Cambridge IGCSE · Physics 0625 · Notes

Electromagnetic spectrum

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Read first: **General properties of waves**, **Light**

What you need to know

This topic is about the family of electromagnetic waves: their order, their speed, what each region is used for, what too much of it does to people, and how they carry signals. The parts marked **Extended only** are tested on Papers 2 and 4 only. By the end of it you should be able to:

1. **Know the main regions of the spectrum in order** of frequency and in order of wavelength: radio waves, microwaves, infrared, visible light, ultraviolet, X-rays, gamma rays.
2. **Know that all electromagnetic waves travel at the same high speed in a vacuum.**
3. **Describe typical uses of each region:**
   - radio waves: radio and television broadcasts, astronomy, radio frequency identification (RFID) tags;
   - microwaves: satellite television, mobile (cell) phones, microwave ovens;
   - infrared: electric grills, short-range communication such as TV remote controllers, intruder alarms, thermal imaging, optical fibres;
   - visible light: vision, photography, illumination;
   - ultraviolet: security marking, detecting fake bank notes, sterilising water;
   - X-rays: medical scanning, security scanners;
   - gamma rays: sterilising food and medical equipment, detecting and treating cancer.
4. **Describe the harmful effects of too much exposure:** microwaves heat cells inside the body; infrared burns the skin; ultraviolet damages surface cells and eyes, leading to skin cancer and eye conditions; X-rays and gamma rays cause mutation of, or damage to, cells in the body.
5. **Know that communication with artificial satellites is mainly by microwaves:** some satellite phones use **low orbit** satellites; other satellite phones and direct broadcast satellite television use **geostationary** satellites.
6. **Extended only:** know that the speed of electromagnetic waves in a vacuum is 3.0×10^8 m/s, and about the same in air.
7. **Extended only:** know why communication systems use the regions they do: mobile phones and wireless internet use **microwaves** (they get through some walls and need only a short aerial); **Bluetooth** uses **radio waves** (they pass through walls but are weakened); **optical fibres** use **visible light or infrared** (glass is transparent to them, and they carry data at high rates).
8. **Extended only:** know the difference between a **digital** and an **analogue** signal.

9. **Extended only:** know that a sound can be sent as a digital or an analogue signal.
10. **Extended only:** explain the benefits of digital signals: a higher rate of data transmission, and a greater range because the signal can be regenerated accurately.

Understand it

What electromagnetic waves are

Light is one member of a large family: the **electromagnetic (e-m) waves**. They are made by changing electric and magnetic fields, not by vibrating particles, so they need no material to travel through. Every e-m wave:

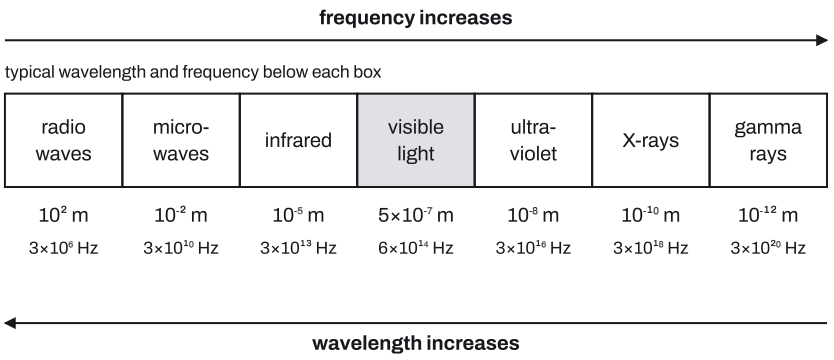
- is **transverse** (the vibrations are at right angles to the direction the wave travels);
- can travel through a **vacuum**, which is how light and heat reach us from the Sun through space;
- travels at the **same speed** in a vacuum;
- **transfers energy** from one place to another, not matter.

