6.3 Electromagnetic waves

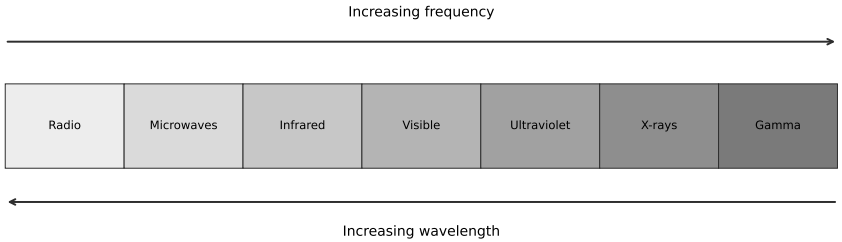
Name: _____ Class: _____ Date: _____ **Total: 23 marks**

KEY WORDS wave

Objective

Order the EM spectrum, match uses and hazards, use $v = f\lambda$ at light speed, and reason about dose and HT refraction ideas. Original questions for spec statements 4.6.2.1–4.6.2.4.

1 Key knowledge and worked examples



All transverse; all at 3×10^8 m/s in air or vacuum.

Radio → microwave → infrared → visible (red→violet) → ultraviolet → X-ray → gamma. Long wavelength to short.

Fact	Credit line
same speed in vacuum/air	3×10^8 m/s
eyes detect	only visible light
UV hazard	skin ages prematurely; skin-cancer risk
X-ray/gamma hazard	**ionising**; mutate genes → cancer
dose	sieverts measure the risk of harm (1000 mSv = 1 Sv)

Uses with (HT) reasons: radio – TV/radio (diffracts, circuit oscillations); microwave – satellites, cooking (passes air, absorbed by water); infrared – heaters, remotes; visible – fibre optics; UV – fluorescent lamps; X-ray – bone imaging; gamma – sterilising, cancer treatment.

(HT) Refraction happens because the **speed differs between substances**; substances absorb/transmit/reflect differently at different wavelengths.

Worked example. A radio wave has frequency 200 MHz.

- Convert: $f = 2.0 \times 10^8$ Hz; $v = 3 \times 10^8$ m/s.

$$\lambda = \frac{v}{f} = \frac{3 \times 10^8}{2 \times 10^8} = 1.5 \text{ m}$$

Worked example (medical choice). Gamma radiation can penetrate sealed packaging and kill microorganisms. X-rays form bone images because bone absorbs them more strongly than surrounding tissue. Ultrasound forms images using partial reflections at internal tissue boundaries; coupling gel reduces reflection at an air gap.

RP10: compare infrared emission from Leslie-cube faces at the same temperature, with a detector at fixed distance and angle; repeat readings and allow for background. For absorption, compare temperature rises of identical containers with different surfaces under equal infrared exposure, controlling water mass, starting temperature, time and source distance. Handle hot water safely. Matt black and shiny metal differ in infrared emissivity; visible colour alone is insufficient.

2 Practice

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

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

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

3 Exam-style questions

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

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

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

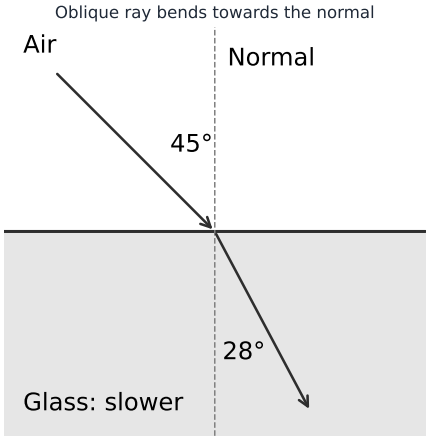
(b) Explain why ultrasound is preferred for scanning a fetus. [2]

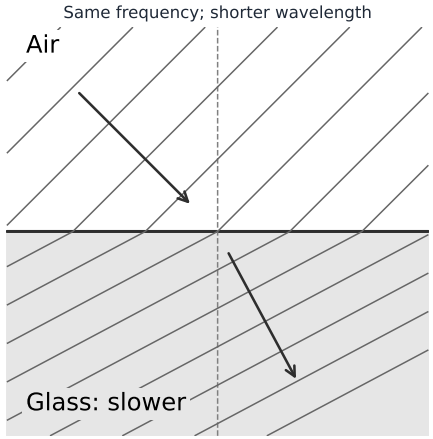
(c) In a hypothetical dose comparison, exposure A gives 0.6 mSv and exposure B gives 20 times this. Calculate the dose from B in mSv. These are supplied practice values, not typical clinical doses. [2]

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]





Solutions

2.1 Radio; gamma.

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)

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

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).

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.