Lectures on Medical Biophysics

Department of Biophysics, Medical Faculty,
Masaryk University in Brno

Occupational Safety When Using Medical Devices

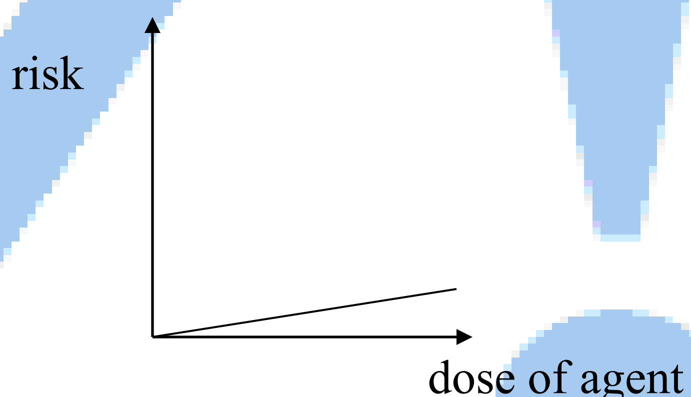
Carmel J Caruana, BioMedical Physics, Institute of Health Care, University of Malta

Risks in Hospital

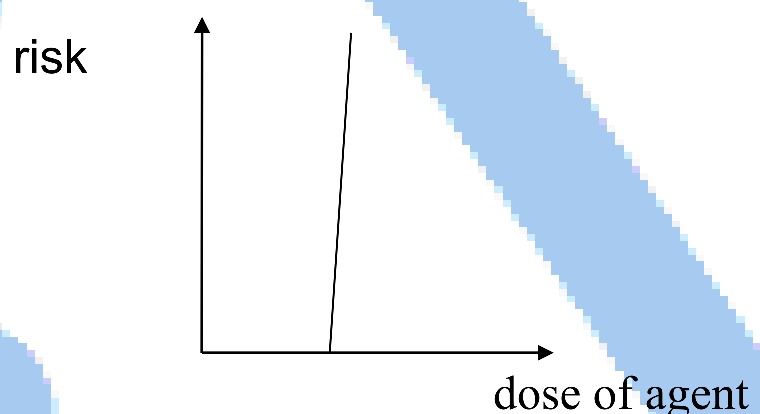
- Risks from Physical, Chemical and Biological 'agents'
- Somatic agents: ability to cause defects in an exposed individual
- Teratogenic agents: ability to cause defects in an exposed conceptus
- Mutagenic agents: can cause mutations in exposed sperm and ova
- Physical agents: mechanical, electrical, magnetic, ionising radiation

Characteristics of Biological Effects

- **Acute** (effects occur short-term) vs **Late** (effects occur long-term)
- **Deterministic** (existence of a threshold dose) vs **Stochastic** (no threshold, dose and risk proportional)



stochastic effects



deterministic effects

Mechanical

- Care in the presence of moving objects (centrifuges, X-ray systems etc.)
- When walking under objects
- Slippery floors
- Back-pain (lifting heavy equipment, patients etc.)

Electrical Shock

- Conditions for a shock to be possible
  - TWO connections to the body across which there is a voltage (potential difference) are required for a shock to be possible (one often the earth).
  - Shocks are often the result of an ‘earth-seeking’ mains voltage.
- Factors affecting magnitude of effect on the body
  - type of electric energy source
  - the amount and duration of current flow
  - the parts of the body affected (depends on path of current through body)

Magnitude of Current

The human body has an internal resistance of about 500 ohms. Hands and feet have a minimal resistance of 1000 ohms. The resistance of dry skin varies from one individual to another but is often around 100,000 ohms. The resistance of any given contact will depend on the area of contact, pressure applied, the magnitude and duration of current flow, and moisture present. The resistance will vary with time as the skin is charred or perforated and as physiological reactions occur. When the current is large enough to cause tissue damage, skin resistance falls within 5 to 10 seconds.