Sound is not an electromagnetic wave. It is longitudinal and needs a medium (a solid, liquid or gas), so it cannot cross a vacuum, and in air it travels at only about 340 m/s. Ultrasound is sound too. Questions often ask you to tick the properties of sound and of an e-m wave in a table:

Property	Sound	Microwaves (any e-m wave)
Longitudinal	✓	
Transverse		✓
Electromagnetic		✓
Travels through a vacuum		✓

The regions differ only in their **wavelength** and **frequency**, which is why they behave so differently: radio waves pass through buildings, while gamma rays pass through your body.

The regions in order



From **lowest frequency (longest wavelength)** to **highest frequency (shortest wavelength)**:

radio waves → microwaves → infrared → visible light → ultraviolet → X-rays → gamma rays

A memory aid: **R**abbits **M**eet **I**n **V**ery **U**nusual e**X**pensive **G**ardens.

- Frequency and wavelength always go in **opposite** directions: all the regions have the same speed, and $v = f\lambda$, so a higher frequency means a shorter wavelength.
- **Infrared** is just past the **red** end of the visible spectrum ("below red" in frequency); **ultraviolet** is just past the **violet** end ("beyond violet"). So red light has a lower frequency and longer wavelength than violet or blue light.
- Regions next to each other overlap a little; the boundaries are not sharp. X-rays and gamma rays overlap most: they are named by how they are made rather than by exact wavelength.
- Diagrams in questions may run either way (increasing frequency or increasing wavelength). **Read the arrow** before filling in gaps.

You don't need to learn the numbers in the diagram, but they help with order-of-magnitude questions ("a wave of wavelength 10^{-10} m is in which region?"): radio waves are metres to kilometres long, microwaves millimetres to centimetres, visible light about 4 to 7×10^{-7} m (400 to 700 nm), and X-rays and gamma rays far smaller than an atom.

Speed

All e-m waves travel at the **same speed in a vacuum**, whatever their frequency. In air they are only very slightly slower, so the same value is used.

Extended only: the speed of e-m waves in a vacuum is 3.0×10^{8} m/s (that is $300\,000$ km/s), and approximately the same in air. In glass or water they are slower.

Because the speed is fixed, $v = f\lambda$ links frequency and wavelength, as for any wave:

$$\lambda = \frac{v}{f} \qquad f = \frac{v}{\lambda}$$

For a mobile phone signal of 1800 MHz $= 1.8 \times 10^{9}$ Hz: $\lambda = \dfrac{3.0 \times 10^{8}}{1.8 \times 10^{9}} = 0.167$ m.

And since distance = speed × time, a flash of light and an infrared or radio signal sent at the same moment from the same place (a star, the Sun, a satellite) **arrive at the same time**.

Uses of each region

Each region is used for what its wavelength lets it do.

Region	Uses	Why it works
Radio waves	Radio and TV broadcasts; astronomy (radio telescopes); RFID tags (shop security tags, contactless cards, pet chips)	Long waves travel far and pass through buildings; stars and galaxies give out radio waves

Region	Uses	Why it works
Microwaves	Satellite TV; mobile phones; wireless internet (Wi-Fi); microwave ovens	Pass through the atmosphere to satellites; short aerial; absorbed by water in food, heating it
Infrared	Electric grills, toasters and heaters; TV remote controllers; intruder alarms; thermal imaging cameras; optical fibres	Hot objects give out infrared (thermal radiation); detectors sense the infrared from a warm body
Visible light	Vision; photography; illumination (lighting)	The eye and cameras detect it
Ultraviolet	Security marking with special ink; detecting fake bank notes; sterilising water	Makes some inks glow (fluoresce); kills bacteria
X-rays	Medical scanning (images of bones); security scanners at airports	Pass through soft materials but are absorbed by bone and metal
Gamma rays	Sterilising food and medical equipment; detecting cancer and treating it (radiotherapy)	Very penetrating and kill living cells

Thermal radiation from hot objects is **infrared**. A **remote controller** uses **infrared**, not microwaves or radio. The glowing red of a heater is visible light, but most of its heating is done by infrared. An **electric fire** is designed to produce an e-m wave (infrared); a motor, generator or electromagnet is not.

