

Radio waves to gamma rays: uses and risks

Physics grades 9-10 (GCSE · IGCSE · O Level · Class 9-10) · Worksheet answers

Complete answers follow each problem in the same order. Check that you converted prefixes before using the wave equation, and that radar and echo problems use only half of the total distance.

Level: Physics grades 9-10 (GCSE · IGCSE · O Level · Class 9-10) · **Curriculum:** HS-PS4-4, HS-PS4-5

Problem 1 Order of the spectrum

Radio waves, microwaves, infrared, visible light, ultraviolet, X-rays, gamma rays.

Problem 2 Shared properties

1. 3.0×10^8 m/s.
2. Transverse.
3. No, they can travel through a vacuum, which is how sunlight reaches Earth.

Problem 3 Match the use

1. Infrared.
2. Gamma rays.
3. X-rays.
4. Microwaves (or radio waves).
5. Visible light.
6. Ultraviolet.

Problem 4 FM radio wavelength

1. $91.5 \text{ MHz} = 91.5 \times 10^6 \text{ Hz} = 9.15 \times 10^7 \text{ Hz}$.
2. $\lambda = c \div f = 3.0 \times 10^8 \div 9.15 \times 10^7 = 3.3 \text{ m}$.

Problem 5 Unit conversions

1. $2.4 \text{ GHz} = 2.4 \times 10^9 \text{ Hz}$.
2. $550 \text{ nm} = 550 \times 10^{-9} \text{ m} = 5.5 \times 10^{-7} \text{ m}$.
3. $0.12 \text{ nm} = 0.12 \times 10^{-9} \text{ m} = 1.2 \times 10^{-10} \text{ m}$.

Problem 6 Name the regions

1. Microwaves, ultraviolet, gamma rays.

2. The **right-hand end** (gamma rays).
3. The second ? (ultraviolet) borders the **X-ray** region on its right.

Problem 7 Colour of a sodium lamp

1. $590 \text{ nm} = 5.90 \times 10^{-7} \text{ m}$.
2. $f = c \div \lambda = 3.0 \times 10^8 \div 5.90 \times 10^{-7} = \mathbf{5.1 \times 10^{14} \text{ Hz}}$.

Problem 8 Mobile network bands

1. At 1.8 GHz: $\lambda = 3.0 \times 10^8 \div 1.8 \times 10^9 = \mathbf{0.17 \text{ m}}$. At 3.5 GHz: $\lambda = 3.0 \times 10^8 \div 3.5 \times 10^9 = \mathbf{0.086 \text{ m}}$.
2. The **3.5 GHz** wave is shorter; the ratio is $0.167 \div 0.0857 = \mathbf{1.9}$ times.

Problem 9 Radar echo from the Moon

1. Distance = speed $\times$ time = $3.0 \times 10^8 \times 2.56 = 7.68 \times 10^8 \text{ m}$.
2. This is there and back, so the Moon is $\mathbf{3.84 \times 10^8 \text{ m}}$ away.

Problem 10 Holes in the microwave door

1. $12 \text{ cm} = \mathbf{120 \text{ mm}}$.
2. The holes are much smaller than the 120 mm wavelength, so microwaves cannot pass through. Light has a wavelength far smaller than the hole, so it **passes through freely**.

Problem 11 Waves and frequencies

A: $\lambda = 3.0 \text{ m}$, **radio**. B: $\lambda = 3.0 \times 10^{-4} \text{ m}$ (0.30 mm), **infrared**. C: $\lambda = 3.0 \times 10^{-8} \text{ m}$ (30 nm), **ultraviolet**. D: $\lambda = 1.0 \times 10^{-10} \text{ m}$ (0.10 nm), **X-ray**.

Problem 12 Sunburn at midday

1. **Ultraviolet radiation**.
2. UV photons carry enough energy to damage molecules such as DNA in skin cells, so cells die or mutate.
3. Use **sunscreen**, wear a hat and long sleeves, and avoid the midday Sun.

Problem 13 Ionising or not

1. **X-rays** are ionising.
2. Microwaves have a much **lower frequency**, so each wave carries too little energy to remove an electron from an atom; they can only heat tissue.

Problem 14 Vet checks cattle

1. All objects emit infrared, and **hotter objects emit more**, so the camera records more signal from a feverish animal.
2. A normal camera needs visible light, and a dark shed gives **none**.

Problem 15 Spot the errors

1. All EM waves travel at the same speed, **3.0×10^8 m/s**, in a vacuum.
2. Gamma rays have the **shortest** wavelength; radio waves are the longest.
3. Cooking is heating, not ionising; microwaves are **non-ionising**.

Problem 16 Antenna length

1. $\lambda = 3.0 \times 10^8 \div 9.00 \times 10^8 = \mathbf{0.333 \text{ m}}$.
2. $L = \lambda \div 4 = 0.0833 \text{ m} = \mathbf{8.3 \text{ cm}}$.
3. The frequency doubles, so the wavelength halves; the antenna is **4.2 cm**.

Problem 17 Light from the Sun

1. $t = d \div c = 1.50 \times 10^{11} \div 3.00 \times 10^8 = \mathbf{500 \text{ s}}$.
2. $500 \text{ s} = \mathbf{8 \text{ min } 20 \text{ s}}$.
3. X-rays travel at the speed of light; charged particles are slower than light, so they arrive later.

Problem 18 Chest X-ray and background

1. $2.4 \div 365 = \mathbf{0.0066 \text{ mSv per day}}$.
2. $0.020 \div 0.00658 = \mathbf{3.0 \text{ days}}$.
3. X-rays are ionising; the risk of damage adds up with every dose, so doctors only use them when the benefit is greater than the risk.

Problem 19 Sterilising with gamma rays

1. Gamma rays ionise molecules in the bacteria, damaging DNA so they cannot survive or reproduce.
2. Gamma rays **penetrate the packaging**, so the gloves stay sterile; there is no need to heat them.
3. Operate the source in a **thick concrete or lead-lined room**, with the workers outside.

Problem 20 Two radio waves

1. A: $8.0 \div 2 = \mathbf{4.0 \text{ m}}$. B: $8.0 \div 8 = \mathbf{1.0 \text{ m}}$.
2. A: $f = 3.0 \times 10^8 \div 4.0 = \mathbf{7.5 \times 10^7 \text{ Hz}}$. B: $f = 3.0 \times 10^8 \div 1.0 = \mathbf{3.0 \times 10^8 \text{ Hz}}$.
3. **Wave A**, because the longer the wavelength, the more it diffracts around obstacles.