

Radio waves to gamma rays: uses and risks

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

Quick answer: The electromagnetic spectrum is a family of transverse waves that travel at 3.0×10^8 m/s in a vacuum. In order of increasing frequency they are radio waves, microwaves, infrared, visible light, ultraviolet, X-rays and gamma rays. The highest-frequency waves are ionising and can damage living cells.

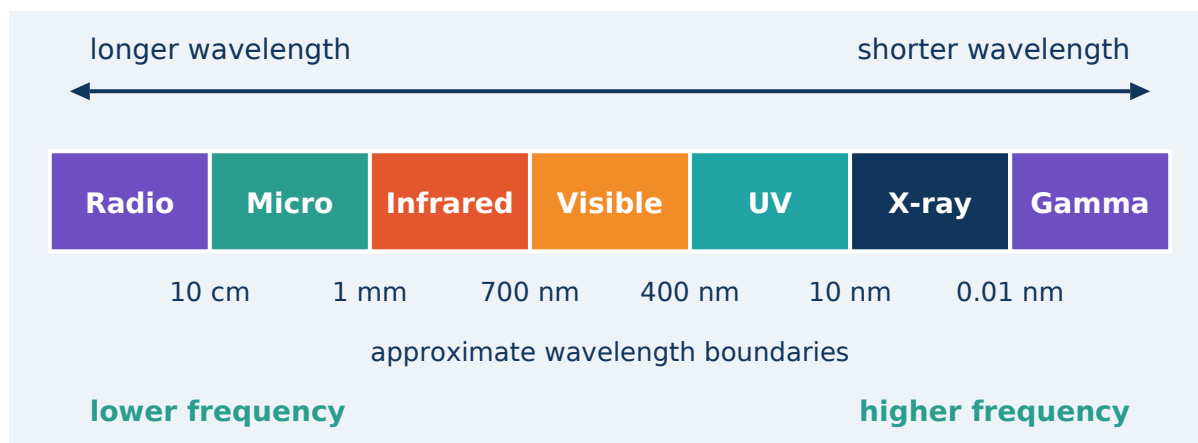
Level: Physics grades 9-10 (GCSE · IGCSE · O Level · Class 9-10) · **Curriculum:** HS-PS4-4, HS-PS4-5

What is the electromagnetic spectrum?

Radio signals, light from a torch, the heat from a fire and the X-rays used for broken bones look very different, yet they are the same kind of wave. Together they form one family, arranged by wavelength and frequency.

Definition

The **electromagnetic spectrum** is the continuous family of transverse waves made of oscillating electric and magnetic fields. They need no medium, so they cross a vacuum, and all travel at the same speed there: 3.0×10^8 m/s.



The electromagnetic spectrum. Moving right, wavelength gets shorter, frequency gets higher and each wave carries more energy.

In order of increasing frequency the seven main regions are radio waves, microwaves, infrared, visible light, ultraviolet (UV), X-rays and gamma rays. The visible part is only a thin slice, from about 700 nm for red to 400 nm for violet.

Lina's tip

Remember the order with *Real Monkeys Invent Very Useful X-ray Gadgets*. Radio, Microwave, Infrared, Visible, UV, X-ray, Gamma. Make up your own if it sticks better.

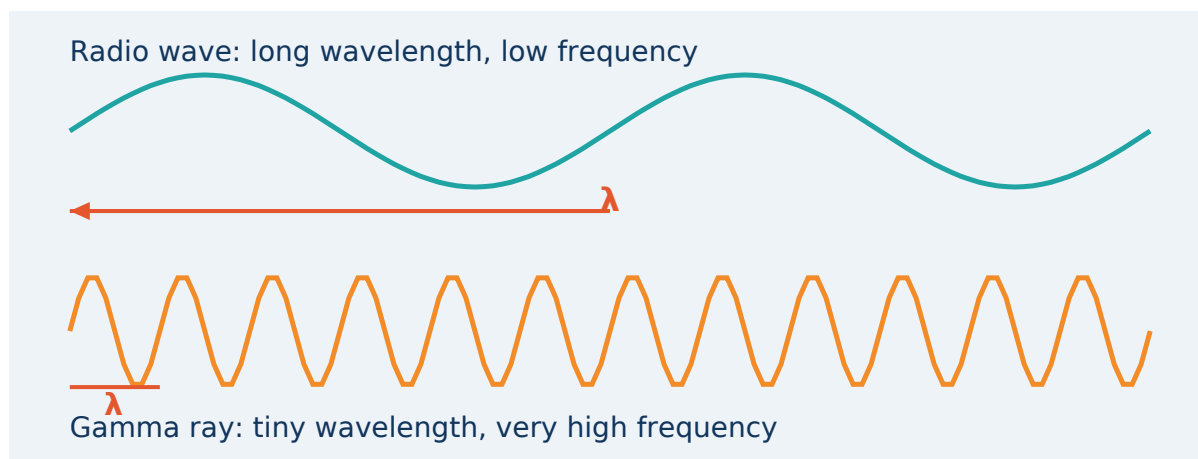
How do wavelength and frequency link up?

In a vacuum every wave in the spectrum travels at the same speed, so a bigger frequency means a smaller wavelength. The wave equation connects them.

Formula

$$c = f \times \lambda$$

c = speed of light (3.0×10^8 m/s), f = frequency (Hz), λ = wavelength (m).



Both travel at 3.0×10^8 m/s in a vacuum. The one with the shorter wavelength has the higher frequency ($v = f \times \lambda$).

