

Exercise walk-through

7.4

Electromagnetic spectrum

A-Level Physics

Sheet 7.4 – what you need to know

You must be able to:

- state that all EM waves are **transverse** and travel at c
- order the regions from radio waves to γ -rays
- use $c = f\lambda$, and recall visible light is 400 to 700 nm

What the exam asks

“State the name of the principal region of the electromagnetic spectrum for the wave.” **[1]**

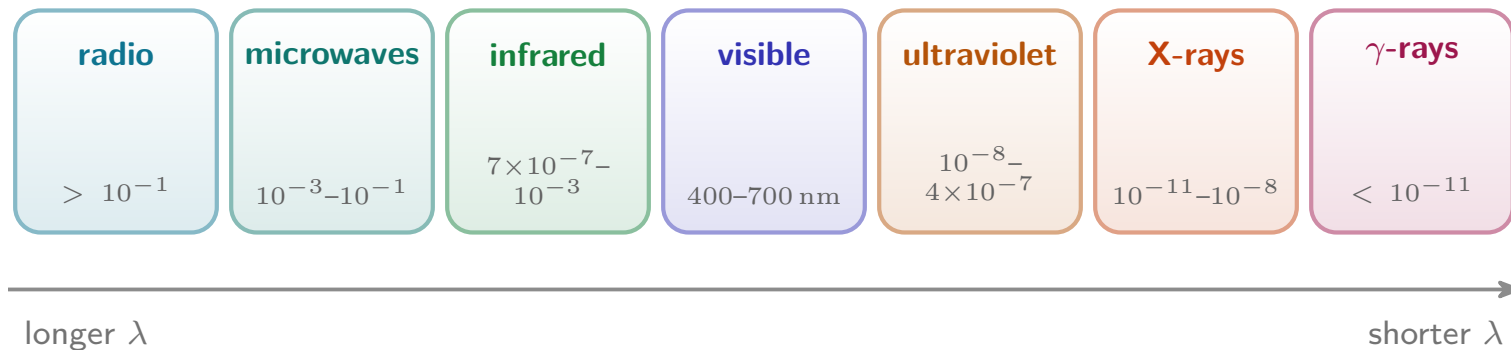
“Calculate the frequency, in THz, of the wave.” **[2]**

“State whether the frequency of the red light is greater than, less than or the same as the frequency of the original light.” **[1]**

Practise on exercise sheet 7.4, then try the real exam questions on past-paper sheet 7.4.

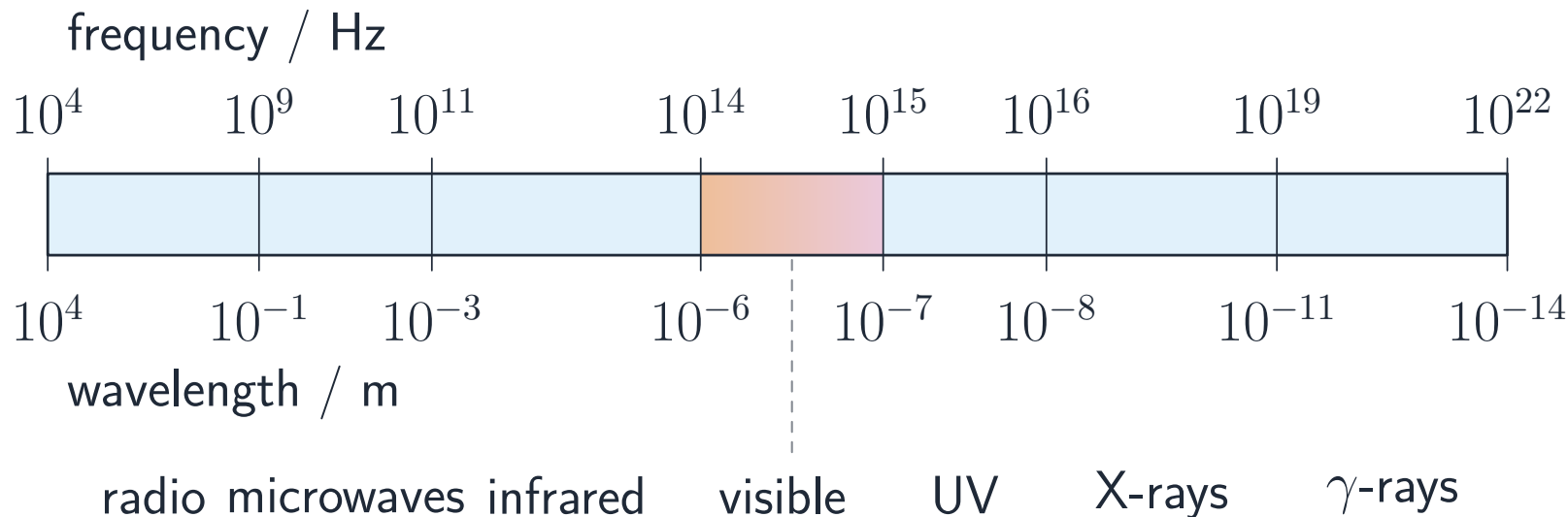
The electromagnetic spectrum

All **electromagnetic waves** are **transverse** and travel in a **vacuum** at $c = 3.00 \times 10^8 \text{ m s}^{-1}$. Use $c = f\lambda$.