Harmful effects

The energy an e-m wave carries can damage the body if there is too much of it. The syllabus names these effects:

Region	Harmful effect of excessive exposure
Microwaves	Internal heating of body cells
Infrared	Skin burns
Ultraviolet	Damage to surface cells and eyes, leading to skin cancer and eye conditions
X-rays and gamma rays	Mutation of (or damage to) cells in the body, which can cause cancer

The higher-frequency regions (ultraviolet, X-rays, gamma rays) are the ones that damage cells and DNA. People who work with X-rays or gamma rays reduce their exposure: they stand behind **lead** screens or wear lead aprons, keep their **distance**, keep the **time** short, and wear badges that record the dose received. Sunscreen and sunglasses reduce ultraviolet exposure.

Communication with satellites

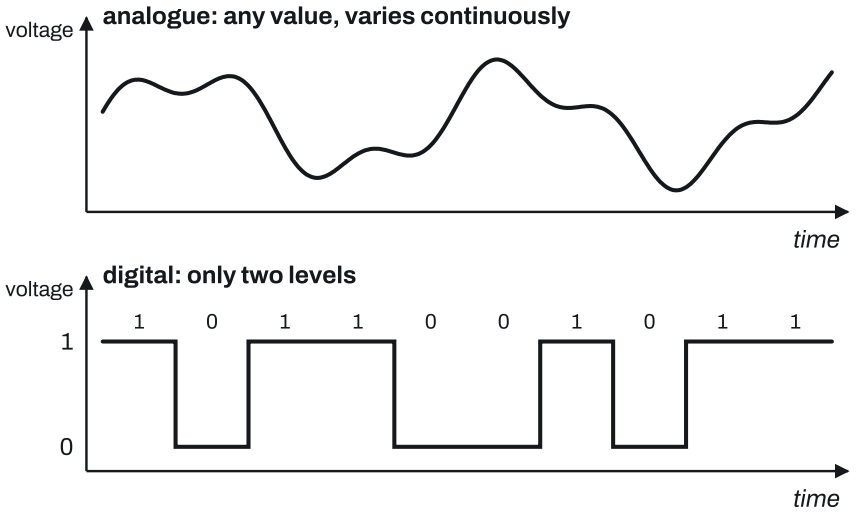
Communication with artificial satellites is **mainly by microwaves**, because microwaves pass through the atmosphere.

- **Geostationary** satellites orbit above the equator once every 24 hours, in the same direction as the Earth spins, so they **stay above the same point** on the Earth. A dish on a house can point at one fixed spot in the sky. They are used for **direct broadcast satellite television** and **some satellite phones**.
- **Low orbit** satellites are much closer to the Earth and move across the sky. They are used for **some satellite phones**.

Extended only: choosing a region for communication

- **Mobile phones and wireless internet use microwaves**: microwaves can **pass through some walls**, and they need only a **short aerial** to send and receive, so the aerial fits inside a phone.
- **Bluetooth uses radio waves**: radio waves **pass through walls, but the signal is weakened** doing so. That is why Bluetooth works only over short distances, such as a phone to headphones in the same room.
- **Optical fibres use visible light or infrared** for cable television and high-speed broadband: **glass is transparent** to visible light and some infrared, so little signal is lost, and visible light and short-wavelength infrared can **carry data at high rates**.

Extended only: analogue and digital signals



- An **analogue** signal varies **continuously** and can take **any value** in its range, like the pressure changes in a sound wave.
- A **digital** signal has only **two values** (states), high and low, written 1 and 0 (on and off). It carries information as a pattern of these pulses.
- A **sound** can be sent either way: as an analogue signal that copies the shape of the sound wave, or as a digital signal made by measuring the sound many times a second and coding each measurement as 1s and 0s.

