TRANSFER OF ENERGY

WAVES   Describing Waves

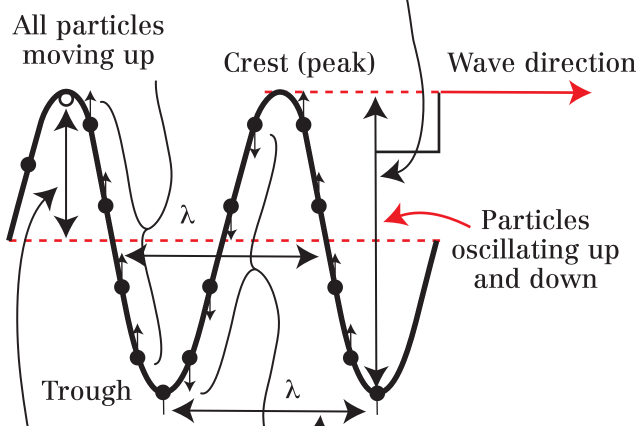
WAVES

- All waves transfer energy from one place to another, without transferring any matter.
- A wave is a periodic disturbance of a medium.
- Speed = distance travelled by a wave crest or compression in one second.
- The direction of wave motion is defined as the direction energy is transferred.
- The medium is the material that is disturbed as the wave passes through it.

Two types

Transverse waves

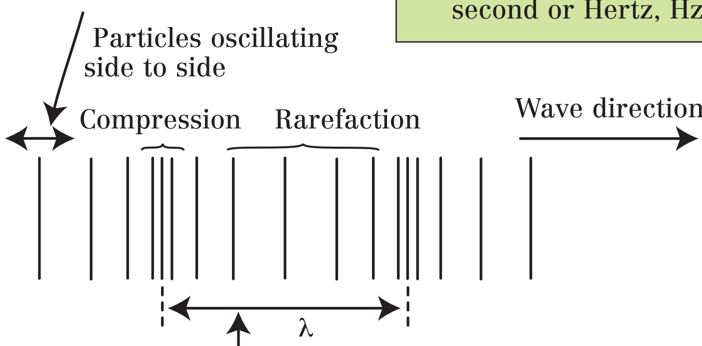
Particles of the medium oscillate about fixed positions at right angles to the direction of wave travel.



Amplitude – distance between a crest or trough and the *undisturbed position*.

Longitudinal waves

The particles of the medium oscillate about fixed positions along the same line as the wave energy travels.



Frequency is the number of waves per second produced by the source that pass through a given point in the medium. Measured in waves per second or Hertz, Hz.

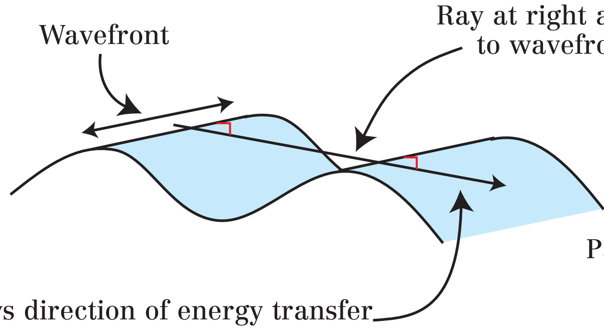
Wavelength (λ) – distance between the same point on two adjacent disturbances. Measured in metres.

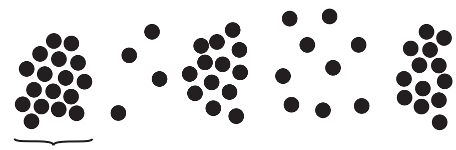
Examples longitudinal:

- Sound

Examples transverse:

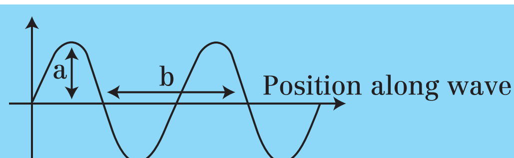
- Surface water waves
- Light
- Plucked guitar string

