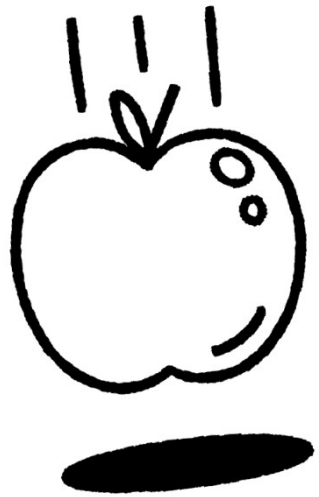
Non-ionising electromagnetic radiation



Physics

Unit: **Electromagnetic waves**

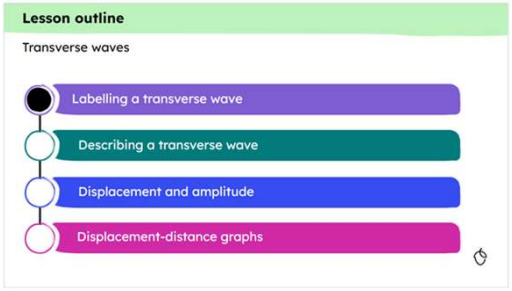
Oak National Academy

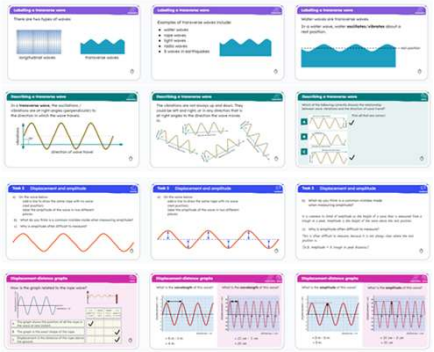
Teacher Guidance

Oak's lesson structure

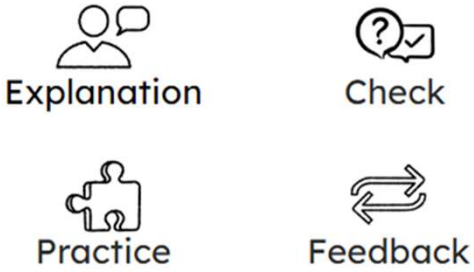
Oak's lessons are structured around **learning cycles**.

These are indicated through colour in the slide deck:





Each **learning cycle** covers several phases:



Useful links

[How our teaching resources are designed for the classroom]

Outcome

I can explain the properties, uses and dangers of non-ionising electromagnetic radiation.

Keywords

frequency

non-ionising

heating

antenna

Keywords

The **frequency** of a wave is the number of oscillations each second.

Radio waves, microwaves, infrared and visible light are **non-ionising** electromagnetic waves as they cannot force electrons from atoms.

Heating is an energy transfer that causes a temperature rise.

An **antenna** is a metal structure designed to emit or absorb electromagnetic waves.

