

Topics covered by the core examination

1. Types of radiation

- Ionising radiation: radiation with sufficient energy to knock electrons out of atoms, thereby having the potential to cause biological damage. Examples include alpha and beta particles, neutrons, protons, cosmic rays, and sufficiently energetic electromagnetic radiation such as x-rays and gamma rays.
- The electromagnetic (e-m) radiation spectrum (in increasing order of energy): radio, microwave, infrared light, visible light, ultraviolet light, x- and gamma rays.
- Ionisation threshold for electromagnetic radiation: e-m radiation that is less energetic than ultraviolet light will not cause ionisation.

2. Radiation dose

- Absorbed dose: measures the amount of energy deposited by ionising radiation in a given mass. SI unit: joules per kilogram (J/kg), also called grays (Gy).
- Effective dose: measures the biological detriment (i.e. damage) caused by a given absorbed dose. It is calculated by multiplying the absorbed dose by factors that account for the damaging power of the radiation and the susceptibility of the organs that have been irradiated. SI unit: sieverts (Sv).
- Natural background radiation dose: typically about 2000 μ Sv per year. Sources of background radiation include naturally occurring radioactive materials (some of which occur within the human body) and cosmic radiation. Artificially produced radiation such as generated by an x-ray machine or a nuclear reactor is *not* classified as background radiation.

3. Biological effects of ionising radiation

Ionising radiation can cause the following biological effects:

- Cancer. The risk of developing cancer is considered to increase with radiation dose, apparently without a threshold. That is, any dose, however small, is assumed to carry an associated risk.
- Genetic damage. The risk of genetic defects is considered to increase with radiation dose, apparently without a threshold.
- Cell damage. Living cells can be damaged by radiation, and will die if overexposed.
- Burns. Burns will occur when a threshold absorbed dose (about 3 Gy) is exceeded.
- Death. The lethal whole body effective dose is considered to be about 5 Sv. A majority of people who receive a dose of this magnitude over a relatively short time span will die from cell damage caused by the radiation. A corresponding absorbed dose delivered to only part of the body will probably cause burns but will not necessarily be lethal.

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4. Dose limits

A dose limit is the maximum amount of radiation (above natural background) that a person is legally permitted to receive. The following dose limits were recommended by the International Commission for Radiological Protection in 1990 and adopted as a legal requirement in Western Australia:

- Radiation workers: 20 mSv per year, averaged over any 5 year period, with a maximum of 50 mSv in any one year.
- Members of the public: 1 mSv per year, averaged over any 5 year period, with a maximum of 5 mSv in any one year.

5. Dose calculations

Multipliers

micro (μ): one millionth.

milli (m): one thousandth.

e.g. $10 \text{ Sv} = 10,000 \text{ mSv} = 10,000,000 \text{ }\mu\text{Sv}$.

Dose = dose rate x time

Note: Dose rate is dose received per time unit.

Ex. 1. What is the radiation dose received by a person exposed to a dose rate of $2.5 \text{ }\mu\text{Sv}$ per hour for one working week? (Assume that a working week has 40 hours.)

$\text{Dose} = 2.5 \text{ }\mu\text{Sv/h} \times 40 \text{ h} = 100 \text{ }\mu\text{Sv}$ (hours cancel out to leave μSv)

Ex. 2. What radiation dose is received by a person exposed to $100 \text{ }\mu\text{Sv}$ per week for one working year? (Assume that a working year has 50 weeks.)

$\text{Dose} = 100 \text{ }\mu\text{Sv/week} \times 50 \text{ weeks} = 5000 \text{ }\mu\text{Sv}$ (weeks cancel out to leave μSv)

Ex. 3. The Radiological Council has set a dose constraint of 2 mSv per year for some radiation workers. What weekly dose corresponds to this constraint? (Assume that a working year has 50 weeks.)

$2 \text{ mSv} = ? \text{ mSv/week} \times 50 \text{ weeks}$ (What number multiplied by fifty equals two?)

$? = 2/50 = 4/100 = 0.04 \text{ mSv/week} = 40 \text{ }\mu\text{Sv/week}$.

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Inverse square law

The intensity of radiation from a point source¹ decreases as the square of the distance from the source. For example, the intensity of radiation 2 m from a point source will be one quarter ($\frac{1}{2} \times \frac{1}{2}$) of the intensity at 1 m, the intensity at 3 m will be one ninth ($\frac{1}{3} \times \frac{1}{3}$) of the intensity at 1 m, and so on.

The following mathematical formula may be used for inverse square law calculations.

$$I(d) = I(d_{ref}) \times (d_{ref} / d)^2$$

In words, the intensity of radiation at a distance of d metres is the intensity at a reference distance of d_{ref} metres multiplied by a factor to account for distance. This factor is the *inverse* of the *square* of the relative distances of d and d_{ref} from the source. The reference distance is the distance at which the radiation intensity is known.

The same formula can be used to calculate doses and dose rates.

E.g. The dose rate 1 m from a radiation source is 40 $\mu\text{Sv/h}$. What is the dose rate 2 m from the source?

In this case, the dose rate at one metre is known. Hence, d_{ref} is 1 m. The other distance, d , is 2 m.

$$\text{Dose rate at 2 m} = \text{Dose rate at 1 m} \times (1 \text{ m} / 2 \text{ m})^2 = 40 \mu\text{Sv/h} \times (1/4) = 10 \mu\text{Sv/h}$$

6. Radiation protection

Three principles are employed to protect an individual from radiation exposure:

- *Decrease time*: decreasing exposure time results in a proportional dose reduction;
- *Increase distance*: increasing the distance between the radiation source and the individual results in a dose reduction that can be calculated by the inverse square law; and
- *Increase shielding*: increasing the amount of shielding between the radiation source and the individual results in a dose reduction that can be calculated by considering the thickness of the shielding material.

It is worth memorising the phrase ‘time, distance, shielding’.

¹ A radiation source can be considered to be a point if its maximum dimension is less than one tenth of the distance under consideration. Therefore, for an x-ray tube with a focal spot of 2 mm diameter, the inverse square law will work for distances of more than 2 cm from the focus.

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7. Radiation monitoring

The regulations and the Radiation Safety Act require designated radiation workers to be monitored for radiation exposure. Monitoring is achieved by means of personal dosimeters such as film badges, TLD badges, OSL badges, and integrating dosimeters. Meters which measure dose rate (e.g. geiger counters) are *not* personal dosimeters. A radiation worker's employer is responsible for maintaining a record of the radiation doses received by each person employed. Personal dosimeters can be obtained by contacting a personal radiation monitoring service provider. A list of such service providers is available from the Radiological Council.