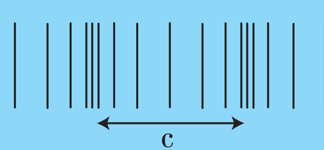




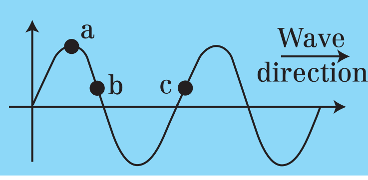
Questions

1. Identify the measurements a, b and c in the following diagrams:





2. Write a sentence to define each of the following terms:
   a. Wavelength.
   b. Frequency.
   c. Amplitude.
2. Give one similarity and one difference between a longitudinal and transverse wave and give an example of each.
3. For each of particles a, b, and c in the diagram decide if the particle is moving up, moving down, or is momentarily stationary.



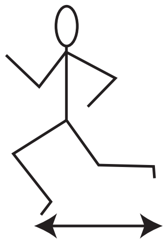
WAVES Wave Speed

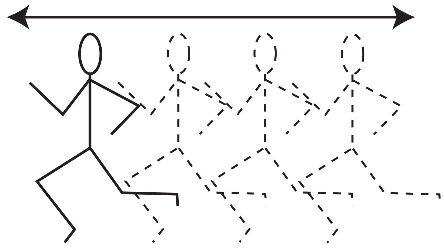
The speed of a wave is given by the equation

Wave speed (m/s) = frequency (Hz) × wavelength (m).

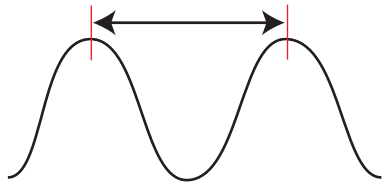
Here is how to see why

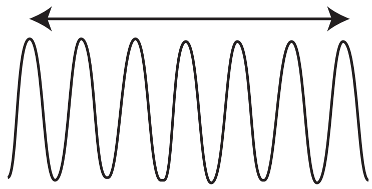
Walking speed (m/s) = stride length (m) × no of steps per second





Wave speed (m/s) = wavelength (m) × no of waves per second (frequency)

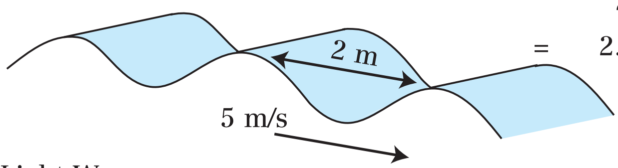




Examples

Water Wave:

$$\text{frequency} = \frac{\text{speed}}{\text{wavelength}} = \frac{5\ \text{m/s}}{2\ \text{m}} = 2.5\ \text{Hz}$$



Light Wave:

Speed of light $= 3 \times 10^8$ m/s

frequency $= 5 \times 10^{14}$ Hz,

$$\text{wavelength} = \frac{\text{speed}}{\text{frequency}} = \frac{3 \times 10^8\ \text{m/s}}{5 \times 10^{14}\ \text{Hz}} = 6 \times 10^{-7}\ \text{m}$$

Common speeds:

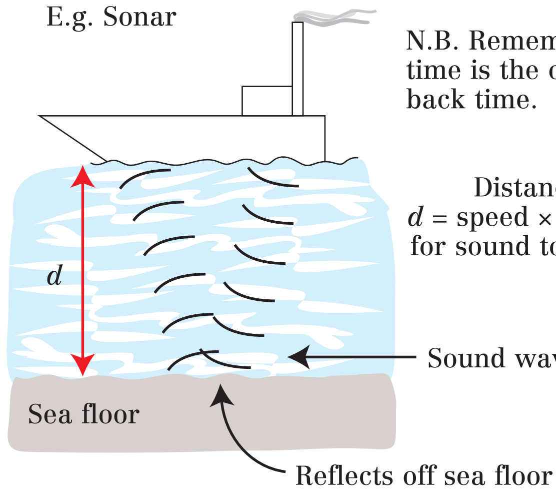
Speed of light $= 3 \times 10^8$ m/s (300 000 000 m/s)

Speed of sound ≈ 340 m/s (in air at room temperature)

Wave speeds can also be calculated by

$$\text{Wave speed (m/s)} = \frac{\text{distance travelled (m)}}{\text{time taken (s)}}$$

E.g. Sonar



N.B. Remember time is the out and back time.

