Exercise walk-through

6.3 Electromagnetic waves (4.6.2.1–4.6.2.4)

AQA · GCSE · Physics

Waves: sound, light and the electromagnetic spectrum

- describe **transverse** and **longitudinal** waves, and use the wave equation;
- measure the speed of waves in water and in a solid;
- describe the electromagnetic spectrum, its uses and its dangers, and investigate infrared radiation;
- (physics only) explain reflection, sound, ultrasound and seismic waves, lenses, colour and black body radiation.

Transverse and longitudinal waves

- In a **transverse** wave, the oscillations are at right angles to the direction the wave travels. Examples: ripples on water, waves on a string, and all electromagnetic waves.
- In a **longitudinal** wave, the oscillations are in the same direction as the wave travels. Sound waves in air are **longitudinal**. They have **compressions**, where the particles are close together, and **rarefactions**, where they are spread out.

Electromagnetic waves

- Electromagnetic (EM) waves are **transverse** waves that transfer energy from a source to an absorber.
- They form a continuous spectrum, and they all travel at the same speed in a vacuum or in air: 3×10^8 m/s.
- In order of decreasing wavelength and increasing **frequency**:
- Our eyes detect only visible light, a very small part of the spectrum.

radio $\rightarrow$ microwaves $\rightarrow$ infrared $\rightarrow$ visible light $\rightarrow$ ultraviolet $\rightarrow$ X-rays $\rightarrow$ gamma rays

Exercises 2.1·2.2

2.1 Name the EM wave with the longest wavelength and one with the highest frequency. [2]

EM spectrum

2.2 Calculate the wavelength of a 1.5 GHz microwave signal. [3]

$f = 1.5$ GHz

$c = 3.0 \times 10^8 \ \frac{\text{m}}{\text{s}}$

Exercises 2.1·2.2

2.1 Name the EM wave with the longest wavelength and one with the highest frequency. [2]

EM spectrum

2.1 Radio; gamma.

2.2 Calculate the wavelength of a 1.5 GHz microwave signal. [3]

$f = 1.5$ GHz $\quad c = 3.0 \times 10^8 \ \frac{\text{m}}{\text{s}}$

2.2 Convert: $f = 1.5 \times 10^9$ Hz (C1).

$$\lambda = \frac{v}{f} = \frac{3 \times 10^8}{1.5 \times 10^9} = \mathbf{0.20}\ \text{m}$$

(C1, A1)

Exercises 2.3·3.1

2.3 Give one use each for infrared and ultraviolet. [2]

infrared ultraviolet

3.1 Compare radio waves and gamma rays: give three similarities and two differences. [5]

radio waves gamma rays

Exercises 2.3·3.1

2.3 Give one use each for infrared and ultraviolet. [2]

infrared ultraviolet

2.3 Infrared: remote controls / heaters / night vision. Ultraviolet: fluorescent lamps / sterilising / tanning.

3.1 Compare radio waves and gamma rays: give three similarities and two differences. [5]

radio waves gamma rays

3.1 Similarities: both transverse; both travel at the same speed in air/vacuum; both transfer energy from a source to an absorber / both can be reflected, refracted, absorbed (any three, B1 each). Differences: gamma has much shorter wavelength and much higher frequency; gamma is ionising and radio is not / different production and detection (any two, B1 each).

Setup for exercise 3.2

3.2 A hospital compares two scanning methods for a broken arm: X-ray imaging and ultrasound.

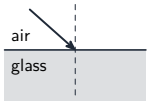
X-ray imaging ultrasound

(a) Explain why X-rays form an image of the bone. [2]

(b) Explain why ultrasound is preferred for scanning a fetus. [2]

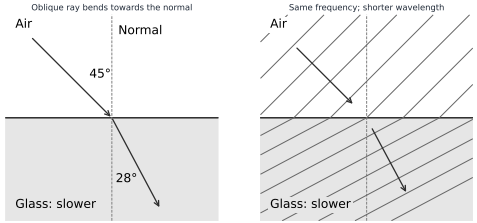
(c) In a hypothetical dose comparison, exposure A gives 0.6 mSv and exposure B gives 20 times this. Calculate the dose from B in mSv. These are supplied practice values, not typical clinical doses. [2]

3.3 Light meets a stationary air–glass boundary at an oblique angle and slows down in the glass.



(a) Explain, in terms of speed, why the light changes direction. [2]

(b) The wavefront diagram: state what happens to the spacing of wavefronts in the glass and why frequency is unchanged. [3]



Exercise 3.2

3.4 For each type of electromagnetic wave, give **one** use and explain why the wave is suitable for that use.

(a) microwaves [2]

microwaves infrared visible light

(b) infrared [2]

(c) visible light [2]

Exercise 3.2

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(b) infrared [2]

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3.2 (a) X-rays pass through flesh but are absorbed by dense bone, so the shadow of the bone forms the image. (b) Ultrasound is non-ionising, avoiding the ionisation risk associated with X-rays; partial reflections at tissue boundaries form an image. This does

Full solution on next slide

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Full solution 3.2

3.2 (a) X-rays pass through flesh but are absorbed by dense bone, so the shadow of the bone forms the image. (b) Ultrasound is non-ionising, avoiding the ionisation risk associated with X-rays; partial reflections at tissue boundaries form an image. This does not mean all ultrasound exposure is harmless. (c) $D_B = 20D_A = 20 \times 0.6 = \mathbf{12}$ mSv (C1, A1).

3.3 (a) One side of each wavefront enters the glass first and slows; the other side, still fast, pivots the front – the ray bends towards the normal. (b) Wavefronts become closer together: the speed falls and $\lambda = v/f$ falls with it; frequency cannot change at the boundary – the same fronts arrive per second.

3.4 (a) Satellite communication: microwaves pass through the atmosphere to and from the satellite without being absorbed or reflected. Or cooking, because water molecules in food absorb microwaves and heat up. (b) Thermal imaging cameras: all objects emit infrared, and hotter objects emit more, so warm bodies show up. Or cooking and heaters, because infrared is absorbed by surfaces and heats them. (c) Fibre-optic communication: visible light is totally internally reflected along the glass fibre with little absorption, so the signal travels a long way.