Lesson outline

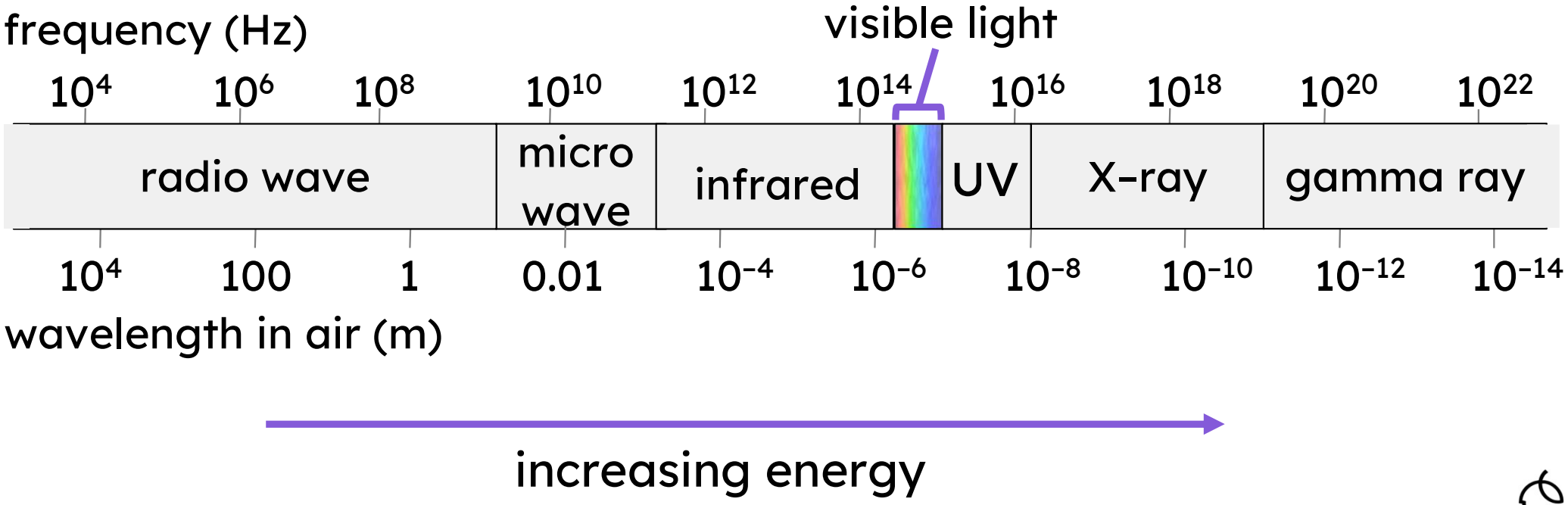
Non–ionising electromagnetic radiation

- Ionising and non–ionising EM radiation
- Radio waves and microwaves
- Infrared and visible light

Ionising and non-ionising EM radiation

Explanation

The energy transferred by one ‘chunk’ or ‘packet’ of EM radiation increases with frequency.



Ionising and non-ionising EM radiation

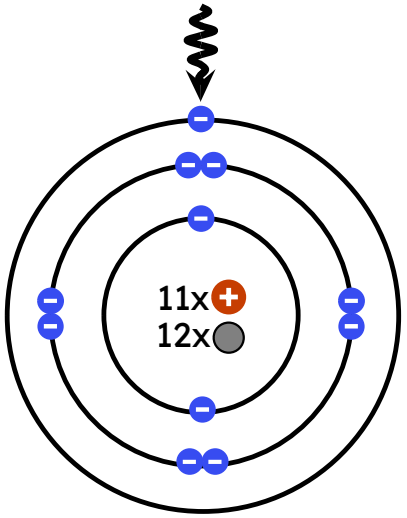
Explanation

Only UV, X-ray and gamma radiation have enough energy to ionise atoms.

Ionising radiation can ionise atoms in living cells.
This can cause harmful changes to how cells work.

Exposure to ionising radiation can increase the risk of cancer.

a sodium ion
(not to scale)



protons

neutrons

electrons

ionising EM radiation

Ionising and non-ionising EM radiation

Explanation

Radio, microwave, IR and visible light are types of **non-ionising** EM radiation.

A single 'packet' of non-ionising EM radiation does not have enough energy to force electrons off atoms to form ions.

High intensity non-ionising EM radiations can harm cells by **heating**.

Non-ionising EM radiation can push electrical currents through electrical conductors and trigger chemical reactions like photosynthesis.

high intensity light in lasers can damage eyes

Ionising and non-ionising EM radiation

Check

Which types of EM radiation are non-ionising?

a radio waves ✓

b microwaves ✓

c infrared ✓

d visible ✓

e UV

f X-rays

g gamma rays

Task A Ionising and non-ionising EM radiation

Practice

1) Describe how the frequency of EM waves affects their ability to ionise atoms.
2) Explain why the ability of EM waves to ionise atoms changes with frequency.
3) State how infrared radiation can damage living cells.

Task A Ionising and non-ionising EM radiation

Feedback

1) Describe how the frequency of EM waves affects their ability to ionise atoms.
The higher the frequency, the more ionising EM waves are. Light and EM waves with a lower frequency than light are non-ionising.

2) Explain why the ability of EM waves to ionise atoms changes with frequency.
The higher the frequency, the more energy is transferred by a single packet of radiation.

3) State how infrared radiation can damage living cells.
Infrared radiation can damage cells by heating them, causing burns.

