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7/1989 -Sf-

Instruction Sheet

401 03

(11)

Vibrating Thread Apparatus

The vibrating thread apparatus can produce standing transverse waves of circular polarization. The frequency f of the waves remains constant but the wavelength λ can be altered. The wavelength changes with the specific mass m^* (mass per length) of the thread and with the tension F applied to the thread. This force F is measured by a spring balance tied to one end of the thread.

This compact arrangement allows for an easy demonstration of Melde's experiment showing the velocity of propagation c (phase velocity) of transverse waves along cords under tension:

(I)+) $c = \sqrt{\frac{F}{\rho \cdot A}}$ for homogeneous materials (for example wires) of the density ρ and the cross section A

or $c = \sqrt{\frac{F}{m^*}}$ for inhomogeneous materials (for example stranded threads) with m^* being the specific mass

Results obtainable with this apparatus:

The wavelength of a cord subjected to the force F is half that of a cord subjected to 4 x F.

The wavelength of a cord with the mass m^* is twice that of a cord having four times that mass m^* under the same force.

Thus the proportionality

$$\lambda \sim \sqrt{\frac{F}{m^*}}$$

is verified.

Using the equation $c = \lambda \cdot f$ it follows that

$$c \sim \sqrt{\frac{F}{m^*}}$$

λ = wavelength
f = frequency
c = velocity of propagation

Further possible experiments:

Experimental derivation of $c \sim \sqrt{F}$ by quantitative examination of the relation between F and λ for a number of λ values; evaluation of the propagational velocity c according to (I).

Comparison of the value of c obtained according to method (I) and the value calculated from the equation $c = \lambda \cdot f$ (stroboscopic measurement of f).

This apparatus also allows for a comparison between circular and linear polarized waves. The influence of a polarizer on the rotating plane of oscillation of a circularly polarized wave can also be demonstrated.

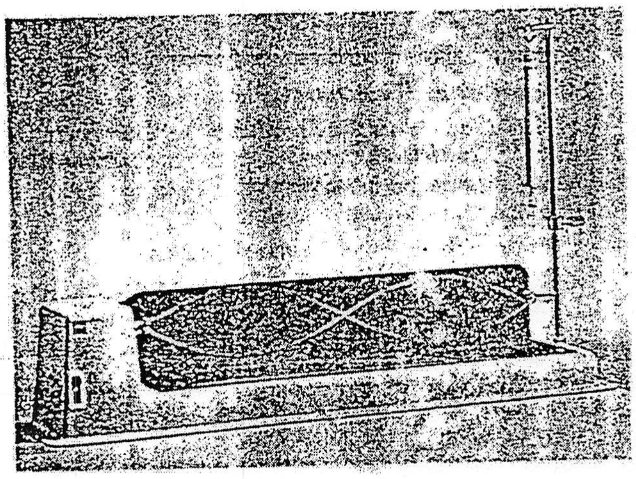

Fig. 1

Literature: Physics Experiments, Volume 2 (599 922)
New Physics Leaflets for Colleges and Universities, Volume 1 (599 952)

1. Technical Data

Effective lengths l of the thread for standing waves	approx. 0.485 m or approx. 0.38 m
Specific mass m^* of the thread	approx. 5 mg/cm
Tension as shown on the spring balance	range max. 1 N
Excitation of the thread by an eccentric of a drive motor	
Power supply voltage:	220 V/50 Hz
Rated power:	approx. 23 VA
Frequency:	approx. 44 Hz
Dimensions (excluding the vertically adjustable holder; max. height 55 cm)	approx. 70 cm x 15 cm x 14 cm
Weight:	approx. 2.5 kg

+) Eq. 1 follows from the solution of the wave equation of cords and threads under tension, neglecting bending strength. The derivation may be found in theoretical physics books.