Why digital is better. Every signal gets weaker and picks up random changes (noise) as it travels, so it must be amplified or boosted along the way.

- An analogue signal is amplified with its noise, and the noise builds up: the copy is never quite the original.

- A digital signal only needs to be read as "high" or "low", so a noisy pulse can be **regenerated** as a perfect clean copy. The signal can therefore be sent over a **greater range** without losing quality.
- Digital signals allow a **higher rate of data transmission**: more information per second.

Key facts and formulas

The 0625 papers have no formula sheet, so learn everything here.

Formula	Status
Order (increasing frequency): radio, microwaves, infrared, visible, ultraviolet, X-rays, gamma	Learn it
All e-m waves travel at the same speed in a vacuum	Learn it
Extended only: speed of e-m waves in a vacuum $c = 3.0 \times 10^8$ m/s, about the same in air	Learn it
$v = f\lambda$, so $\lambda = \frac{v}{f}$ and $f = \frac{v}{\lambda}$	Learn it
distance = speed $\times$ time (halve the time for there and back)	Learn it
$f = \frac{1}{T}$ (frequency from the period)	Learn it
Prefixes: k $= 10^3$, M $= 10^6$, G $= 10^9$; mm $= 10^{-3}$, μm $= 10^{-6}$, nm $= 10^{-9}$	Learn it
Uses and harmful effects of each region (the tables above)	Learn it

How to do it

We have tagged 102 questions for this topic across Papers 1–4, 2021–2025; 17 are repeats on other papers, leaving 85 different questions. 46 of the 102 mix two or more types (most structured questions do), so the counts add up to more than 102.

Question type	Questions
Match a region to a use (or a device to its region)	52
Order the regions, name missing ones, compare wavelength and frequency	43
State or use the speed of e-m waves	33
Calculate with $v = f\lambda$ (and distance = speed $\times$ time)	14
Harmful effects of too much exposure, and precautions	13
Properties shared by all e-m waves; which waves are e-m	10
Extended: explain the choice of region for communication	6
Extended: digital and analogue signals	1

1. Match a region to a use (52 questions)

1. **Read the use** and ask what it needs: heat, passing through walls or the atmosphere, making ink glow, passing through the body, killing cells.
2. **Name the exact region** from the uses table. "Light" or "radiation" is not a region; "microwaves" and "radio waves" are different regions.
3. In a **line-matching** diagram draw exactly one line from each use. In a **multiple-choice row**, check every column: most wrong rows get one entry right.

Variations you will meet:

- **Common pairs to know cold:** remote controller → infrared; intruder alarm → infrared; thermal imaging, grills, heaters → infrared; mobile phones, satellite TV, Wi-Fi, microwave ovens → microwaves; radio and TV broadcasts, Bluetooth, RFID → radio waves; security marking, fake notes, sterilising water → ultraviolet; airport security scanners, broken bones → X-rays; sterilising food and equipment, cancer treatment → gamma rays; optical fibres → infrared (or visible light).
- **"Thermal radiation" is which region?** Infrared.
- **Cancer:** gamma rays are used to detect and treat it. X-rays are accepted for killing cancer cells in some mark schemes, but gamma rays is the syllabus answer.
- **"Describe one use"** of a region: be specific. "Sterilising medical equipment" earns the mark; "medical uses" does not. Don't give an X-ray use when asked about gamma rays.
- **Which device produces an e-m wave?** An electric fire (infrared); not a motor, generator or electromagnet.
- **A medical scan comparison**: an X-ray image is made with e-m waves; an ultrasound scan (of a fetus) uses sound, which is not electromagnetic.

2. Order the regions and compare wavelength and frequency (43 questions)

1. **Write the order out** first: radio, microwaves, infrared, visible, ultraviolet, X-rays, gamma (increasing frequency, decreasing wavelength).
2. **Read the arrow** on the question's diagram: is it increasing frequency or increasing wavelength? Fill the gaps so the order matches.
3. **Compare two regions**: the one nearer gamma has the **higher frequency and shorter wavelength**; the one nearer radio has the **lower frequency and longer wavelength**. Their **speeds in a vacuum are equal**.