Effect on Various Tissue Types

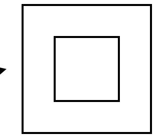
- Tissues differ in their resistance to the passage of electric current. Nervous tissue is the least resistant,followed by blood vessels, muscle, skin, tendon, fat, and bone. The actual passage of current through the body will depend on the resistance of the various tissues This explains why nervous tissues are so often damaged by electric shock while other tissues are relatively intact.

Current Thresholds for Physiological Effects

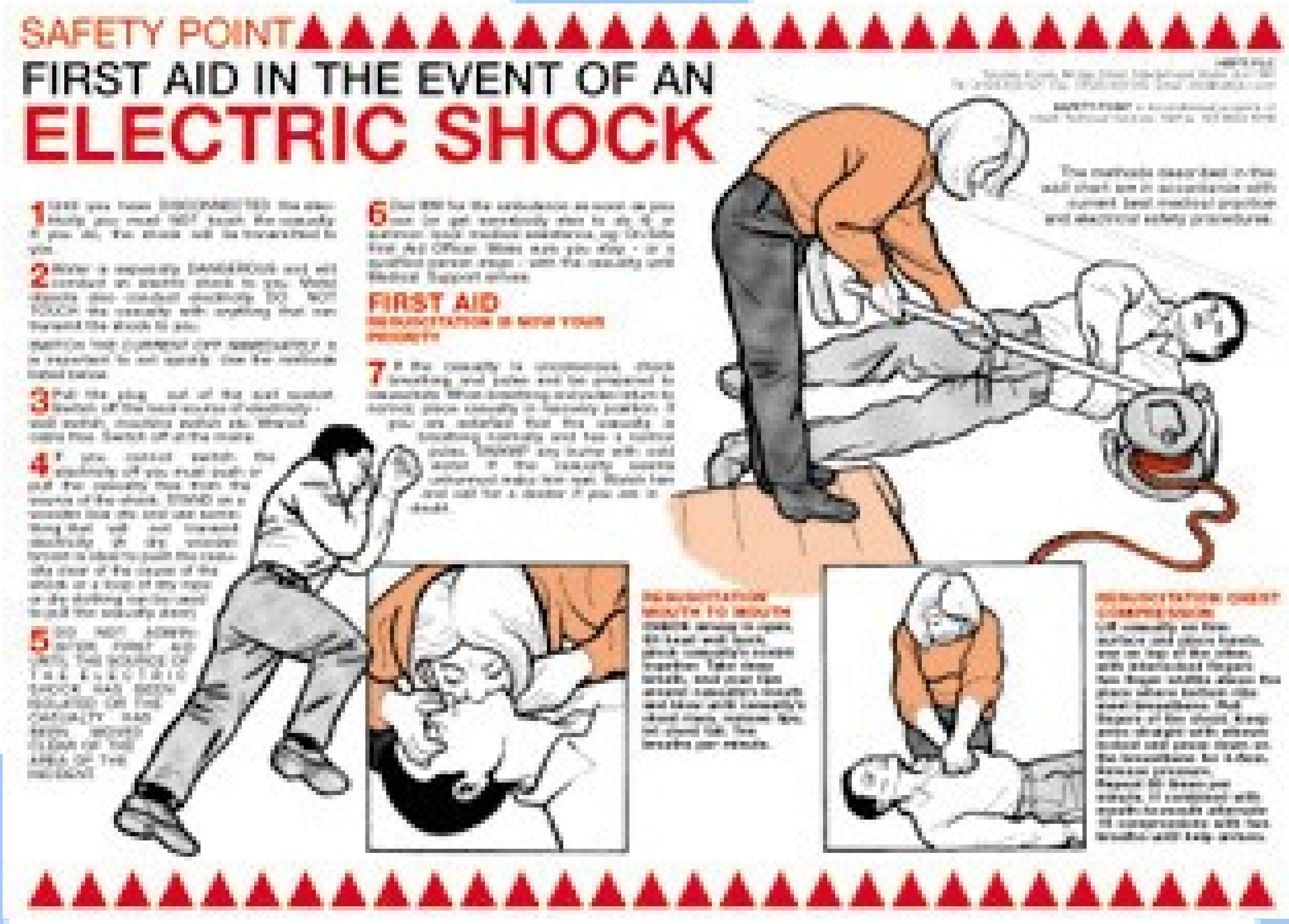
- 1 mA: threshold of feeling
- 5 mA: max ‘harmless’ current
- 10 – 20 mA: sustained muscular contraction (‘can’t let go’)
- 50 mA: pain, fainting
- 100 – 300 mA: ventricular fibrillation (uncoordinated ventricular contraction) leading to very low blood supply to brain etc - usual cause of death by electric shock