Description

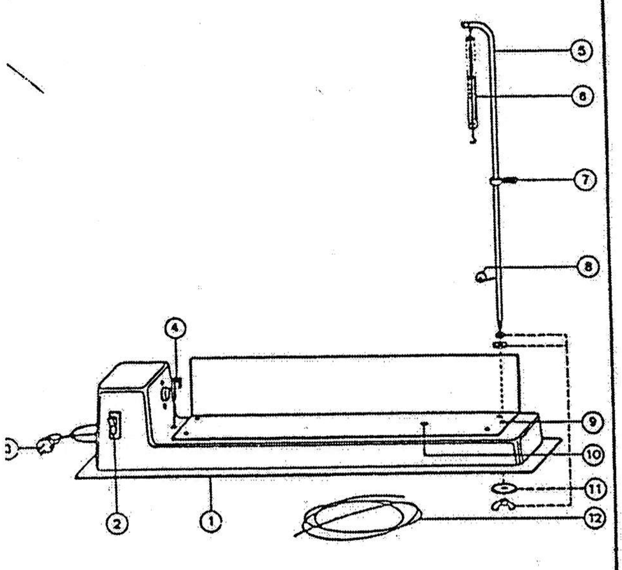

Fig. 2

2.1. Parts included in standard specification

Complete with basic apparatus (motor, housing and base), holder, vertically adjustable to be mounted on the base, 1 spring balance (range 1 N), approx. 5 m of thread.

① Basic apparatus with motor
② Mains switch with indicator lamp
③ Mains cable
④ Excenter
⑤ Vertically adjustable holder for the spring balance ⑥
⑥ Spring balance, 1 N
⑦ Screw to fix the heigth of ⑤
⑧ Guide roller for near frictionless transmission of the force to the horizontally mounted thread
⑨ and ⑩ Bores for the holder ⑤
⑪ Hexagonal nut, butterfly nut and washers for mounting the holder ⑤ onto the base of ①
⑫ Approx. 5 m of thread for making threads of various masses and lengths. (See 3.1.)

2.2. Principle of Operation

The excenter of the motor produces a circular movement of the thread end whereby the frequency f of the motor remains nearly constant under any load for these experiments. This periodical dislocation moves along the thread with the propagation velocity c so that a circularly polarized wave is produced.

This wave is reflected off the guide roller with a phase shift because the guide roller acts as a fixed end. As the arriving wave interferes with the reflected wave a standing wave appears when the following conditions are met: The wavelength λ as given by the force F and the specific mass m^* must be so that just a multiple integer of $\frac{\lambda}{2}$ can be accommodated along the thread.

3. Operation

3.1. Preoperation measures (usually only required before initial operation)

Prepare the necessary threads for the experiments according to Fig. 3.

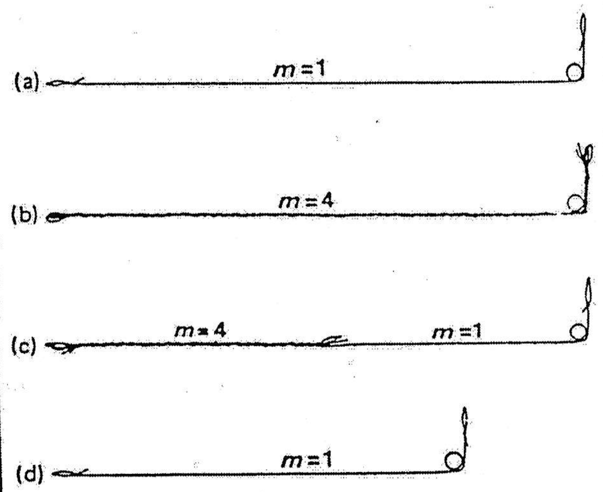

Fig. 3

Thread (a): Approx. 0.6 m of thread is needed; effective length l = 0.485 m, single mass m; to verify: $\lambda \sim \sqrt{F}$

Thread (b): Approx. 2.40 m of thread is needed; effective length l = 0.485 m; four times the single mass = 4 m used with thread (a) to verify: $\lambda \sim \sqrt{\frac{1}{m^*}}$

Thread (c): Approx. 1.35 m of thread is needed; effective length l = 0.485; one half is of the single mass m, the other half is of four times the single mass 4 m used to verify: $\lambda \sim \sqrt{\frac{1}{m^*}}$

Thread (d): Approx. 0.50 m of thread is needed; effective length l = 0.38 m; single mass m; used together with thread (a) to derive $\lambda \sim \sqrt{F}$

Mount the adjustable holder on to the basic apparatus by inserting it into the bores in the base using the hexagonal nut, the two washers and the butterfly nut as shown in Fig. 2.