Variations you will meet:

- **Two blanks in a diagram**: the most common missing regions are ultraviolet and X-rays, or microwaves and infrared.
- **"Which region has longer wavelengths than visible light?"** Infrared, microwaves or radio waves. Shorter: ultraviolet, X-rays or gamma rays.
- **"Which of these has the lowest frequency?"** The one furthest towards radio.

- **Colours**: blue and violet light have a higher frequency and shorter wavelength than red light. Ultraviolet has a higher frequency than any visible colour.
- **A given wavelength or frequency** (Extended multiple choice): match its order of magnitude to the spectrum diagram. A frequency of 10^{16} Hz is above visible light ($\approx 5 \times 10^{14}$ Hz) and below X-rays, so ultraviolet. If a table gives the ranges of some regions, the answer is the region that fits in the gap between them.
- **From gamma rays to radio waves**: frequency decreases, wavelength increases, speed stays the same.

3. State or use the speed of e-m waves (33 questions)

1. **All e-m waves have the same speed in a vacuum.** Different frequency or wavelength does not change this.
2. **Extended only:** the value is 3.0×10^8 m/s, and approximately the same in air. Always give the unit.

Variations you will meet:

- **Unit traps** in multiple choice: 3.0×10^8 m/s $= 300\,000$ km/s (not $300\,000\,000$ km/s, and not 300 m/s).
- **The sound trap**: 340 m/s is the speed of **sound** in air, not of any e-m wave.
- **"Do gamma rays travel faster than radio waves?"** No: the same speed in a vacuum. A shorter wavelength does not mean a greater speed.
- **Two waves from the same source** (infrared and light from the Sun, or from a star) arrive **at the same time**, because they travel at the same speed. Give the reason, not just the answer.
- **"Where do all e-m waves travel at the same speed?"** In a vacuum. In glass or water, different frequencies travel at slightly different speeds (that is why a prism disperses light).

4. Calculate with $v = f\lambda$ (14 questions)

1. **Write the equation**: $v = f\lambda$. This earns a mark on its own.
2. **Convert prefixes** to powers of ten: 600 kHz $= 6.0 \times 10^5$ Hz; 1800 MHz $= 1.8 \times 10^9$ Hz; 2.5 GHz $= 2.5 \times 10^9$ Hz; 500 nm $= 5.0 \times 10^{-7}$ m.
3. **Rearrange and substitute**, using $v = 3.0 \times 10^8$ m/s unless the question gives another speed.
4. **Give the answer** with its unit (m or Hz) to 2 or 3 significant figures.

For example, a radio station at 600 kHz: $\lambda = \dfrac{3.0 \times 10^8}{6.0 \times 10^5} = 500$ m. Light of frequency 6.0×10^{14} Hz: $\lambda = \dfrac{3.0 \times 10^8}{6.0 \times 10^{14}} = 5.0 \times 10^{-7}$ m.

Variations you will meet:

- **A speed in a medium is given** (for example 2.0×10^8 m/s in glass): use that speed, not 3.0×10^8. With $f = 4.0 \times 10^{14}$ Hz, $\lambda = \dfrac{2.0 \times 10^8}{4.0 \times 10^{14}} = 5.0 \times 10^{-7}$ m.
- **A range of frequencies**: the "middle" of 2.0 GHz to 3.0 GHz is 2.5 GHz; use it as asked.

