

Radio to gamma waves and digital signals

Grade 8 science (Year 9 · Class 8) · Lesson

Quick answer: The electromagnetic spectrum is the family of transverse waves that all travel at 3.0×10^8 m/s in a vacuum, from radio waves through visible light to gamma rays. Higher frequency means shorter wavelength and more energy. Digital signals use only 1 and 0, so noise can be removed.

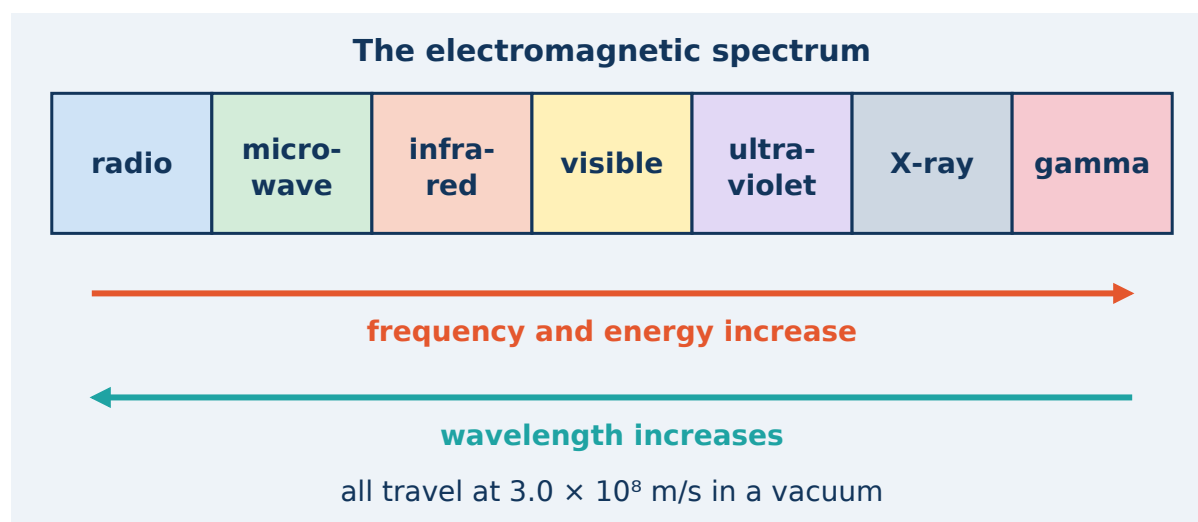
Level: Grade 8 science (Year 9 · Class 8) · **Curriculum:** MS-PS4-3

What is the electromagnetic spectrum?

Light is only one member of a large family of waves. These waves are made of oscillating electric and magnetic fields, and they can travel through empty space. They are transverse waves, and they all carry energy from a source to a receiver. The whole family is called the electromagnetic spectrum.

Definition

The electromagnetic (EM) spectrum is the 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.



Going from radio to gamma, frequency and energy rise while wavelength falls. The speed in a vacuum never changes.

Radio waves can be longer than a football pitch, while gamma rays are smaller than an atom. Higher frequency means more energy in each wave packet, which is why the waves at the right-hand end of the spectrum can harm living cells.

Common mistake

Many students think gamma rays travel faster than radio waves because they are more

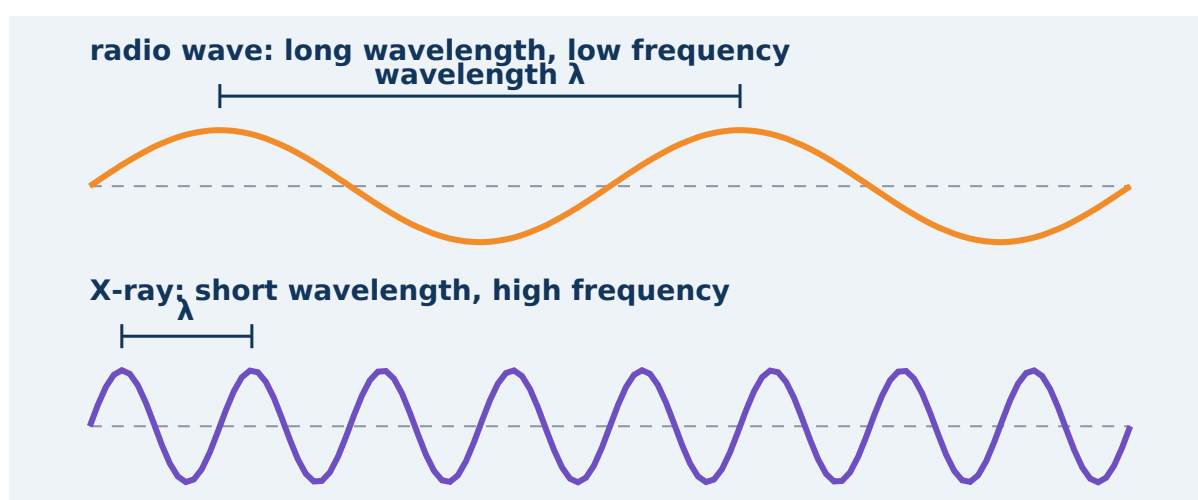
energetic. In a vacuum every EM wave has the same speed. Only the frequency and the wavelength are different.