To Improve Electrical Safety

- Handle devices with care
- Protect cords from heat, alcohol, traffic pathways
- Use 3-pin plugs (unless using doubly insulated devices)



- Do not use damaged plugs, frayed wires or outlets that do not hold the plug firmly
- Never remove a plug by pulling on the cord
- Discontinue using and report any device that emits a shock or tingle
- Never plug in devices whilst touching pathways to earth (eg patient metal bedrails, plumbing etc)
- Do not touch two electrical devices simultaneously
- Avoid moist hands, being barefoot, wet floors.
- Do not touch any part of patient, bedrail, gelled areas during defibrillation or cardioversion, check for cracks in the defibrillator paddle
- Devices should be checked for safety at regular intervals



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Magnetic

- Magnetic Resonance Imaging (MRI), cannot enter room:
  - with metal objects (they become projectiles)
  - if have metal implants
  - heart-pacemaker

Ionising Radiation

Basics

- Definition: particles or photons of electromagnetic radiation ($f > 3 \times 10^{15}$ Hz i.e., UV, X and γ) which have enough energy to ionise body atoms.
- These ions can lead to the formation of FREE RADICALS (H·, OH· from water) and other highly chemically reactive compounds e.g., H_2O_2 which may bring about changes in biologically important molecules e.g., DNA hence producing serious biological effects e.g., carcinogenesis, mutagenesis.
- The unit of RADIATION 'DOSE' is the Sievert (Sv). Doses in practice are of the order of mSv. A certain risk of serious biological effect is associated with each Sv e.g., a risk of 2 per million per mSv for leukaemia.

Uses of Ionising Radiation in Hospitals

- Radiodiagnostics (XRI)
- Nuclear medicine
- Radiotherapy
- Radioimmunoassay
- bone-densitometry

Interaction of Radiation with Tissue

- Particles: The kinetic energy of the particle is totally absorbed by the tissue.
- Photons: The energy of the photon is either totally absorbed by the body or partially absorbed (during scatter).
- The higher the number of particles / photons absorbed by the body and the higher the energy of each particle / photon, the higher the number of free radicals etc produced, the higher the dose, the higher the risk.

Some Radiation Hazards

- Stochastic
  - Carcinogenesis : induction of cancer (increased risk of dying of cancer at a future date is increased by 0.005% per mSv)
  - Mutagenesis (change in a gene in gametes)
- Deterministic
  - Eye-lens cataracts
  - Skin injuries
  - Effect on conceptus in the uterus (relevant to pregnant workers)

Effects of Radiation on Cells

- Cells are most vulnerable during mitosis (cell division)
- Possible effects of radiation on cells:
  - Cell death prior to or after mitosis
  - Delayed or prolonged mitosis
  - Abnormal mitosis followed by repair
  - Abnormal mitosis followed by replication - this is the major problem as damage is replicated in daughter cells e.g., changes in cell control mechanism leads to carcinogenesis

Radiosensitivity of Cells

- Law of Bergonie and Tribondeau: radiosensitivity of cells is proportional to rate of cell division (mitotic frequency) and inversely prop. to the level of cell specialisation (aka cell ‘differentiation’). Some exceptions e.g., mature lymphocytes are very radiosensitive
- High sensitivity: bone marrow, spermatogonia, granulosa cells surrounding the ovum
- Medium sensitivity: liver, thyroid, connective tissue, vascular endothelium
- Low sensitivity: nerve cells, sense organs
- Radiosensitivity increases the lower the age