Distance, d = speed × $\frac{1}{2}$ time for sound to return

Questions

1. Calculate the speed of the following waves:
   a. A water wave of wavelength 1 m and frequency 2 Hz.
   b. A water wave of wavelength 3 m and frequency 0.4 Hz.
2. Rearrange the formula wave speed = frequency × wavelength to read:
   a. wavelength = _____. b. frequency = ______.
3. Calculate the frequency of a sound wave of speed 340 m/s and wavelength:
   a. 2 m. b. 0.4 m.
4. Calculate the wavelength of a light wave of speed 300 000 000 m/s and frequency:
   a. 4.62×10^{14} Hz. b. 8.10×10^{14} Hz.
5. Calculate the speed of the following waves. Why might we say that all of these waves belong to the same family?
   a. Wavelength 10 m, frequency $= 3 \times 10^7$ Hz.
   b. Wavelength 4×10^{-3} m, frequency 7.5×10^{10} Hz.
   c. Wavelength 6×10^{-10} m, frequency 5×10^{17} Hz.
6. In the sonar example above, the echo takes 0.3 s to return from the sea floor. If the sea is 225 m deep, show that the speed of sound in seawater is about 1500 m/s.
7. A radar station sends out radiowaves of wavelength 50 cm and frequency 6×10^8 Hz. They reflect off an aircraft and return in 4.7×10^{-5} s. Show that the aircraft is about 7 km from the radar transmitter.

WAVES Electromagnetic Waves

Electromagnetic waves, like all waves transfer energy. They also have the following properties in common.

Electromagnetic waves

- Will travel across empty space. They do not need a medium (solid, liquid, or gas) to travel, unlike sound waves.
- They all travel at the speed of light (300 000 000 m/s) in a vacuum.
- As the speed is fixed, as wavelength increases frequency decreases and *vice versa*.
- They can all be reflected, refracted, diffracted, and interfere.
- The electromagnetic spectrum of increasing frequency and decreasing wavelength is broken up into blocks and given names. These group the wavelengths that are produced in similar ways.
- They obey the wave speed equation: Wave speed (m/s) = frequency (Hz) × wavelength (m).

Notice that ultraviolet, X-rays, and gamma rays wavelengths overlap but they are named according to their source.

	Radiowaves	Microwaves	Infrared (IR)	Visible light	Ultraviolet (UV)	X-rays	Gamma Rays
	INCREASING FREQUENCY →						
Frequency range (Hz)	3×10^9	3×10^{11}	4.3×10^{14}	7.5×10^{14}	3×10^{17}	3×10^{20}	
	← INCREASING WAVELENGTH						
Wavelength range	10 cm	1 mm	7×10^{-7} m	4×10^{-7} m	UV 1×10^{-9} m	X-rays 1×10^{-12} m	γ-rays
Sources	Radio transmitters (electrons accelerating up and down metal aerials)	Microwave transmitters (Klystron or magnetron tube)	Any hot object →	Very hot, luminous objects Light emitting diodes →	Extremely hot gases, e.g. the Sun, UV lamps	X-ray tubes	Nuclei of radio-active atoms
Detectors	Aerials	Microwave receiver (aerial)	← (special) Photographic film →; ← Charge coupled device – used in digital cameras and camcorders →; Thermistor	Light dependent resistor	Fluorescent materials	← GM tube →	
	INCREASING ENERGY →						

Detectors: Things which produce an observable response to the radiation they absorb.

Notice that light is just one of this family of radiations and that the visible spectrum, red–violet, can be extended on both sides.

Questions

1. State three properties all electromagnetic waves have in common.
2. Calculate the wavelength of electromagnetic waves of the following frequencies:
   a. 5×10^9 Hz. b. 5×10^{14} Hz. c. 5×10^{15} Hz.
   d. What part of the electromagnetic spectrum does each of these waves come from?
2. Calculate the frequencies of electromagnetic waves of the following wavelengths:
   a. 1 m. b. 1×10^{-5} m. c. 5×10^{-8} m.
   d. What part of the electromagnetic spectrum does each of these waves come from?
3. List the electromagnetic spectrum in order of increasing energy.
4. Which has the longest wavelength, red or blue light? List the colours of the visible spectrum in order of increasing frequency.