Lesson outline

Non–ionising electromagnetic radiation

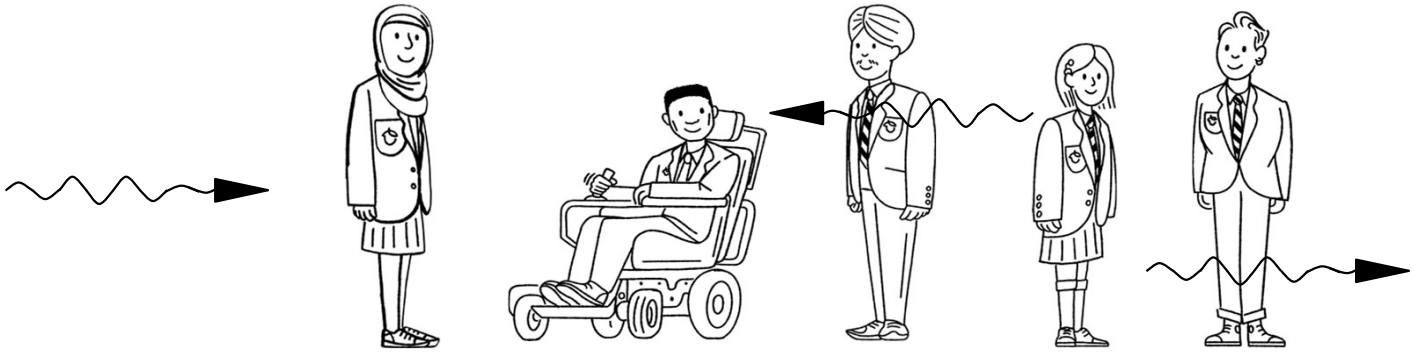
- Ionising and non–ionising EM radiation
- Radio waves and microwaves
- Infrared and visible light

Radio waves and microwaves

Explanation

Radio waves can transmit information for TV, radio, mobile phones, bluetooth and Wifi signals.

Low intensity radio waves are passing through our bodies all the time. Exposure to low-intensity radio waves is not thought to be harmful.



However, looking into an intense source of radio waves at close range can cause damage to the lens of the eye by **heating**.

Radio waves and microwaves

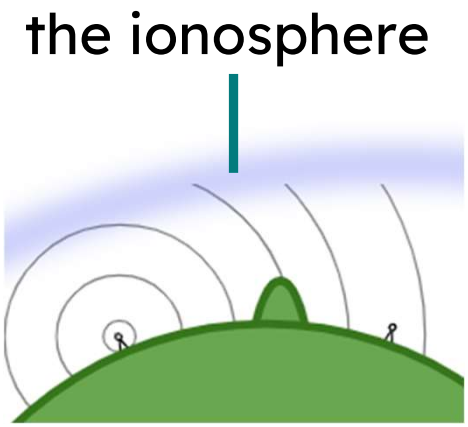
Explanation

Radio waves can be used for long-distance communication because:

- they are transmitted well through air, buildings and foliage,
- they can reflect off very large objects, not absorbed.

Lower frequency radio waves bend (diffract) around large obstacles like hills and around the curve of Earth.

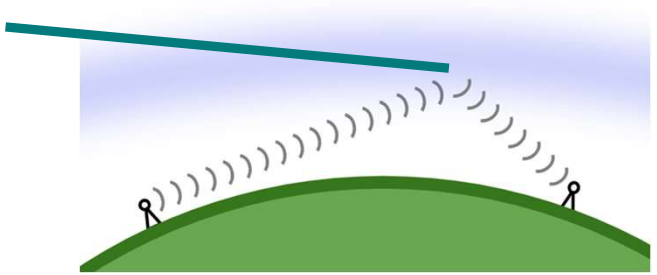
They do not pass through the ionosphere.



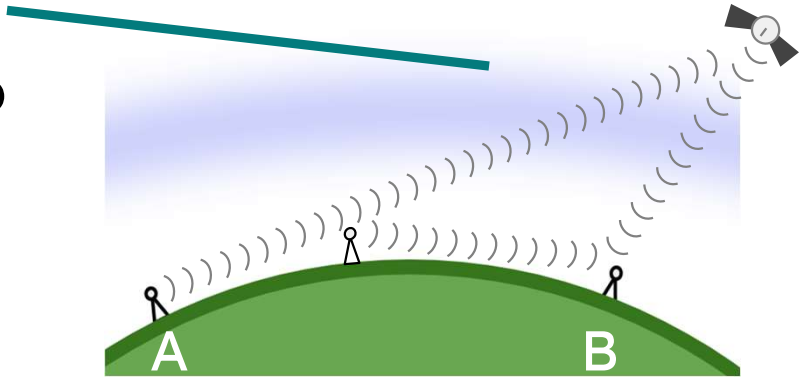
Radio waves and microwaves

Explanation

Some higher **frequency** radio waves can reflect from the ionosphere to travel further.