Radiosensitivity: Tissue Weighting Factor

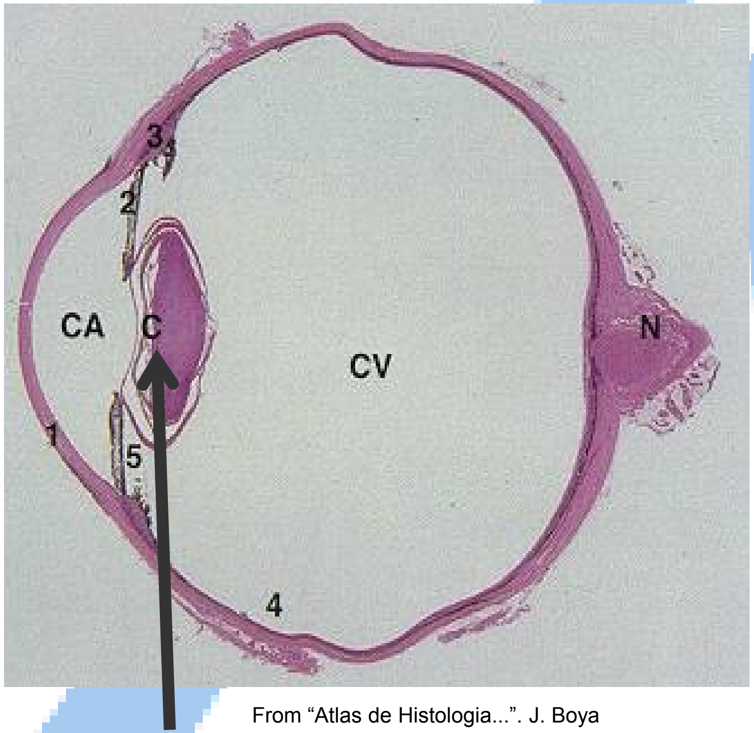
Tissue or organ	Tissue weighting factors, w_T
Gonads	0,20
Bone marrow (red)	0,12
Colon	0,12
Lung	0,12
Stomach	0,12
Bladder	0,05
Breast	0,05
Liver	0,05
Oesophagus	0,05
Thyroid	0,05
Skin	0,01
Bone surface	0,01
Remainder	0,05 (**) (***)

(**) For the purposes of calculation, the remainder is composed of the following additional tissues and organs: adrenals, brain, upper large intestine, small intestine, kidney, muscle, pancreas, spleen, thymus and uterus. The list includes organs which

(Ref. 96/29/Euratom)

Effects on the Eyes

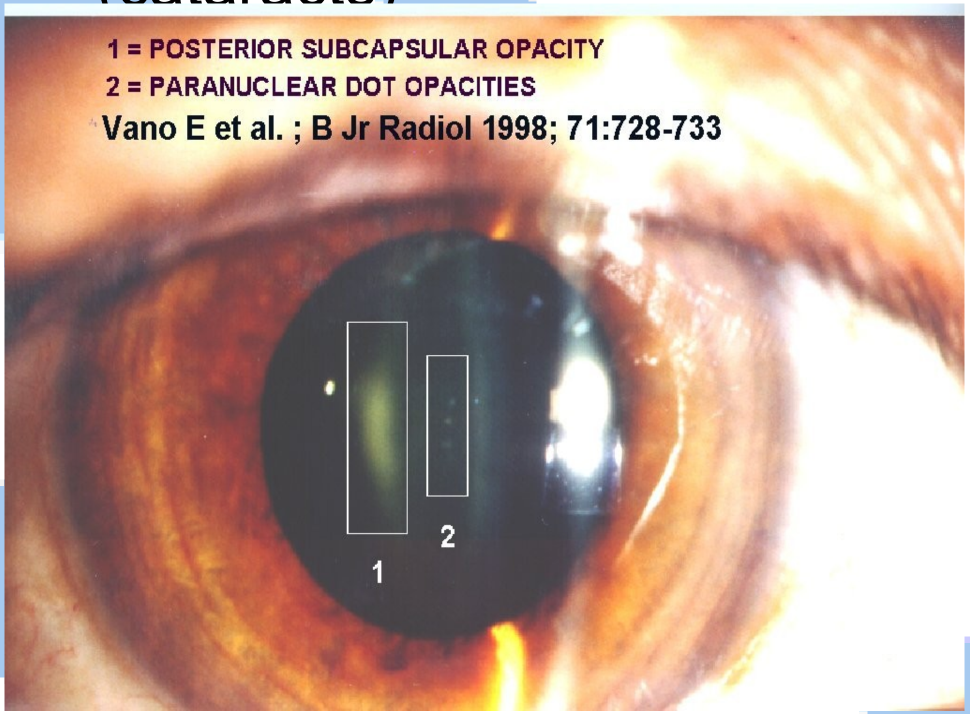
Sagittal section of eye:



From "Atlas de Histologia...". J. Boya

Eye lens is highly RS, moreover, it is surrounded by highly RS cuboid cells.

- lens opacities leading to visual impairment (cataracts)



Occupational Dose Limits (Legal Permissible Max Doses)

- Set by the ICRP (Intern Commission for Radiological Protection)
- Deterministic effects: dose limits are set below thresholds to avoid deterministic effects
- Probabilistic effects: cannot be zero! The occupational dose limits are set in a way that the risk is comparable to that found in other socially acceptable occupations / situations.
- *Dose limits are NOT safe limits and ALARA (As Low As Reasonably Achievable) must be practiced even when doses are below these limits*.

Minimising Doses from External Sources

- Avoid ionising radiation when possible
- Never put yourself in path of beam
- Minimise source strengths
- Minimise particle energies and maximise photon energies
- Minimise exposure time (free!!)
- Maximise distance (inverse square law) (free!!)
- If all else fails introduce Pb shielding, however shielding is the most expensive option

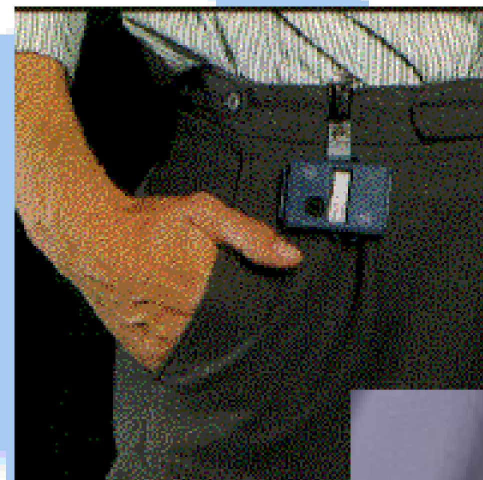
Minimising Doses from Internal Radiation

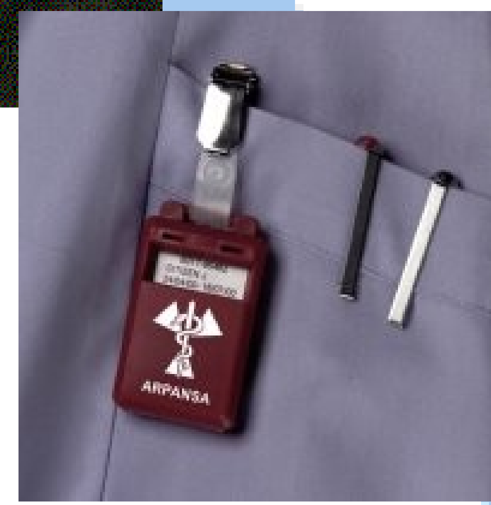
- Arise from **open** sources (powders, liquids, gases)
- Minimise source activities and energies
- Appropriate procedures: no mouth pipetting, spillages immediately cleaned up, throwaway tissues, containment using splashtrays
- Personal hygiene: appropriate clothing (labcoats, overshoes, gloves, masks), washing and monitoring of hands, clothes and shoes
- Appropriate lab design: non-absorbent surfaces, special basins, bins for radioactive waste, adequate ventilation, availability of washbasins and showers, laminar flow cabinets, glove boxes, installed dose and contamination monitors

Installed Dosemeters

Portable Dosemeters (contamination monitors)