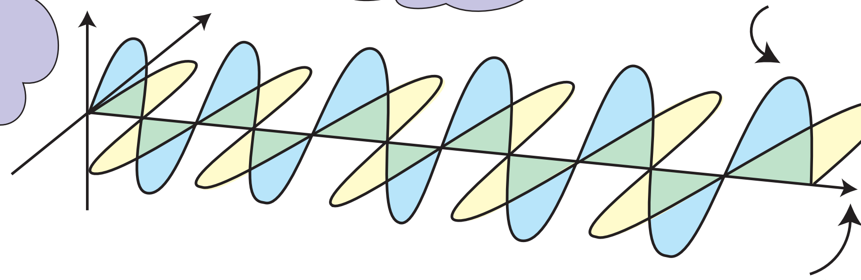
WAVES How Electromagnetic Waves Travel

What is 'waving' in an electromagnetic wave?
It is formed from linked oscillating electric and magnetic fields, hence the name.

No need for a medium as electric and magnetic fields travel in empty space.

Two fields oscillate at right angles.

Electric field



Magnetic field

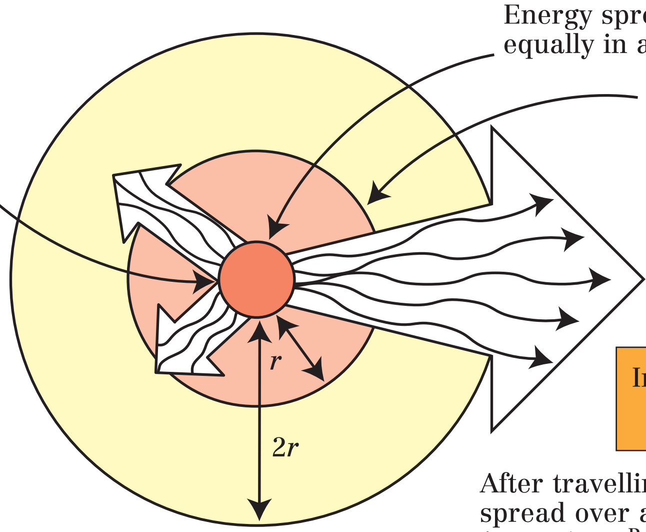
Direction of travel

Electromagnetic radiation from a point source (e.g. a star, lamp filament) obeys the inverse square law.

Source has a power output of P watts (i.e. it is losing P Joules every second by the emission of electromagnetic waves).

Energy spreads out (radiates) equally in all directions.

After travelling a distance r, it will be spread over a sphere of surface area A (Intensity, P/A).



Intensity (W/m^2) = $\dfrac{\text{power (W)}}{\text{area (m}^2\text{)}}$

Doubling the distance from the source reduces the intensity to a quarter.

I.e. Intensity $\propto 1/r^2$

After travelling a distance $2r$, it will be spread over a sphere of surface area $4A$. (Intensity, $\frac{P}{4A}$)

Laser light

Stands for
'**L**ight **A**mplification by **S**timulated **E**mission of **R**adiation'

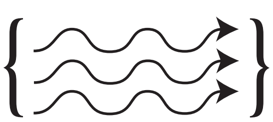
Only one wavelength from a given source.

Waves form a narrow beam with very little spreading so the light is very intense.

Generally a mixture of wavelengths from a source.

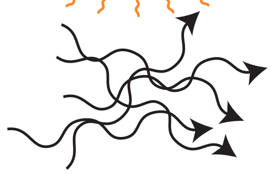
Laser light *vs.* **Ordinary light**

All waves travel together in step (in phase).



Peaks and troughs always coincide.

Waves travel in all directions.