How do you find the wavelength or frequency of an EM wave?

Because the speed is fixed, a wave with a higher frequency must have a shorter wavelength. The three quantities are linked by the wave equation.

Formula

$v = f \times \lambda$, so $\lambda = v \div f$. Here v is the wave speed in m/s (3.0×10^8 m/s for EM waves in a vacuum), f is the frequency in hertz (Hz) and λ is the wavelength in metres (m). 1 MHz = 10^6 Hz and 1 GHz = 10^9 Hz.



A long wavelength means a low frequency, and a short wavelength means a high frequency.

Worked example

A radio station in Nairobi broadcasts at 98.0 MHz. **Data:** $f = 98.0 \times 10^6$ Hz = 9.80×10^7 Hz, $v = 3.0 \times 10^8$ m/s. **Method:** $\lambda = v \div f = 3.0 \times 10^8 \div 9.80 \times 10^7$. **Answer:** $\lambda = 3.1$ m.

Worked example

A home Wi-Fi router uses microwaves of frequency 2.4 GHz. **Data:** $f = 2.4 \times 10^9$ Hz. **Method:** $\lambda = 3.0 \times 10^8 \div 2.4 \times 10^9$. **Answer:** $\lambda = 0.125$ m, which is about 13 cm.

What are the uses and dangers of each type of wave?

Each part of the spectrum interacts with matter in its own way, so each has its own jobs. The high-frequency waves are ionising: they carry enough energy to knock electrons out of atoms and damage the DNA in living cells.

Wave	Typical use	Main danger
Radio	radio and TV broadcasting	very low risk

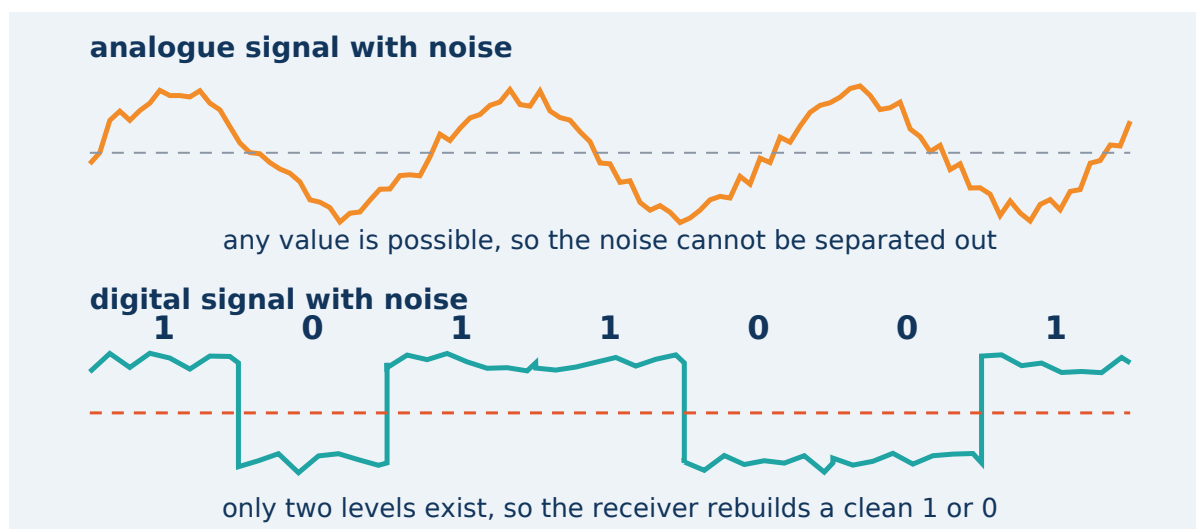
Wave	Typical use	Main danger
Microwave	mobile phones, satellites, Wi-Fi, cooking	heating of body tissue at high power
Infrared	remote controls, thermal cameras	skin burns
Visible light	seeing, optical fibres	bright lasers can damage eyes
Ultraviolet	sterilising water, security marks	sunburn, skin cancer, eye damage
X-rays	imaging bones, luggage scanners	ionising: can damage cells
Gamma rays	sterilising equipment, treating cancer	ionising: cell damage

What is the difference between analogue and digital signals?