Very high frequency radio waves and some microwaves can pass through the atmosphere and transmit information to and from satellites.



Microwaves travel in straight lines and often need relay towers or satellites to extend their range.

relay towers or satellites pass microwaves from A and B

Radio waves and microwaves

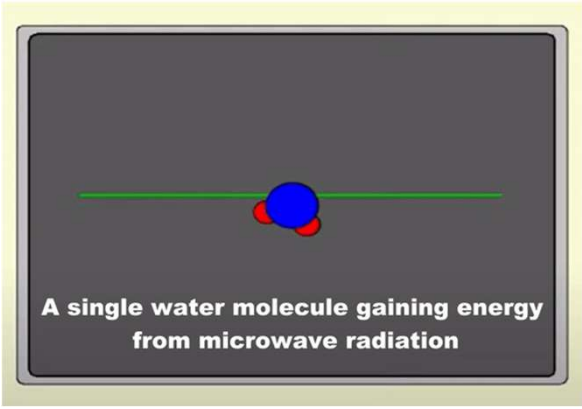
Explanation

Water is a good absorber of microwave radiation.

Microwave frequencies transfer energy to the water.
Microwaves **heat** water by causing water molecules to spin.

Food with a high water content can be heated by microwaves in a microwave oven.

Microwaves are absorbed by 3 – 4 cm of food and cook food from the inside.



Metal sides and a metal mesh in the glass door of a microwave oven reflect microwaves and stop them escaping.

Simulation by PhET Interactive Simulations, University of Colorado Boulder, licensed under CC-BY-4.0 (https://phet.colorado.edu)

Radio waves and microwaves

Check

Do each of the following applications use radio waves, microwaves, or both?

1) FM radio — *radio waves*

2) satellite communication — *some frequencies of both*

3) cooking food — *microwaves*

4) mobile phone networks — *some frequencies of both*

Task B Radio waves and microwaves

Practice

1) Explain why radio frequencies are well suited for long-distance communication on Earth.
2) Explain why microwave frequencies are suitable for satellite communications.
3) Explain why microwave frequencies are suitable for cooking food.

Task B Radio waves and microwaves

Feedback

1) Explain why some radio frequencies are well suited for long-distance communication and broadcasting on Earth.
   Radio waves are not absorbed by air, buildings and foliage.
   Low radio frequencies bend around obstacles and the curve of Earth, and higher radio frequencies reflect back down from the ionosphere.
2) Explain why microwave frequencies are suitable for satellite communications.
   Microwave frequencies pass through the atmosphere. Because they travel in straight lines, signals can be aimed at individual satellites.
3) Explain why microwave frequencies are suitable for cooking food.
   Most foods have a high water content. Microwave frequencies are absorbed well by water, so transfer energy to water efficiently, heating it.

Lesson outline

Non–ionising electromagnetic radiation

- Ionising and non–ionising EM radiation
- Radio waves and microwaves
- Infrared and visible light

Infrared and visible light

Explanation

All objects radiate EM waves all of the time.

They emit infrared (IR) radiation.

Thermal cameras measure the intensity of IR from each part of an image and convert this to a temperature.

A thermal image shows each temperature as a different colour.

Above 600°C, objects emit both visible light and IR.

Infrared and visible light

Explanation

IR radiation can be absorbed by the surface of an object, **heating** up the object from the outside in.

Heating elements emit a lot of infrared radiation.

Because they are so hot, they often emit a little visible light as well.

Intense IR radiation can cause burns.

heating elements in an IR heater, toaster and grill

Infrared and visible light

Check

Which type of radiation is emitted by a hot heating element?

a Just infrared radiation.

b Mainly infrared and a little light radiation. ✓

c Infrared and light radiation in roughly equal amounts.

Infrared and visible light

Explanation

In security systems, a moving object can set off an alarm if it blocks an (invisible) IR beam.

A TV remote control uses a beam of IR radiation to send information short distances to a TV.

Laptops, computers and video game controllers sometimes use IR to transmit data.

