.
2. Calculation of the minimum wavelength of the photons based on the maximum energy of the bremsspectrums.
3. Graphical representation of the relationship between the anode voltage and the minimum wavelength of the bremsspectrums..

X-Ray Experiments



Contrast medium experiment with a blood vessel model



X-Ray Experiments No. 01189.02

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Monochromatization of molybdenum X-rays

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Monochromatization of copper X-rays

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K_α doublet splitting of molybdenum X-rays / fine structure

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K_α doublet splitting of iron X-rays / fine structure

9 (25409)
Duane-Hunt displacement law and Planck's “quantum of action”

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Characteristic X-ray lines of different anode materials/ Moseley's Law; Rydberg frequency and screening constant

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K and L absorption edges of X-rays / Moseley's law and the Rydberg constant

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X-ray investigation of cubic crystal structures / Debye-Scherrer powder method

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X-ray investigation of hexagonal crystal structures / Debye-Scherrer powder method

16 (25416)
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23 (25423)
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Energy-dispersive X-ray fluorescence analysis 01190.02

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Qualitative X-ray fluorescence spectroscopy of metals

5 (25446)
Qualitative X-ray fluorescence analysis of alloyed materials

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Qualitative X-ray fluorescence analysis of liquids

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5.4.47-00	5.4.48-00	5.4.50-00	5.4.51-00	5.4.52-00	5.4.60-00	5.4.61-00	5.4.62-00	5.4.63-00

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1.3.16-01	1.3.16-11	1.3.18-00	1.3.19-00	1.3.20-00	1.3.21-00	1.3.22-00	1.3.23-01	1.3.23-11
1.3.25-01	1.3.25-11	1.3.26-11	1.3.27-01	1.3.27-11	1.3.28-01	1.3.28-11	1.3.30-00	1.3.31-00
1.3.32-00	1.3.33-00	1.3.34-00	1.3.35-00	1.4.01-00	1.4.02-00	1.4.03-00	1.4.04-00	1.4.05-00
1.4.06-11	1.4.07-00	1.4.08-00	1.5.01-00	1.5.03-11	1.5.04-11	1.5.05-15	1.5.06-01/15	1.5.07-01/15
1.5.08-11	1.5.09-11	1.5.10-00	1.5.11-00	1.5.12-00	1.5.13-00	1.5.14-00	1.5.15-15	1.5.16-15
1.5.17-15	1.5.18-00	1.5.19-15	1.5.20-00	1.5.21-15	1.5.22-00	1.5.23-00	1.5.24-15	2.1.01-01
2.1.02-00	2.1.03-00	2.2.01-00	2.2.02-00	2.2.03-00	2.2.04-00	2.2.05-00	2.2.05-05	2.2.06-00
2.2.07-00	2.2.07-05	2.2.09-00	2.2.10-00	2.2.11-00	2.2.12-05	2.2.12-06	2.3.01-00	2.3.02-00
2.3.03-00	2.3.04-00	2.3.04-05	2.3.05-00	2.3.06-00	2.3.06-05	2.4.02-01	2.4.02-11	2.4.04-00
2.5.01-00	2.5.01-05	2.5.02-00	2.5.03-00	2.5.04-00	2.6.01-00	2.6.01-05	2.6.03-00	2.6.03-05
2.6.03.06	2.6.04-00	2.6.05-11	2.6.07-01/05	2.6.08-00	2.6.09-00	2.6.10-00	2.6.11-00	2.6.12-00
2.6.13-00	3.1.01-00	3.2.01-01	3.2.01-15	3.2.02-01	3.2.02-11	3.2.03-00	3.2.04-00	3.2.05-00
3.2.06-00	3.3.01-01	3.3.01-11	3.3.02-00	3.4.01-00	3.4.02-00	3.4.04-00	3.5.01-01/15	3.5.02-00
3.6.01-00	3.6.02-00	3.6.03-00	3.6.04-01/15	4.1.01-01	4.1.01-15	4.1.02-00	4.1.03-00	4.1.04-01/15
4.1.06-01/15	4.1.07-00	4.1.08-00	4.1.09-01	4.1.09-15	4.1.11-00	4.1.12-00	4.1.13-15	4.2.01-00
4.2.02-01	4.2.02-15	4.2.03-00	4.2.04-01	4.2.04-15	4.2.05-00	4.2.06-00	4.3.01-00	4.3.02-01/15
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4.4.04-01/11	4.4.05-01/15	4.4.06-01/11	4.4.07-00	4.4.08-00	4.4.09-01/15	4.4.10-00	4.4.11-00	4.4.12-11
4.5.02-00	4.5.04-00	4.5.05-00	4.5.06-00	4.5.08-00	4.5.09-00	5.1.01-00	5.1.02-00	5.1.03-11
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5.1.13-00	5.2.01-01	5.2.01-11	5.2.03-11	5.2.04-00	5.2.20-15	5.2.21-01/11/15	5.2.22-11/15	5.2.23-11/15
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5.3.01-01	5.3.01-11	5.3.02-01/11	5.3.03-00	5.3.04-01/11	5.3.10-00	5.3.11-00	5.3.20-00	5.4.01-00
5.4.02-00	5.4.03-00	5.4.04-00	5.4.05-00	5.4.06-00	5.4.07-00	5.4.08-00	5.4.09-00	5.4.10-00
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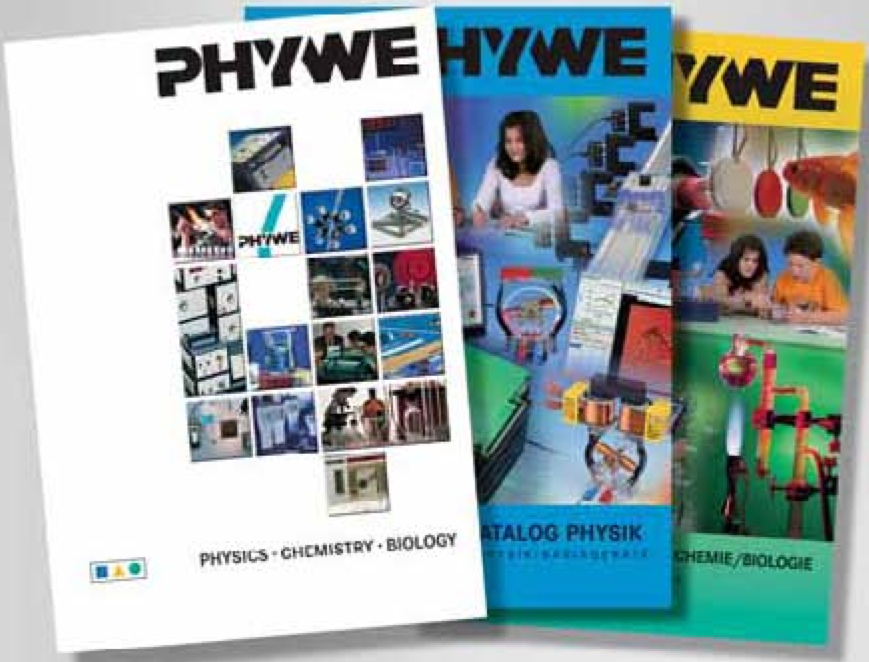

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