Properties of electromagnetic waves 2

6.6.2.3 · Physics · revision notes

How electromagnetic waves are produced and absorbed (by changes in atoms and nuclei, and, at Higher tier, by oscillating currents in circuits), and the harm that ultraviolet, X-rays and gamma rays can do to the body. Expect recall questions and 'use the data' questions on radiation dose.

Key facts

- EM waves can be produced or absorbed by changes in atoms and nuclei
- Grade 7+ only Alternating current in a circuit → radio waves of the same frequency
- Ultraviolet: premature skin ageing and higher risk of skin cancer
- Radiation dose (Sv) = a measure of the risk of harm from exposure
- Gamma rays come from changes in the nucleus
- Grade 7+ only Radio waves absorbed by an aerial → alternating current of the same frequency
- X-rays and gamma rays: ionising; can cause mutation of genes and cancer
- 1 Sv = 1000 mSv

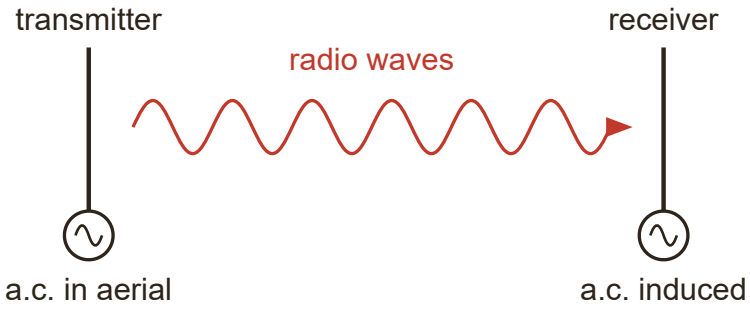
Notes

Producing and absorbing EM waves

- EM waves over a wide range of frequencies can be produced or absorbed by changes inside **atoms** and their **nuclei**. For example, when electrons in atoms change energy level, EM waves such as light can be emitted or absorbed.
- **Gamma rays** come from changes in the **nucleus** of an atom.

Radio waves and circuits Grade 7+ only

- Radio waves can be produced by **oscillations** in electrical circuits: an alternating current in a transmitter's aerial produces radio waves with the same frequency as the current.
- When radio waves are absorbed by a receiver's aerial, they may create an **alternating current** with the **same frequency** as the radio waves. So radio waves can themselves induce oscillations in a circuit.



The induced current has the same frequency as the radio waves.

- This is how a signal travels from a radio transmitter to a radio receiver.

Hazards to the body

- Ultraviolet, X-rays and gamma rays can have hazardous effects on human body tissue. The effects depend on the **type** of radiation and the **size of the dose**.
- **Ultraviolet** can cause skin to age prematurely and increases the risk of skin cancer.
- **X-rays and gamma rays** are **ionising** radiation. They can cause the mutation of genes and cancer.

Radiation dose

- **Radiation dose**, in **sieverts (Sv)**, is a measure of the **risk of harm** from the body being exposed to radiation.
- 1000 millisieverts (mSv) = 1 sievert (Sv). You do not need to remember the unit, but you must be able to use it.
- The bigger the dose, the greater the risk. Use given data to compare risks, for example the dose from a medical scan with the yearly dose from background radiation, and to judge whether a benefit is worth the risk.

How to answer each type of question

State the hazards of ultraviolet, X-rays and gamma rays

1 to 4 marks | **Grade 4**

1. Ultraviolet: skin ageing prematurely and risk of skin cancer.
2. X-rays and gamma rays: ionising, so mutation of genes and cancer.
3. Use these exact effects; 'it damages you' is too vague.

Example. (a) Give **two** harmful effects of ultraviolet radiation on the human body.
(b) Explain why X-rays can cause cancer.

Model answer.

(a) It makes skin age prematurely (1). It increases the risk of skin cancer (1).