- **Distance = speed × time** (Core too): light from the Sun takes about 500 s to reach the Earth, so the distance is $3.0 \times 10^8 \times 500 = 1.5 \times 10^{11}$ m. For a signal that goes **there and back** (a laser pulse reflected from the Moon, a radar echo), **halve the time** first: an echo after 2.0×10^{-4} s means the object is $3.0 \times 10^8 \times 1.0 \times 10^{-4} = 3.0 \times 10^4$ m away.
- **Period from a graph**: read the time for one cycle T, then $f = \frac{1}{T}$, then $\lambda = \frac{v}{f}$.
- **Multiple choice**: estimate the power of ten first; the options usually differ by factors of 10^3 (a prefix mistake) or are the upside-down answer $\frac{f}{v}$.

5. Harmful effects and precautions (13 questions)

1. **Name the region**, then give **its** effect from the table: microwaves, internal heating of body cells; infrared, skin burns; ultraviolet, damage to surface cells and eyes (skin cancer, eye conditions); X-rays and gamma, mutation of or damage to cells.
2. **Be specific.** "It is dangerous" or "it causes illness" earns nothing; "mutation of cells" or "skin cancer" does.

Variations you will meet:

- **"Which radiations cause cell damage?"** Gamma rays and ultraviolet (and X-rays). Visible light and radio waves do not.
- **Use and harm in one row** (infrared): used in heaters or remote controls; harm, skin burns.
- **Why precautions are needed with X-rays**: they can damage or cause mutation of cells. **Precautions**: lead screens or aprons, distance, short exposure time, dose badges. Answer for the people named in the question (hospital staff, not patients).

6. Properties shared by all e-m waves (10 questions)

1. **State the shared properties**: transverse; travel through a vacuum; same speed in a vacuum; transfer energy.
2. **Pick out the odd one**: sound and ultrasound are **not** e-m waves (longitudinal, need a medium).

Variations you will meet:

- **A tick table** of sound against an e-m wave: sound is longitudinal only; the e-m wave is transverse, electromagnetic and travels through a vacuum.
- **"Which statement about e-m waves is not correct?"** Look for 340 m/s, "longitudinal", or "need a medium".
- **A similarity and a difference** between two regions (say visible light and infrared): similar, both transverse, same speed in a vacuum, both travel through a vacuum; different, wavelength (and frequency).

7. Extended only: explain the choice of region for communication (6 questions)

1. **Name the region** the system uses.
2. **Give the reason** from the syllabus, in words that match the system:

- mobile phones and wireless internet (microwaves): pass through some walls; only a short aerial needed; also pass through the atmosphere to satellites and carry lots of data;
- Bluetooth (radio waves): pass through walls but are weakened, so the range is short;
- optical fibres (visible light or infrared): glass is transparent to them, so little is absorbed; they carry data at a high rate;
- satellite TV (microwaves, geostationary satellite): the satellite stays above the same point, so the dish can stay fixed.

Variations you will meet:

- **"State two reasons why microwaves are used for mobile phones"**: give two different reasons (walls, short aerial), not one reason twice.
- **"Why doesn't Bluetooth work across a building?"**: the radio waves are weakened each time they pass through a wall.

8. Extended only: digital and analogue signals (1 question)

1. **Draw both**: a digital signal as a square pattern with only two levels (vertical jumps, flat tops); an analogue signal as a smooth curve that changes continuously. Label the axes voltage and time.
2. **Describe the difference in words**: digital has only two values (1 and 0, on and off); analogue can have any value.
3. **Benefits of digital**: a higher rate of data transmission; the signal can be regenerated accurately, removing noise, so it has a greater range (and better quality).

Worked examples

The bold codes show where marks are earned, as in Cambridge mark schemes. The number is how many marks.

- **A1** accuracy mark: for a correct answer; it needs the M mark before it.
- **B1** mark for a correct result on its own, with no method needed.

