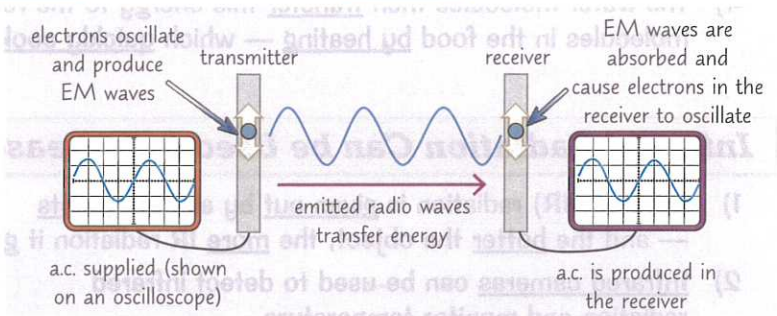
EM Waves for Communication

Different EM waves have different properties, which make them useful to us in different ways.

Radio Waves are Made by Oscillating Charges

1) EM waves are made up of oscillating electric and magnetic fields.
2) Alternating currents (a.c.) (p.192) are made up of oscillating charges. As the charges oscillate, they produce oscillating electric and magnetic fields, i.e. electromagnetic waves.
3) The frequency of the waves produced will be equal to the frequency of the alternating current.
4) You can produce radio waves using an alternating current in an electrical circuit. The object in which charges (electrons) oscillate to create the radio waves is called a transmitter.
5) When transmitted radio waves reach a receiver, the radio waves are absorbed.
6) The energy carried by the waves is transferred to the electrons in the material of the receiver.
7) This energy causes the electrons to oscillate and, if the receiver is part of a complete electrical circuit, it generates an alternating current.
8) This current has the same frequency as the radio wave that generated it.

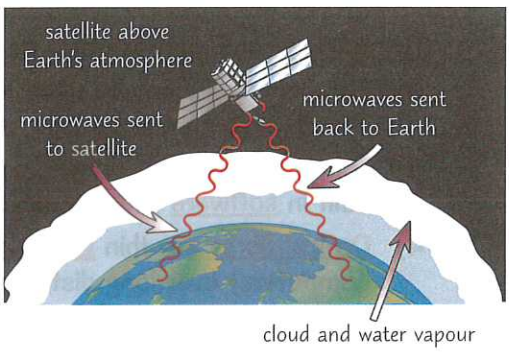


Radio Waves are Used Mainly for Communication and Broadcasting

1) Long-wave radio (wavelengths of 1 – 10 km) can be received halfway round the world from where they started, because long wavelengths bend around the curved surface of the Earth. This makes it possible for radio signals to be received even if the receiver isn't in the line of sight of the transmitter.
2) Short-wave radio signals (wavelengths of about 10 m – 100 m) can, like long-wave, be received at long distances from the transmitter. That's because they are reflected by the Earth's atmosphere.
3) Bluetooth® uses short-wave radio waves to send data over short distances between devices without wires (e.g. wireless headsets so you can use your phone while driving a car).
4) The radio waves used for TV and FM radio transmissions have very short wavelengths. To get reception, you must be in direct sight of the transmitter — the signal doesn't bend or travel far through buildings.

Microwaves and Radio Waves are Used by Satellites

1) Communication to and from satellites (including satellite TV signals and satellite phones) uses EM waves which can pass easily through the Earth's watery atmosphere.
2) These waves are usually microwaves, but can sometimes be relatively high frequency radio waves.
3) For satellite TV, the signal from a transmitter is transmitted into space and picked up by the satellite receiver dish orbiting thousands of kilometres above the Earth.
4) The satellite transmits the signal back to Earth in a different direction, where it's received by a satellite dish on the ground.



Size matters — and my wave's longer than yours...

Producing radio waves — who knew it was so tricky? It's worth it though — they're just so darn useful.

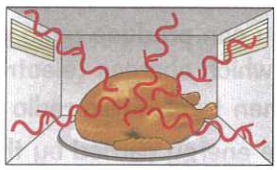
Q1 Explain why signals between satellites are usually transmitted as microwaves. [1 mark]

Microwaves and Infrared

Haven't had enough uses of EM waves? Good, because here are just a few more uses of those incredibly handy waves — complete with the all-important reasons for why they have been used. Get learning.