Personal Dosemeters





Radiation Notices

Non-Ionising Radiations

- laser
- Ultrasound (other lecture)
- ultraviolet
- radio-frequencies (RF – other lecture)
  - Microwaves
  - Short-waves

Lasers

- devices: CT, MRI, radiotherapy systems, laser surgery, eye-lens corrections, DVDs etc
- bioeffects: thermal and photochemical damage to skin, retina as eye-lens can focus laser to a very intense point on the retina, cornea burn
- Laser Protection Adviser (LPA) and Laser Protection Supervisors
- laser controlled areas
- local rules
- appropriate training
- protective eye-wear
- Maximum Permissible Exposure levels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Invisible laser radiation.
DO NOT STARE
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Laser Classes

- classes 1 - 4 in increasing power
- Class 1: Inherently safe (max permitted limit cannot be exceeded) because laser is very low power or housed in an enclosure that does not allow harmful levels of exposure (eg laser printer, CD drive)
- Class 2: low power where safety is afforded by blink mechanism of eye (eg laser lecturing pointer)
- Class 3A and 3B: direct beam viewing could be hazardous
- Class 4: high power devices. Direct beam and reflections hazardous.

UV

- devices: spectrophotometers, photo-therapy, suntan machines, photocopiers etc.
- careful as non-visible
- UVA, UVB, UVC increasing frequency
- bioeffects: skin cancer, erythema, premature aging of skin, cataracts

Personal Protective Equipment (PPE)

- Any device or appliance designed to be worn or held by an individual for protection against one or more health hazards
- Directive 89/686/EEC

Additional Information for Radiation Workers

Radiation Quantities and Units 1

- External sources: ABSORBED DOSE – the amount of energy absorbed per unit mass of tissue. Units JKg^{-1} (Gray Gy). The higher the absorbed dose the higher the number of ions produced and the higher the risk.
- Internal sources: COMMITTED ABSORBED DOSE amount of energy absorbed per unit mass of tissue over a period of 50 years (70 years for children).

$$D_{T,R} = \frac{energyabs}{m}$$

Radiation Quantities and Units 2

Effective Dose and Committed Effective Dose (units Sv):

$$E = w_R D_{T,R}$$

$w_R =$ radiation weighting factor

$w_T =$ tissue weighting factor

The radiation weighting factor is necessary because certain radiations are more risky than others. γ and X (ext/int) 1, α (internal) 20.

The tissue weighting factor is necessary because different tissues have different *radiosensitivity*.

The effective dose is often referred to simply as the *dose*.

Units of H are Sievert Sv (usually mSv used).

Shielding

- a no shielding required since stopped by skin
- b usually 1cm of perspex is enough
- X / g radiation require shielding (usually Pb)

$$t = \frac{1}{\mu} \ln \frac{E_I}{E_T}$$

μ = linear energy attenuation coefficient of the shielding material

t = thickness of shielding required to reduce effective dose from E_I to E_T

Half Value Layer (HVL) = 0.693 / μ

Tenth Value Layer (TVL) = 2.303 / μ

Old Units

- 1 RAD = 0.01Gy
- 1 REM = 0.01 Sv
- Quality factor = radiation weighting factor
- Roentgen (R): measure of radiation exposure used for X and g only.

(Exposure: In a small volume of the air, it is the quotient *q/m*, where *q* is total negative (or positive) electric charge produced in the air volume with mass *m*. The exposure unit is coulomb per kilogram ($C.kg^{-1}$). An older unit of exposure is roentgen (R):

$$\boldsymbol{1\ R = 2{,}58.10^{-4}\ C.kg^{-1}}$$)

Websites for additional information on radiation sources and effects

European Commission (radiological protection pages): **europa.eu**

International Commission on Radiological Protection: **www.icrp.org**

World Health Organization: **www.who.int**

International Atomic Energy Agency: **www.iaea.org**

United Nations Scientific Committee on the Effects of Atomic Radiation: **www.unscear.org**

Author:

Carmel J. Caruana

Graphic design and content collaboration:

Vojtěch Mornstein

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