Example 1

The diagram shows the regions of the electromagnetic spectrum in order of **increasing wavelength**. Two regions are labelled A and B.

gamma rays · **A** · ultraviolet · visible light · **B** · microwaves · radio waves

(a) Name regions A and B. **[2]**

(b) State one use of region A and one use of microwaves. **[2]**

(c) State one harmful effect on people of too much exposure to ultraviolet. **[1]**

(d) A TV remote controller sends signals using one of the regions shown. Name the region. **[1]**

(e) Compare the speed of gamma rays in a vacuum with the speed of radio waves in a vacuum. **[1]**

(a) A is **X-rays B1**; B is **infrared B1**. (The arrow is increasing wavelength, so the order runs from gamma to radio.)

(b) X-rays: medical scanning of bones, or security scanners at airports **B1**. Microwaves: mobile phones, satellite TV or microwave ovens **B1**.

(c) Damage to skin (surface) cells or eyes, leading to skin cancer **B1**.

(d) Infrared **B1**.

(e) They are the same **B1**. All e-m waves travel at the same speed in a vacuum.

Example 2

Extended only. A wireless router sends signals using microwaves of frequency 5.0 GHz.

(a) State the speed of the microwaves in air. **[1]**

(b) Calculate the wavelength of the microwaves. **[3]**

(c) Give two reasons why microwaves are used for wireless internet. **[2]**

(d) State the harmful effect of excessive exposure to microwaves. **[1]**

(a) 3.0×10^8 m/s **B1** (the unit is needed).

(b) $v = f\lambda$ **C1**. $\lambda = \dfrac{3.0 \times 10^8}{5.0 \times 10^9}$ **C1** $= 0.060$ m **A1**. (The mark scheme's C marks come from the equation and the substitution; forgetting that G means 10^9 loses only the last mark.)

(c) They can pass through some walls **B1**; they need only a short aerial to send and receive **B1**.

(d) Internal heating of body cells **B1**.

Example 3

A television company sends its programmes to a **geostationary** satellite, which sends them on to dishes on houses.

(a) State the region of the electromagnetic spectrum used for the satellite television signal. **[1]**

(b) Describe the orbit of a geostationary satellite. **[2]**

(c) The satellite is 3.6×10^7 m above the transmitter. The signal travels at 3.0×10^8 m/s. Calculate the time for the signal to go from the transmitter up to the satellite and back down to a house next to the transmitter. **[3]**

(d) **Extended only.** The programmes are sent as digital signals. Describe how a digital signal differs from an analogue signal, and give two benefits of digital signals. **[3]**

(a) Microwaves **B1**.

(b) It orbits the Earth once every 24 hours (above the equator) **B1**, so it stays above the same point on the Earth's surface **B1**.

(c) Distance there and back $= 2 \times 3.6 \times 10^{7} = 7.2 \times 10^{7}$ m. time $= \dfrac{\text{distance}}{\text{speed}}$ **C1** $= \dfrac{7.2 \times 10^{7}}{3.0 \times 10^{8}}$ **C1** $= 0.24$ s **A1**.

(d) A digital signal has only two values (1 and 0, high and low), while an analogue signal varies continuously and can take any value **B1**. Benefits: a higher rate of data transmission **B1**; it can be regenerated accurately so noise is removed, giving a greater range **B1**.

Common mistakes

- **Mixing up the order**, especially swapping ultraviolet and infrared, or X-rays and gamma rays. Write the full order in the margin before answering, and check the direction of the arrow on the diagram.
- **Thinking shorter-wavelength waves travel faster.** Examiners report that many candidates say gamma rays are faster than radio waves "because they have a shorter wavelength". Every e-m wave has the same speed in a vacuum.
- **Giving the speed of sound.** 340 m/s is sound. E-m waves travel at 3.0×10^{8} m/s.
- **Remote controllers use infrared**, not microwaves or radio waves: this confusion comes up in examiner reports year after year.
- **Microwaves versus radio waves for phones and satellite TV.** Satellite TV and mobile phones use microwaves; broadcast radio and Bluetooth use radio waves.
- **Vague uses and harms.** "Medical uses" or "in hospitals" for gamma rays, or "it is harmful" for ultraviolet, earn nothing. Name the exact use ("sterilising medical equipment") or effect ("skin cancer"). Don't describe an X-ray use when the question asks about gamma rays.
- **Prefixes and standard form.** MHz is 10^{6}, GHz is 10^{9}, kHz is 10^{3}. Examiners report powers-of-ten errors and missing units (Hz) in frequency answers, and some candidates work out $\frac{1}{\lambda}$ instead of $\frac{v}{\lambda}$.
- **Forgetting to halve** the time for a signal that goes there and back.
- **Extended only: describing digital as "not analogue"** or as "used in electronic devices". Say it has only two states (1 and 0); a clear sketch of both signals helps.