Worked example 1

Kofi in Accra tunes a radio to 94.5 MHz. Calculate the wavelength.

$$f = 94.5 \text{ MHz} = 9.45 \times 10^7 \text{ Hz. } \lambda = c \div f = 3.0 \times 10^8 \div 9.45 \times 10^7 = \mathbf{3.2 \text{ m}}$$

Worked example 2

Green light has wavelength 520 nm. Calculate its frequency.

$$\lambda = 520 \times 10^{-9} \text{ m. } f = c \div \lambda = 3.0 \times 10^8 \div 5.20 \times 10^{-7} = \mathbf{5.8 \times 10^{14} \text{ Hz}}$$

What are the uses and dangers of each wave?

Each region behaves differently, so each has its own job. The higher the frequency, the more energy each wave delivers, and the greater the risk to living cells.

Wave	Typical use	Main danger
Radio	Broadcasting, mobile and TV signals	Very low at normal power
Microwave	Cooking, satellite links, radar	Heats body tissue at high power
Infrared	Remote controls, heaters, thermal cameras	Skin burns

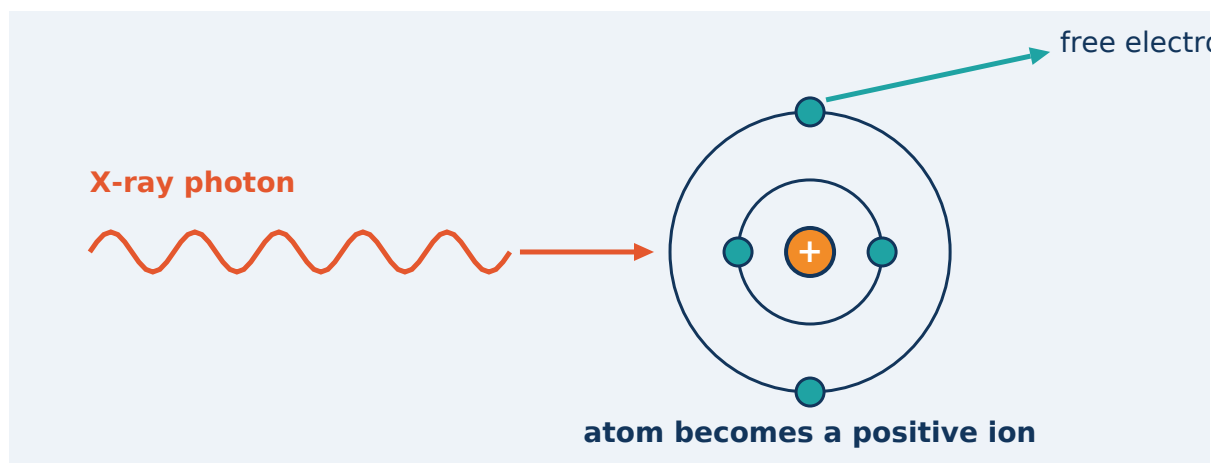
Wave	Typical use	Main danger
Visible	Seeing, photography, optical fibres	Eye damage from lasers or the Sun
Ultraviolet	Sterilising water, security marks, fluorescent lamps	Sunburn, eye damage, skin cancer
X-ray	Medical imaging, airport scanners	Cell damage, cancer
Gamma	Treating cancer, sterilising equipment	Cell damage, cancer

Infrared warms things because objects absorb it and their particles vibrate faster. Microwaves of one particular frequency are absorbed strongly by water, which is why they cook wet food quickly.

What is ionising radiation and why is it dangerous?

Definition

Ionising radiation carries enough energy to knock electrons out of atoms and molecules, forming charged particles called ions. In the electromagnetic spectrum, this means high-end ultraviolet, X-rays and gamma rays.



Ionisation: a high-frequency photon gives an electron enough energy to leave the atom. The atom becomes a positive ion.

An ion in a living cell can break a DNA strand or change a chemical reaction. A damaged cell may die, or copy itself wrongly and cause cancer. Radio waves, microwaves, infrared and visible light are **non-ionising**: they can heat tissue but cannot remove electrons.

Common mistake

Thinking that mobile phones give out X-rays, or that anything with "radiation" in its name is ionising. Radiation just means energy that spreads out; only the high-frequency end of the spectrum ionises.

Radiographers reduce the risk with three rules: keep exposure short, stay far from the source, and use shielding such as lead aprons. The chance of damage depends on the dose, which is

why a single dental X-ray is considered safe but a worker near a source wears a badge to record exposure.

Key points to remember

- All EM waves travel at 3.0×10^8 m/s in a vacuum.
- $c = f \times \lambda$ links speed, frequency and wavelength.
- Order, low to high frequency: radio, microwave, infrared, visible, UV, X-ray, gamma.
- UV, X-rays and gamma rays are ionising and can cause cancer.
- Higher frequency means a shorter wavelength and more energy per wave.

Radio waves to gamma rays: uses and risks: frequently asked questions

Which electromagnetic wave has the longest wavelength?

Radio waves have the longest wavelengths in the spectrum, from about 10 cm to many kilometres. They also have the lowest frequencies and carry the least energy.

Do all electromagnetic waves travel at the same speed?

Yes, in a vacuum they all travel at 3.0×10^8 m/s. In materials such as glass or water they slow down by different amounts.

Which electromagnetic waves are ionising?

High-frequency ultraviolet, X-rays and gamma rays are ionising. They can remove electrons from atoms, which can damage DNA and cause cancer.

How do you find the wavelength of a radio wave?

Divide the speed of light by the frequency: $\lambda = c \div f$. Convert units first, so 100 MHz becomes 1.00×10^8 Hz, and the wavelength is 3.0 m.

Why are X-rays used in hospitals?

X-rays pass through soft tissue but are absorbed by dense bone, so they form a shadow image on a detector. Doctors limit exposure because X-rays are ionising.