The boundaries are **not sharp**. Learn the orders of magnitude, not the edges.

The electromagnetic spectrum, in detail



One family, one speed: only the wavelength changes across it.

Which region of the spectrum?

A wave of frequency 2.5×10^{14} Hz

$$\lambda = \frac{c}{f} = \frac{3.00 \times 10^8 \text{ m s}^{-1}}{2.5 \times 10^{14} \text{ Hz}} = 1.2 \times 10^{-6} \text{ m}$$

just longer than red light: **infrared**

A wave of wavelength 8.4×10^{-6} m

$$f = \frac{c}{\lambda} = \frac{3.00 \times 10^8 \text{ m s}^{-1}}{8.4 \times 10^{-6} \text{ m}} = 3.6 \times 10^{13} \text{ Hz}$$

= **36 THz**, also infrared

Visible light is 400 to 700 nm, about 4×10^{14} to 7.5×10^{14} Hz: work from there.

Exercises 2.1·2.2

2.1 State **two** properties common to **all** electromagnetic waves.

[2]

electromagnetic waves

2.2 State the speed of EM waves in a **vacuum**.

[1]



Exercises 2.1·2.2

2.1 State **two** properties common to **all** electromagnetic waves.

[2]

electromagnetic waves

2.1

- any two: they are **transverse**; they travel at the **same speed** c in a vacuum; they can travel through a vacuum
-

2.2 State the speed of EM waves in a **vacuum**.

[1]



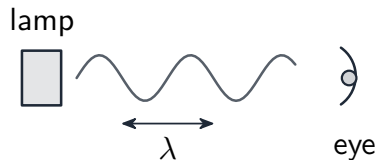
2.2

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

Exercises 2.3·2.4

2.3 State the wavelength range of **visible** light.

[1]



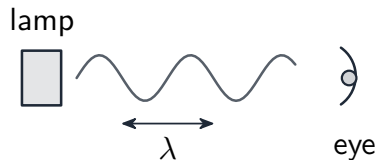
2.4 Put these in order of **increasing frequency**: X-rays, radio waves, visible light. [1]

EM spectrum

Exercises 2.3·2.4

2.3 State the wavelength range of **visible** light.

[1]



2.3

- **400** nm to **700** nm

2.4 Put these in order of **increasing frequency**: X-rays, radio waves, visible light. [1]

EM spectrum

2.4

- radio waves < visible light < X-rays

Exercise 3.1

3.1 Which EM wave has the **shortest** wavelength?

[1]

☐

A radio waves

B infrared

C ultraviolet

D γ -rays



Exercise 3.1

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[1]

☐

A radio waves

B infrared

C ultraviolet

D γ -rays



3.1 D

- γ -rays have the highest frequency (shortest wavelength) on the EM spectrum

Exercise 3.2

3.2 A radio wave has frequency 100 MHz. Find its wavelength. ($c = 3.0 \times 10^8 \frac{\text{m}}{\text{s}}$) [2]



100 MHz

$$c = 3.0 \times 10^8 \text{ m s}^{-1}$$

Exercise 3.2

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100 MHz

$$c = 3.0 \times 10^8 \text{ m s}^{-1}$$

3.2

- $\lambda = c/f$

$$\lambda = \frac{c}{f} = \frac{3.0 \times 10^8 \frac{\text{m}}{\text{s}}}{100 \times 10^6 \text{ Hz}} = \mathbf{3.0 \text{ m}}$$

Exercise 3.3

3.3 A surveyor points a laser rangefinder at the far wall of a valley. The reflected pulse returns $8.4 \mu\text{s}$ after it was sent. **Determine** the width of the valley, and **state** the assumption you make about the path of the light. [3]



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3.3

- the pulse covers the width **twice** (there and back)

$$d_{\text{total}} = ct = (3.0 \times 10^8 \frac{\text{m}}{\text{s}})(8.4 \times 10^{-6} \text{ s}) = 2520 \text{ m}$$

$$\text{width} = \frac{1}{2}d_{\text{total}} = \frac{1}{2} \times 2520 \text{ m} = \mathbf{1.3 \times 10^3 \text{ m}}$$

- assumption: light travels in a straight line at c through air (air treated as a vacuum)

Exercise 3.4

3.4 State whether **infrared** or **ultraviolet** has the higher frequency, and explain using the spectrum. [2]

infrared

ultraviolet

Exercise 3.4

3.4 State whether **infrared** or **ultraviolet** has the higher frequency, and explain using the spectrum. [2]

infrared

ultraviolet

3.4

- **ultraviolet** has the higher frequency
- on the spectrum UV is **closer to the high-frequency end** (shorter λ) than infrared