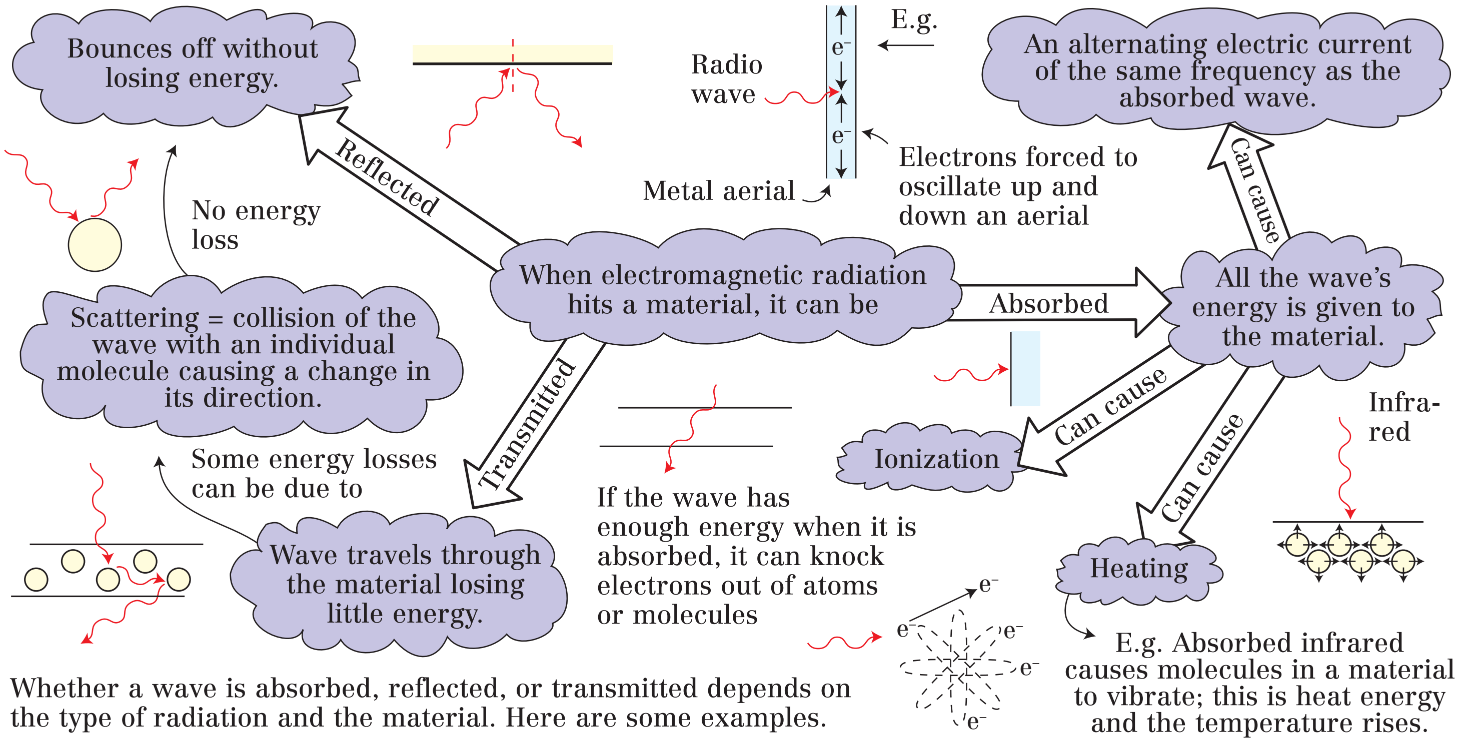


Waves do not travel in step.

Questions

1. What is waving in an electromagnetic wave?
2. A 60 W light bulb can be considered a point source of light. What is the intensity of the light:
   a. 1 m from the bulb when it has spread through a sphere of area 12.6 m^2?
   b. 2 m from the bulb when it has spread through a sphere of area 50.3 m^2?
   c. Suggest what the intensity would be 3 m from the bulb.
3. The intensity of the Sun's radiation at the Earth is about 1400 W/m^2. Jupiter is about five times further from the Sun. Show that the intensity of the Sun's radiation here is about 56 W/m^2.
4. Suggest three differences between laser light and ordinary light from a lamp.

WAVES Absorption, Reflection, and Transmission of Electromagnetic Waves



Whether a wave is absorbed, reflected, or transmitted depends on the type of radiation and the material. Here are some examples.