(b) X-rays are ionising radiation (1), so they can cause mutation of genes, which can lead to cancer (1).

Convert between Sv and mSv

1 to 2 marks | **Grade 5**

1. Sv to mSv: multiply by 1000.
2. mSv to Sv: divide by 1000.

Example. A radiographer receives a dose of 0.0035 Sv in one year.
Convert this dose into millisieverts.

Model answer. 0.0035 × 1000 (1) = 3.5 mSv (1)

Use radiation dose data to compare risks

2 to 3 marks | **Grade 5**

1. Quote the numbers from the data and do the comparison (e.g. how many times bigger).
2. Link a bigger dose to a greater risk of harm.
3. If asked, weigh the benefit against the risk.

Example. A doctor can choose between two scans for a patient. A chest X-ray gives a dose of 0.02 mSv. A CT scan of the abdomen gives a dose of 8 mSv.
(a) How many times greater is the dose from the CT scan?
(b) Suggest why doctors only use a CT scan when it is needed.

Model answer.

(a) 8 ÷ 0.02 = 400 times (1)

(b) The CT scan gives a much bigger dose, so a greater risk of harm such as cancer (1). It should only be used when the benefit of the diagnosis outweighs this risk (1).

Explain how radio waves carry a signal 3 marks **Grade 7**

1. Transmitter: an alternating current (oscillation) produces radio waves.
2. State that the frequency of the waves matches the frequency of the current.
3. Receiver: the waves are absorbed and induce an alternating current of the same frequency.

Example. A radio transmitter sends a signal to a radio receiver.
Explain how the radio waves are produced and how they produce a signal in the receiver.

Model answer. An alternating current (oscillation) in the transmitter's circuit produces radio waves (1) with the same frequency as the current (1). The radio waves are absorbed by the receiver's aerial and induce an alternating current with the same frequency as the radio waves (1).

Don't lose marks

- Describing radiation dose vaguely as 'how much radiation'. It is a measure of the risk of harm from exposure to radiation.
- Confusing mSv and Sv: 5 mSv is 0.005 Sv, not 5000 Sv.
- Saying gamma rays come from electrons. They come from changes in the nucleus.
- Saying radio waves produce a direct current in a receiver. They induce an alternating current of the same frequency.
- In data questions, writing only 'it is more dangerous' without using the numbers.

More tips

Memory tricks

- The dangerous three are at the high-frequency end: ultraviolet, X-rays, gamma rays.
- Milli means a thousandth: mSv → Sv, divide by 1000; Sv → mSv, multiply by 1000.
- Radio in, same frequency out: the current induced in a receiver oscillates at the frequency of the radio waves.

Exam technique

- In data questions, quote values from the table and make a comparison, e.g. 'the CT dose is 400 times bigger'.
- In risk questions, weigh up both sides: the benefit (e.g. a diagnosis) against the risk from the dose.
- Name specific effects: 'skin cancer', 'mutation of genes', 'skin ageing prematurely'.

What each grade needs

What you need to be able to do, from the first marks up to the top grade.

Grade 3 **Name the EM waves that harm body tissue**
Ultraviolet, X-rays and gamma rays can have hazardous effects on human body tissue.

Grade 4 **State the effects of ultraviolet on skin**
Ultraviolet can make skin age prematurely and increases the risk of skin cancer.

Grade 5

State the effects of X-rays and gamma rays

They are ionising radiation and can cause mutation of genes and cancer.

Grade 5

State where gamma rays come from

Gamma rays come from changes in the nucleus of an atom.

Grade 5

Use radiation dose data to compare risks

Compare doses in sieverts or millisieverts: the bigger the dose, the greater the risk of harm.

Grade 7

Explain how radio waves are produced

Oscillations (an alternating current) in an electrical circuit produce radio waves of the same frequency.

Grade 8

Explain how radio waves are received

Radio waves absorbed by an aerial can induce an alternating current with the same frequency as the waves.

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