How to get the marks

- **"Name the region"**: use the syllabus names exactly (radio waves, microwaves, infrared, visible light, ultraviolet, X-rays, gamma rays). "UV" and "IR" are usually accepted; "heat" or "light rays" for infrared are not.

- **Line-matching**: typically 2 marks for all four lines right and 1 mark for two right. Never draw two lines from one use.
- **"State the speed"**: a number **with its unit**, 3.0×10^8 m/s.
- **Calculations** (usually 3 marks): the equation in symbols (**C1**), the numbers substituted with prefixes converted (**C1**), the answer with a unit (**A1**). The C marks are earned even if the final answer is wrong, so always write them.
- **"Describe one use"** or **"one harmful effect"**: one specific use or effect for that region. Giving several answers where one is wrong can cancel the mark.
- **Multiple choice with two or three columns** (region and use, frequency and use): check every column of the row you pick.
- **"Explain" questions** (why microwaves, why Bluetooth has a short range): give the property **and** link it to the use, for example "microwaves pass through walls, so the phone works indoors".
- **Extended only: digital and analogue**: a labelled sketch plus one sentence each ("two values only" and "any value, continuously varying") scores best.

Quick check

1. List the regions of the electromagnetic spectrum in order of **decreasing frequency**, starting with gamma rays. Which region has the longest wavelength?
2. Name the region used for each of these: (a) an intruder alarm, (b) sterilising water, (c) a security scanner at an airport, (d) treating cancer, (e) an RFID tag.
3. A radio station broadcasts at 750 kHz. Calculate the wavelength of its waves.
4. **Extended only.** An e-m wave has a wavelength of 1.0×10^{-8} m in a vacuum. Calculate its frequency, and use the spectrum diagram to say which region it is in.
5. **Extended only.** Explain why Bluetooth headphones may stop working when the phone is two rooms away, and give two benefits of sending a sound as a digital signal rather than an analogue one.

Answers

1. Gamma rays, X-rays, ultraviolet, visible light, infrared, microwaves, radio waves. Radio waves have the longest wavelength.
2. (a) Infrared; (b) ultraviolet; (c) X-rays; (d) gamma rays; (e) radio waves.
3. $\lambda = \dfrac{v}{f} = \dfrac{3.0 \times 10^8}{7.5 \times 10^5} = 400$ m.
4. $f = \dfrac{v}{\lambda} = \dfrac{3.0 \times 10^8}{1.0 \times 10^{-8}} = 3.0 \times 10^{16}$ Hz. That is higher than visible light ($\approx 6 \times 10^{14}$ Hz) and lower than X-rays ($\approx 3 \times 10^{18}$ Hz), so it is ultraviolet.
5. Bluetooth uses radio waves, which pass through walls but are weakened each time, so after two walls the signal may be too weak. Digital benefits: a higher rate of data transmission; the signal can be regenerated accurately (noise removed), giving a greater range.

Past questions to try

- **0625/33/O/N/24 Q7**: uses of three regions and a satellite television link (Core).
- **0625/41/O/N/21 Q6**: naming missing regions, the frequency of X-rays and X-ray safety (Extended).
- **0625/41/M/J/23 Q6**: the wavelength of mobile phone microwaves, why microwaves, and digital against analogue (Extended).
- **0625/12/F/M/25 Q26**: identifying a region from its frequency.