Radiation	Metals	Glass	Living Tissue	Water
Radiowaves	Absorbed by aerials, but otherwise reflected	Transmitted	Transmitted	Reflected
Microwaves	Reflected, e.g. satellite dishes and inside of microwave ovens	Transmitted	Transmitted except 12 cm wavelength which is absorbed by water in the tissues	12 cm wavelength absorbed, otherwise transmitted
Infrared	Absorbed by dull/black surfaces, reflected by shiny ones	Transmitted/ reflected depending on wavelength	Absorbed	Absorbed
Visible light	Absorbed by dull/black surfaces, reflected by shiny ones	Transmitted	Some wavelengths absorbed, some reflected – giving the tissue a distinctive colour	Transmitted
Ultraviolet	Absorbed	Absorbed	Absorbed and causes ionization	Absorbed
X-rays	Partially absorbed and partially transmitted. The denser the material the more is absorbed		Partially absorbed and partially transmitted. The denser the tissue the more is absorbed	Transmitted
Gamma rays			Transmitted	Transmitted

Questions

1. Define the following and give an example of a type of radiation and material that illustrates each:
   a. Transmission. b. Reflection. c. Absorption.
2. Suggest three possible results of the absorption of electromagnetic radiation by a material.
3. Copy and complete the table using words below (look ahead to p33 and 34 if you need help).

Sending signals to mobile phones. Cooking. Aerials. Broadcasting. Suntans. Sterilization. Medical X-rays. Mirrors. Walls of a microwave oven.

	Transmission	Absorption	Reflection
Radiowave			Round the globe broadcasting by bouncing off the ionosphere
Microwave			
Infrared		Cooking	
Visible light	Lenses		
Ultraviolet			
X-ray			
Gamma ray			

WAVES The Earth's Atmosphere and Electromagnetic Radiation

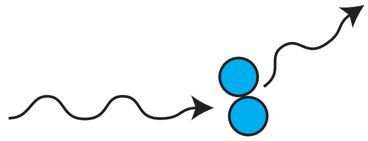
Electromagnetic waves either

pass straight through the atmosphere

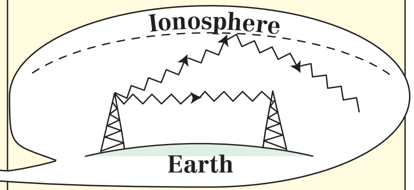
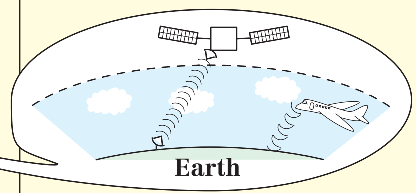
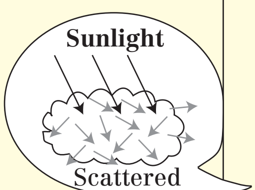
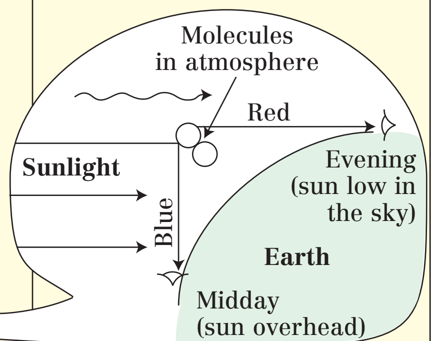
or