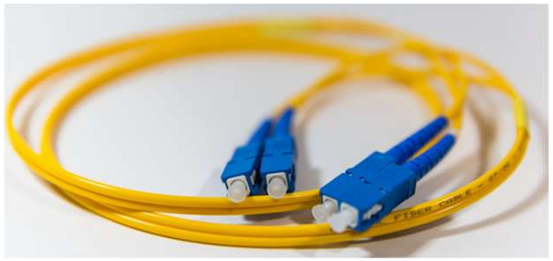
IR is often used to send information along optical fibres.

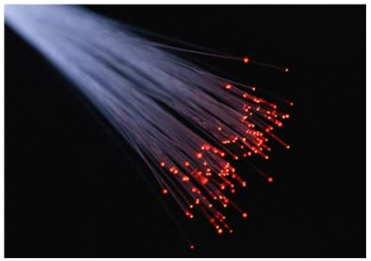
Infrared and visible light

Explanation

Fibre optic cables contain bundles of clear plastic fibres that can transmit light or IR signals.

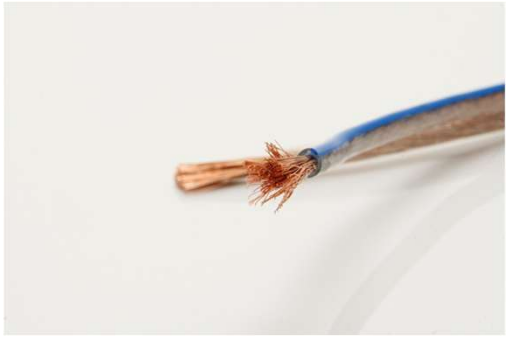
They can transmit huge amounts of information very quickly over long distances, using a digital code.





a fibre optic cable

Electric cables can’t transmit as much information every second.



Infrared and visible light

Explanation

Our eyes can detect visible light. We see objects by the light reflected off them and into our eyes.

Cameras work in a similar way. They detect light using a light-sensitive computer chip (a CCD). In the past, light caused chemical changes to a film in the back of a camera.

LED bulbs emit mostly visible EM radiation.

Filament bulbs are less efficient. As well as emitting light, they emit a lot of IR radiation that does not help to light a room.

Infrared and visible light

Check

Do each of the following applications use infrared (IR), visible light or both?

a	photography	*visible light*
b	thermal imaging	*IR*
c	fibre optic communication	*both*
d	cooking food in a toaster	*IR*
e	TV remote controls	*IR*

Task C Infrared and visible light

Practice

Fill in the table to summarise the properties of non-ionising EM radiation.

Some columns can be merged as the properties are the same for all.

	radio waves	microwaves	infrared (IR)	visible light
what are they?				
speed in air				
how ionising?				
dangers				
example uses				
example sources				
example absorbers				

Task C Infrared and visible light

Feedback

Fill in the table to summarise the properties of non-ionising EM radiation.

	radio waves	microwaves	infrared (IR)	visible light
what are they?	*EM waves with lower frequencies (and longer wavelengths) than ultraviolet. From radio waves to visible light, frequency increases and wavelength decreases.*			
speed in air	*300 000 000 m/s*			
how ionising?	*non-ionising*			
dangers	*At high intensities they all cause heating.* *Eyes are particularly vulnerable.* *High intensity IR can burn.*			

Task C Infrared and visible light

Feedback

Fill in the table to summarise the properties of non-ionising EM radiation.

	radio waves	microwaves	infrared (IR)	visible light
example uses	wireless data transmission (TV, radio, phone, Wi-Fi, bluetooth)	cooking food wireless data transmission (including to satellites)	fibre optic and short-range wireless data transmission cooking electric heaters	fibre optic data transmission photography lighting
example sources	a metal antenna connected to a changing electric current		IR LEDs, all surfaces emit IR	lighting the Sun
example absorbers	metal antennas water (absorbs microwaves especially well)		all surfaces (except metals) absorb some IR	black objects

Summary Non-ionising electromagnetic radiation

Radio waves, microwaves, IR and visible light are **non-ionising** EM radiation. They can harm cells by **heating**.

Radio waves and microwaves are used for long distance communication, broadcasting and data transmission.

Microwaves are absorbed by water so can be used to cook food from within. IR radiation cooks the surface of food.

IR is used for heating and thermal imaging.
Visible light and IR are used for data transmission in optical fibres.

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