Hint

For the experiments it is sufficient to generate waves of λ = 0.48 m and 0.32 m. This can be done by mounting the adjustable holder at bore ⑨ giving an effective length of 0.48 m.

When making a graph of the function $\lambda = f(F)$ it is advisable to make additional measurements with a thread having a length of 0.38 m in order to obtain different λ-values. To do this the adjustable holder may be mounted on the base using bore ⑩.

3.2. General hints for experimenting

The apparatus is ready for the experiments when the spring balance and a suitable thread (see 3.1.) are set up as shown in Fig. 1 and after having connected the motor to the mains.

When relaxing the screw ⑦ the height of the holder should be varied slowly and continuously whilst observing the thread until standing waves appear with their maximum amplitude. Then tighten the screw and note the force as shown by the spring balance.

Tensions above 0.7 N impair the frequency of the motor.

Specific mass $m^* = 0.52 \times 10^{-3}$ kg/m (calculated from weighing 0.6 m of thread)

I	λ (from 1.1; 1.2)	m	0.76	0.485	0.38	0.323	0.253	0.194
	F (from 1.1; 1.2)	N	0.58	0.24	0.15	0.1	0.07	0.04
	λ^2	m^2	0.578	0.24	0.14	0.104	0.064	0.038
II	$c = \sqrt{\frac{F}{m^*}}$	$\frac{m}{s}$	33.4	21.48	16.98	13.87	11.6	8.77
III	f	$\frac{1}{s}$	44.6	44.8	44.8	44.6	44.7	44.8
	$c = \lambda \cdot f$	$\frac{m}{s}$	33.9	21.73	17.02	14.41	11.31	8.69

Table 2

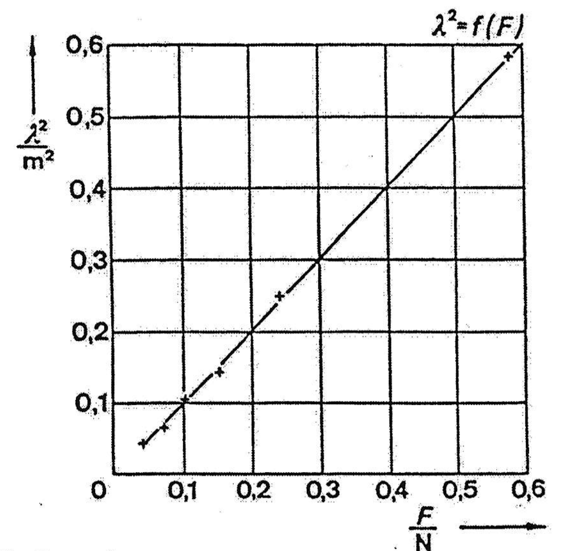

Fig. 7

5.3. Polarization

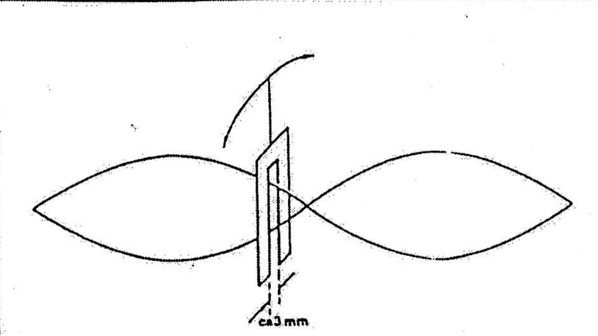

Fig. 8

Hold the polarizer (either a piece of bent wire or a piece of cardboard with a slit) as shown in Fig. 8 and turn it slowly as indicated by the arrows.

(Illumination by the stroboscope 451 28 is advisable); observe the plane of oscillation before and after the wave has passed the polarizer.