Types of electromagnetic waves

4.6.2.1 · Waves · revision notes

Electromagnetic (EM) waves are transverse waves that transfer energy from a source to an absorber. You need the order of the EM spectrum by wavelength and frequency, the fact that all EM waves travel at the same speed through a vacuum, and examples of EM waves transferring energy. Expect recall questions and v = f λ calculations.

Key facts

- EM waves are transverse and transfer energy from a source to an absorber
- Frequency increases from radio to gamma; wavelength decreases
- Visible light: red (longest λ) to violet (shortest λ)
- v = f λ, so λ = v ÷ f and f = v ÷ λ
- Order (longest λ → shortest λ): radio, microwave, infrared, visible, ultraviolet, X-ray, gamma
- All EM waves travel at 3.0×10^8 m/s in a vacuum (and air)
- Our eyes detect only visible light
- 1 MHz = 10^6 Hz; 1 GHz = 10^9 Hz

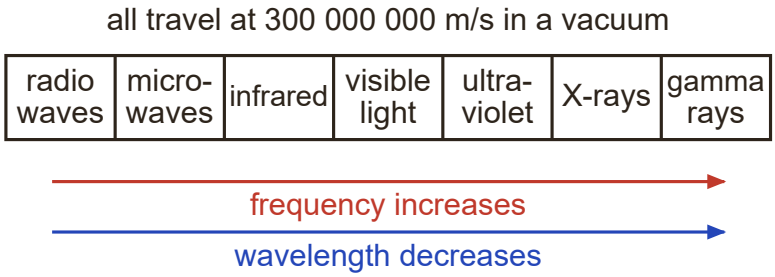
Notes

What EM waves are

- Electromagnetic waves are **transverse** waves. They transfer energy from the source of the waves to an absorber.
- They do not need a medium: they can travel through a vacuum. This is how light from the Sun reaches the Earth.
- All EM waves travel at the **same speed** through a vacuum or air: 3.0×10^8 m/s (300 000 000 m/s). Exam questions normally give you this value.

The electromagnetic spectrum

- EM waves form a **continuous spectrum**: there are no gaps, and each group merges into the next.
- In order of **increasing frequency** and **decreasing wavelength**: radio waves, microwaves, infrared, visible light, ultraviolet, X-rays, gamma rays.



Radio waves to gamma rays: frequency up, wavelength down.

- The wavelengths cover a huge range: some radio waves are kilometres long, while gamma rays have wavelengths smaller than an atom.
- Visible light runs from red (longest wavelength) to violet (shortest wavelength).
- Our eyes only detect visible light, so we can only see a very small part of the spectrum.

Energy transfer and the wave equation

- Examples of EM waves transferring energy: infrared and visible light from the Sun warm the Earth; microwaves transfer energy to food in a microwave oven; radio waves transfer energy from a transmitter to the aerial of a radio; X-rays transfer energy to the detector that records an X-ray image.
- $v = f \lambda$ applies to EM waves. Because v is the same for all of them, frequency and wavelength are inversely proportional: double the frequency and the wavelength halves.
- So as you go from radio waves to gamma rays, the frequency goes up and the wavelength goes down.

How to answer each type of question

Recall: complete the EM spectrum 1 to 3 marks **Grade 3**

1. Write out the whole spectrum in order in the margin first.
2. Match each gap to its position.

Example. Some groups of the electromagnetic spectrum are listed in order of increasing frequency.
radio waves, microwaves, **A**, visible light, ultraviolet, **B**, **C**
Name the groups A, B and C.

Model answer.

A: infrared (1)
B: X-rays (1)
C: gamma rays (1)

Compare wavelength, frequency or speed of EM waves

1 to 2 marks | Grade 4

1. Higher frequency means shorter wavelength.
2. In a vacuum or air, the speed is the same for every type.

Example. (a) Which type of electromagnetic wave has the highest frequency? Tick (✓) **one** box.
infrared / microwaves / ultraviolet / X-rays
(b) Compare the speed of X-rays in a vacuum with the speed of microwaves in a vacuum.

Model answer.

(a) X-rays (1)
(b) They travel at the same speed (1)

Give an example of energy transfer by EM waves

2 marks | Grade 5

1. Name the type of EM wave.
2. Name the source and the absorber, and say what the energy does.

Example. Give **one** example of electromagnetic waves transferring energy from a source to an absorber. Name the type of wave, the source and the absorber.

Model answer. Infrared (1) from an electric heater is absorbed by a person's skin, which warms up (1).

Calculate the wavelength or frequency of an EM wave

3 marks | Grade 6

1. Convert MHz or GHz to Hz using standard form.
2. Rearrange $v = f \lambda$ for the unknown.
3. Use $v = 3.0 \times 10^8$ m/s (or the value given) and give the unit.

Example. A Wi-Fi router emits microwaves with a frequency of 2.4 GHz. The speed of electromagnetic waves is 3.0×10^8 m/s.
Calculate the wavelength of the microwaves.

Model answer.

$2.4\ \text{GHz} = 2.4 \times 10^9\ \text{Hz}$ (1)
$\lambda = v \div f = 3.0 \times 10^8 \div 2.4 \times 10^9$ (1)
$\lambda = 0.125$ m (0.13 m to 2 significant figures) (1)

Don’t lose marks

- ✗ Saying different EM waves travel at different speeds in a vacuum.

- Getting the order of the spectrum wrong, e.g. putting ultraviolet before visible light, or swapping microwaves and infrared.
- Mixing up frequency and wavelength: gamma rays have the highest frequency but the shortest wavelength.
- Losing powers of ten when converting MHz or GHz to Hz.
- Calling EM waves longitudinal.

More tips

Memory tricks

- Order of the spectrum: 'Rowdy Monkeys In Vans Use X-ray Goggles' (radio, microwaves, infrared, visible, ultraviolet, X-rays, gamma).
- Left to right (radio → gamma): frequency up, wavelength down.
- Quick anchor: with a speed of 3×10^8 m/s, a frequency of 300 MHz gives a wavelength of exactly 1 m.
- Sense check: a microwave wavelength should come out in millimetres or centimetres, and visible light in hundreds of nanometres.

Exam technique

- Learn the spectrum in order: questions often give part of it and ask you to fill the gaps.
- Use the $\times 10^x$ key for standard form, and give very large or very small answers in standard form.
- Use the value of the speed of EM waves given in the question.

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 parts of the EM spectrum in order**
Radio waves, microwaves, infrared, visible light, ultraviolet, X-rays, gamma rays.

Grade 3 — **State that EM waves are transverse**
EM waves are transverse waves that transfer energy from a source to an absorber.

Grade 4 — **Link spectrum position to wavelength and frequency**
Radio waves have the longest wavelength and lowest frequency; gamma rays have the shortest wavelength and highest frequency.

Grade 5 — **State that all EM waves travel equally fast**
All EM waves travel at the same speed through a vacuum (space) or air: 3.0×10^8 m/s.

Grade 5 — **Give examples of EM waves transferring energy**
E.g. infrared from a fire warming your skin, or microwaves heating food in an oven.

Grade 6 — **Use v = f λ with standard form**
E.g. find the wavelength of a 100 MHz radio wave using a speed of 3.0×10^8 m/s.

Grade 7 — **Explain why higher frequency means shorter wavelength**
All EM waves have the same speed, so a higher frequency means a proportionally shorter wavelength.

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