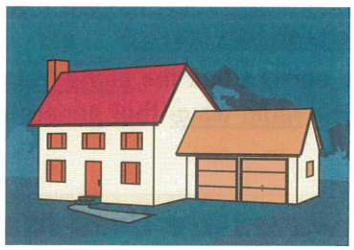
Microwave Ovens Use a Different Wavelength from Satellites

1) In communications, the microwaves used need to pass through the Earth's watery atmosphere.
2) In microwave ovens, the microwaves need to be absorbed by water molecules in food — so they use a different wavelength to those used in satellite communications.
3) The microwaves penetrate up to a few centimetres into the food before being absorbed and transferring the energy they are carrying to the water molecules in the food, causing the water to heat up.
4) The water molecules then transfer this energy to the rest of the molecules in the food by heating — which quickly cooks the food.



Infrared Radiation Can be Used to Increase or Monitor Temperature

1) Infrared (IR) radiation is given out by all hot objects — and the hotter the object, the more IR radiation it gives out.
2) Infrared cameras can be used to detect infrared radiation and monitor temperature.
3) The camera detects the IR radiation and turns it into an electrical signal, which is displayed on a screen as a picture. This is called thermal imaging.
4) Thermal imaging is used by police to see suspects that are trying to escape or hide in the dark.



Different colours represent different amounts of IR radiation being detected. Here, the redder the colour, the more infrared radiation is being detected.

5) Infrared sensors can be used in security systems. If a change in infrared radiation is detected, an alarm sounds or a security light turns on.
6) Absorbing IR radiation causes objects to get hotter. Food can be cooked using IR radiation — the temperature of the food increases when it absorbs IR radiation, e.g. from a toaster's heating element.
7) Electric heaters heat a room in the same way. Electric heaters contain a long piece of wire that heats up when a current flows through it. This wire then emits lots of infrared radiation (and a little visible light — the wire glows). The emitted IR radiation is absorbed by objects and the air in the room — energy is transferred by the IR waves to the thermal energy stores of the objects, causing their temperature to increase.

Infrared Can Also Transfer Information

1) Infrared radiation can also be used to transfer information.
2) For example, it can be used to send files between mobile phones or laptops. The distances must be fairly small and the receiver must be in the line of sight of the emitter.
3) This is also how TV remote controls work. In fact, some mobile phones now have built in software which means that you can use your phone as a TV remote.
4) Optical fibres are thin glass or plastic fibres that can carry data (e.g. from telephones or computers) over long distances as pulses of infrared radiation. They usually use a single wavelength to prevent dispersion, which can otherwise cause some information to be lost.
5) They use total internal reflection to send lots of data over long distances.

Revision time — adjust depending on brain wattage...

The next time you're feeling hungry and zap some food in the microwave, think of it as doing revision.

Q1 Give three uses of infrared radiation. [3 marks]

More Uses of EM Waves

And we're still not finished with uses of waves — is there no end to their talents...

Photography Uses Visible Light

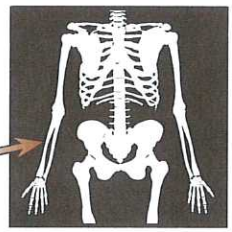
1) Visible light is the light that we can see. So it's only natural that we use it for illuminating things so that we can see them.
2) Photographic film reacts to light to form an image. This is how traditional cameras create photographs.
3) Digital cameras contain image sensors, which detect visible light and generate an electrical signal. This signal is then converted into an image that can be stored digitally or printed.

Ultraviolet is Used in Fluorescent Lamps

1) Fluorescence is a property of certain chemicals, where ultraviolet (UV) radiation is absorbed and then visible light is emitted. That's why fluorescent colours look so bright — they actually emit light.
2) Fluorescent lights use UV to emit visible light. They're energy-efficient (p.158) so they're good to use when light is needed for long periods (like in your classroom).
3) Security pens can be used to mark property (e.g. laptops). Under UV light the ink will glow, but it's invisible otherwise, helping to identify stolen property.
4) Bank notes and passports use a similar technique to detect forgeries — genuine notes and passports have special markings that only show up under UV light.
5) Ultraviolet radiation is sometimes used to sterilise water. It kills bacteria in the water, making it safe to drink. (Gamma rays are used in a similar way, see below.)

X-rays Let Us See Inside Things

1) X-rays can be used to view the internal structure of objects and materials, including our bodies.
2) They affect photographic film in the same way as light, meaning you can take X-ray photographs. But X-ray images are usually formed electronically these days.
3) Radiographers in hospitals take X-ray images to help doctors diagnose broken bones — X-rays are transmitted by flesh but are absorbed by denser material like bones or metal.
4) To produce an X-ray image, X-ray radiation is directed through the object or body onto a detector plate. The brighter bits of the image are where fewer X-rays get through, producing a negative image (the plate starts off all white).
5) X-rays are also used in airport security scanners to detect hidden objects that can't be detected with metal detectors.