A signal is a pattern that carries information, such as a voice. An analogue signal copies the sound with a wave that can take any value in a range. A digital signal uses only two states, high or low, which are written as 1 and 0.

Definition

An analogue signal varies continuously and can take any value. A digital signal has only two levels, 1 and 0. A digital receiver decides whether each pulse is nearer to high or low, and rebuilds a clean pulse.



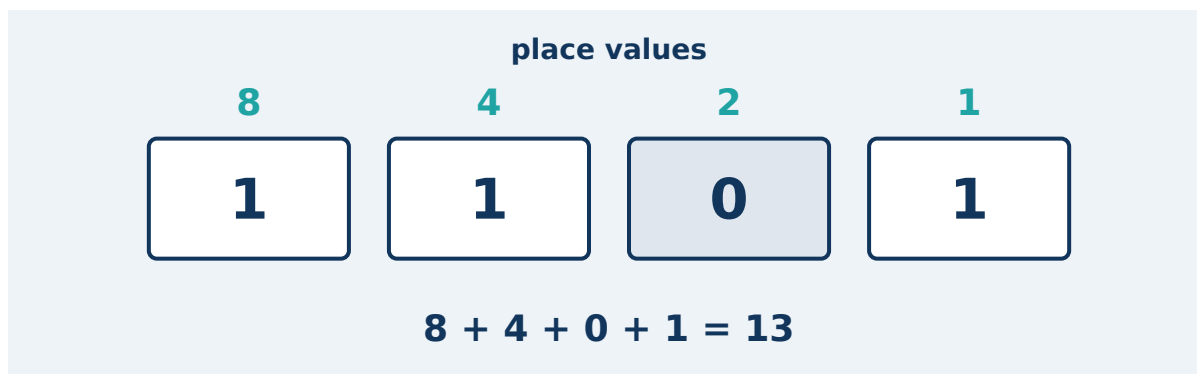
Noise stays in an analogue signal, but a digital receiver can remove it by rebuilding each pulse.

Every time a signal is carried over a long distance, noise is added. An amplifier increases the noise as well as the signal in analogue transmission. A digital signal can be regenerated, so the message arrives in perfect quality. Digital signals also store more information on the same cable and are easy for computers to process.

How does binary store numbers?

Computers write numbers in binary, a system with only two digits, 0 and 1. A single binary

digit is a bit, and 8 bits make one byte. In binary, each place is worth double the place on its right: 1, 2, 4, 8, 16 and so on. A byte can store $2^8 = 256$ different values.



Add the place values that hold a 1. Here 1101 in binary is 13 in decimal.

Worked example

Convert 13 to binary. **Method:** 8 fits into 13 ($13 - 8 = 5$), 4 fits into 5 ($5 - 4 = 1$), 2 does not fit into 1, and 1 fits into 1. **Answer:** the digits are 1, 1, 0, 1, so 13 is **1101** in binary.

Lina's tip

To change a decimal number into binary, write the place values 8, 4, 2, 1 above four boxes. Subtract the biggest value that fits, put a 1 there, and put a 0 where nothing fits.

Key points to remember

- Order: radio, microwave, infrared, visible, ultraviolet, X-ray, gamma.
- All EM waves travel at 3.0×10^8 m/s in a vacuum.
- Wave equation: $v = f \times \lambda$, with f in Hz and λ in m.
- UV, X-rays and gamma rays are ionising and can damage cells.
- A digital signal has two levels, 1 and 0, so noise can be removed.

Radio to gamma waves and digital signals: frequently asked questions

Why can EM waves travel through space?

They are oscillating electric and magnetic fields, so they do not need particles to carry them. That is why sunlight reaches Earth through the vacuum of space.

Which EM wave has the highest energy?

Gamma rays have the highest frequency and the most energy in each wave packet. This is why they can damage living cells and are used to kill cancer cells in careful doses.

How do I calculate the wavelength of a radio wave?

Use $\lambda = v \div f$ with $v = 3.0 \times 10^8$ m/s. Convert the frequency to hertz first, because 1 MHz is 10^6 Hz.

Why are digital signals better than analogue signals?

A digital receiver only has to decide between a high and a low level, so it can rebuild each pulse and remove noise. Analogue noise stays in the signal and builds up.

How many values can a byte store?

A byte has 8 bits, and each bit has two possible states. That gives $2^8 = 256$ different values, from 0 to 255.