# 3.1 Wave properties and the EM spectrum

Name: _____ Class: _____ Date: _____ **Total: 25 marks**

**KEY WORDS** wavelength • diffraction

## Objective

Build the skills to answer exam questions on **waves and the electromagnetic spectrum** : transverse and longitudinal waves, wave measurements, $v = f\lambda$, what happens at a boundary, diffraction, and the uses and dangers of electromagnetic waves.

**You must be able to:**

- describe transverse and longitudinal waves and their amplitude, wavelength, frequency and period
- use $v = f\lambda$ and $T = \frac{1}{f}$
- describe reflection, refraction, absorption and diffraction
- give the order, uses and dangers of the electromagnetic spectrum

## 1 Key knowledge and worked examples

### ■ Waves and the electromagnetic spectrum

| idea | equation or rule |
|---|---|
| transverse, longitudinal | vibrations at right angles to the direction of travel (light, water waves); or along it, with compressions and rarefactions (sound) |
| measurements | amplitude, wavelength $\lambda$, frequency $f$ in Hz, period $T = \frac{1}{f}$ |
| wave speed | $v = f\lambda$ |
| at a boundary | reflected, refracted, transmitted or absorbed; diffraction: waves spread out through a gap, most when the gap is about one wavelength |
| electromagnetic spectrum | radio, microwaves, infrared, visible, ultraviolet, X-rays, gamma: shorter wavelength, higher frequency; all travel at $3.0 \times 10^8$ m/s in a vacuum |
| dangers | ultraviolet, X-rays and gamma are ionising: they damage cells and can cause cancer |



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**Worked example 1: wave speed.** A sound wave has frequency 500 Hz and wavelength 0.68 m. Find its speed.

1. Known: $f = 500$ Hz, $\lambda = 0.68$ m.
2. Rule: $v = f\lambda$.
3. Numbers: $500 \times 0.68$.
4. Result: $v = 340$ **m/s**.

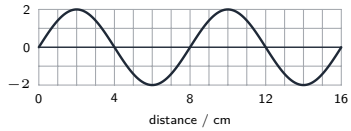
**Worked example 2: a wavelength.** A radio wave has frequency $1.0 \times 10^8$ Hz. Find its wavelength.

1. Known: $v = 3.0 \times 10^8$ m/s, $f = 1.0 \times 10^8$ Hz.
2. Rule: $\lambda = \frac{v}{f}$.
3. Numbers: $\frac{3.0 \times 10^8}{1.0 \times 10^8}$.
4. Result: $\lambda = 3.0$ **m**.

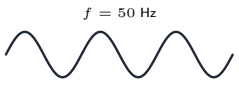
**Answer shapes:** change kHz to Hz and cm to m before you use $v = f\lambda$.

## 2 Practice

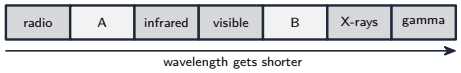
**2.1** The diagram shows a transverse wave. Write down its amplitude and its wavelength. [2]




**2.2** A wave has a frequency of 50 Hz. Calculate its period. [2]




**2.3** The diagram shows the electromagnetic spectrum. Name the waves in boxes A and B. [2]

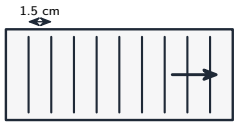




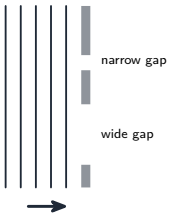

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## 3 Exam-style questions

**3.1** Water waves move across a ripple tank. 12 waves pass a point in 4.0 s. The wavelength is 1.5 cm. Calculate the speed of the waves in m/s. [3]

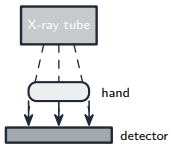



**3.2** Water waves reach a barrier with a wide gap and a narrow gap. Describe and explain what happens to the waves after each gap. [3]




**3.3** A hospital uses X-rays to make images of bones.

(a) The X-rays have a wavelength of $1.0 \times 10^{-10}$ m. Calculate their frequency. [2]




(b) Explain why bones show up on an X-ray image. [2]



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(c) The radiographer stands behind a lead screen when the X-ray machine is on. Explain why. [3]

(d) Describe how three different types of electromagnetic wave are used in a hospital. Explain why some of them are more dangerous than others. [6]



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## Solutions

Marking: **M1** a correct method, **A1** the correct answer, **B1** an independent mark.

Each answer shows the steps, then the **result**.

**2.1**

- amplitude = **2** cm
- wavelength = **8** cm

**2.2**

- $T = \frac{1}{f} = \frac{1}{50}$
- = **0.02** s

**2.3**

- A: **microwaves**
- B: **ultraviolet**

**3.1**

- $f = 12 \div 4.0 = 3.0$ Hz
- $v = f\lambda = 3.0 \times 0.015$
- = **0.045** m/s

**3.2**

- the waves spread out (diffract) after the gaps
- they spread out more after the **narrow** gap, because its width is close to the wavelength
- the wavelength stays the same

**3.3**

(a) $f = \frac{v}{\lambda} = \frac{3.0\times10^{8}}{1.0\times10^{-10}} = \mathbf{3.0 \times 10^{18}}$ Hz

(b) bone absorbs X-rays; soft tissue lets X-rays pass through to the detector

(c) X-rays are ionising; they can damage cells or cause cancer, and the radiographer is exposed every day; lead absorbs X-rays

(d) points to include:

- X-rays: images of bones; gamma: kill cancer cells, sterilise equipment
- infrared: thermometers and thermal imaging; radio or microwaves: communication
- higher frequency waves carry more energy
- X-rays and gamma are ionising: they damage DNA and can cause cancer
- infrared and microwaves only heat tissue, so they are less dangerous

Levels: **5–6** a full, logical answer with correct physics and correct terms; **3–4** several correct points, partly linked; **1–2** one or two relevant points.



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