Gamma Rays are Used for Sterilising Things

1) Gamma rays are used to sterilise medical instruments — they kill microbes (e.g. bacteria).
2) Food can be sterilised in the same way — again killing microbes. This keeps the food fresh for longer, without having to freeze it, cook it or preserve it some other way, and it's perfectly safe to eat.
3) Some medical imaging techniques such as tracers use gamma rays to detect cancer.
4) Gamma radiation is also used in cancer treatments — radiation is targeted at cancer cells to kill them. Doctors have to be careful to minimise the damage to healthy cells when treating cancer like this.

Don't lie to an X-ray — they can see right through you...

I hate to say it, but go back to page 169 and re-read all of the uses for electromagnetic waves to really learn them.

Q1 State two uses of ultraviolet radiation. [2 marks]

Q2 Suggest one advantage of sterilising food with gamma rays. [1 mark]

Uses of EM Waves

Warm-Up

Tick the appropriate boxes to sort the radio wave facts from the fiction.

	True	False
Long-wave radio waves can be transmitted across long distances.	☐	☐
Long-wave radio waves bend and follow the curve of the Earth's surface.	☐	☐
Short-wave radio waves can only be used over short distances.	☐	☐
Wireless headsets use short-wave radio waves to transfer information.	☐	☐

1 Electromagnetic waves have a variety of different uses. Grade 4–6

a) Draw lines to match each type of electromagnetic radiation on the left to its use on the right.

Ultraviolet	photography
Visible light	satellite communications
Infrared	fluorescent lights
Radio waves	security lights

[2]

b) Give **two** examples of infrared waves being used to transfer information.

1. .....

2. .....

[2]

c) A camper has bought a device that filters and sterilises water so he can drink it.
The device uses electromagnetic radiation to sterilise the water.
What is the most likely type of radiation that the device would use?

☐ **A** gamma rays ☐ **B** ultraviolet ☐ **C** infrared ☐ **D** microwaves

[1]

[Total 5 marks]

2 A man uses a security pen to mark his belongings. The security pen contains fluorescent ink which cannot be seen in visible light.

Grade 4-6

a) Which of the following is true for fluorescent ink?

- ☐ **A** Fluorescent ink emits radio waves after it absorbs ultraviolet light.
- ☐ **B** Fluorescent ink emits ultraviolet light after it absorbs visible light.
- ☐ **C** Fluorescent ink emits visible light after it absorbs ultraviolet light.
- ☐ **D** Fluorescent ink emits ultraviolet light after it absorbs radio waves.

[1]

b) Explain how the security ink can be used to find the man's property if it is stolen.

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[2]

c) Give **one** other example of where fluorescence is used in security.

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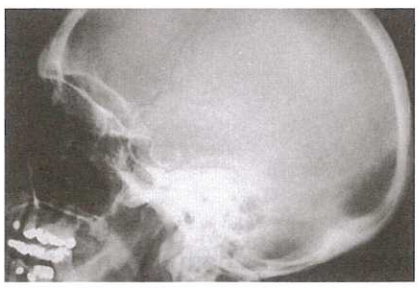
[1]

[Total 4 marks]

3 **Figure 1** shows an X-ray image of a skull.

Grade 6-7

Figure 1



a) Explain how X-rays are used to form images like **Figure 1**.

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[3]

b) Give **one** other non-medical use of X-rays.

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[1]

[Total 4 marks]

4 A police helicopter has an infrared camera attached to its base. Grade 6-7

a) Describe how an infrared camera works.

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[2]

b) Explain the advantages of using an infrared camera rather than a normal camera when searching for criminals at night.

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[3]

[Total 5 marks]

5 A student uses a microwave oven to cook a jacket potato on a glass plate. Grade 6-7

a) Describe how microwaves cook the potato in the microwave oven.

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[3]

b) Explain why the glass plate does not get as hot as the potato when the microwave oven is used.

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[2]

c) Microwaves can also be used to communicate with satellites. Explain why the microwaves used for communications must have different wavelengths to those used in microwave ovens.

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[4]

[Total 9 marks]

6 Walkie-talkies use radio waves to communicate between each other. When a person speaks into the microphone, it creates an electric current. When the walkie-talkie receives a message, the microphone becomes a loudspeaker and converts electrical current into sound waves.

Grade 7-9

a) Briefly describe the steps involved for the creation, transmission and reception of a radio wave between a pair of walkie-talkies. You do not need to describe how microphones or loudspeakers work.

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[6]

b)* A family from northern England are on holiday in France. Explain why they are unable to listen to their local FM radio station from back home, but are still able to listen to the same long-wave radio broadcasts as they do at home.

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[6]

[Total 12 marks]

Exam Practice Tip

In the exams, you may be asked to explain why a given electromagnetic wave is suited to a particular use. So make sure you understand the properties of the different electromagnetic wave types, and know some of their most common uses.