are absorbed by molecules in the atmosphere

or



are scattered by molecules in the atmosphere

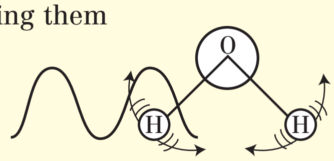
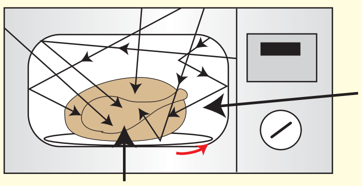
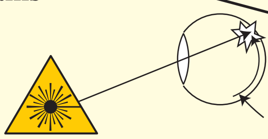
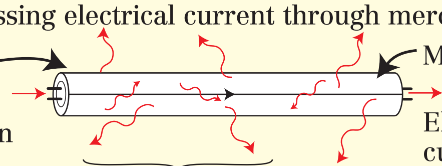
Type of radiation	Effect of the atmosphere	Potential uses	Potential problems
Radiowaves	Generally pass straight through, except some long wavelengths will be reflected by a layer called the ionosphere, high in the atmosphere	Carrying messages over long distances. Bouncing radiowaves off the ionosphere allows them to reach receivers out of the line of sight	
Microwaves	Pass through all parts of the atmosphere	Send information to and from satellites in orbit; send information to and from mobile phones; radar	
Infrared	Absorbed by water vapour and other gases such as carbon dioxide (present in small amounts) and methane (present in minute amounts)	Humans are increasing the amount of greenhouse gases in the atmosphere. Some scientists think this is causing the Earth to warm up. Possible consequences are . . . • Rising sea levels due to melting of the polar ice caps • Extreme weather conditions occurring more often • Loss of farmland (too wet, dry)	Infrared is emitted by all warm surfaces including the Earth's surface. Some is lost into space but some is absorbed by gases (water, carbon dioxide) in the atmosphere warming it. This is called the *Greenhouse effect* and those gases that absorb infrared, greenhouse gases. Too high a concentration of greenhouse gases leads to *global warming*
Visible light 	Passes through clear skies. Blue light is scattered more than red light giving blue skies during the day and red skies at dawn and dusk Randomly scattered from water vapour in clouds	Provides plants with energy for photosynthesis and hence all living things with food. Warms the Earth's surface	
Ultraviolet	Absorbed by ozone gas high in the atmosphere (the ozone layer)	Ozone layer protects plants and animals from exposure to too much ionizing ultraviolet radiation from the Sun which would harm them	Ozone layer is being destroyed by chemical reactions with man-made gases
X-rays and gamma rays	Absorbed by the atmosphere		

Questions

1. Which types of electromagnetic radiation pass straight through the atmosphere, which are scattered, and which are absorbed?
2. What is the Greenhouse effect? Suggest why the concentration of carbon dioxide in the atmosphere has been rising for the last 200 years. Suggest three consequences of global warming.
3. Why are cloudy nights generally warmer than when there are clear skies?
4. If the polar ice caps melt, will the Earth's surface absorb more or less radiation from the Sun? Hence will this increase or decrease the rate of global warming?
5. How is the ozone layer helpful to humans and why should we be concerned about a hole in it?

WAVES Uses of Electromagnetic Waves, Including Laser Light

There is an almost limitless range of uses for electromagnetic waves.
The selection below gives a flavour of some of the more common.

Type of radiation	
Radiowaves	Broadcasting (long, medium, and shortwave radio, TV [UHF]) (see pages 97, 99). Emergency services communications
Microwaves	Microwaves are strongly absorbed by water molecules making them vibrate violently. This can be used to heat materials (e.g. food) containing water.  Microwave energy penetrates more deeply than infrared so food cooks more quickly  Microwaves bounce off the metal walls until absorbed by the food Food must be rotated to ensure all parts are cooked evenly Sending signals to and from mobile phones or orbiting satellites (see p97)
Infrared	Fibre-optic cables (see p104) Remote controls Toasters and ovens Infrared cameras for looking at heat loss from buildings, night vision, and searching for trapped people under collapsed buildings
Visible light	Seeing and lighting → Fibre-optic cables (see p104) Laser light → To read CDs, DVDs, and barcodes in shops (see p107) Laser light → Surveying, as laser beams are perfectly straight Laser light → Eye surgery (can be used to 'weld' a detached retina back into place on the back of the eyeball)  Retina
Ultraviolet	Can be produced by passing electrical current through mercury vapour If the tube is coated with a fluorescent chemical this absorbs the ultraviolet radiation and emits visible light  Mercury vapour Electric current Ultraviolet radiation produced Fluorescent strip lights Washing powder contains fluorescent chemicals to make clothes look 'whiter than white' Security markers use fluorescent chemicals, which glow in ultraviolet radiation but are invisible in visible light Used for tanning lamps in sun beds
X-rays	Absorption depends on density of the material so can be used to take shadow picture of bones in bodies or objects in luggage (see p108)
Gamma rays	Used to kill cancerous cells Sterilize hospital equipment and food

Questions

1. Write a list of all the things you use electromagnetic radiation for during a typical day.
2. Food becomes hot when the molecules in it vibrate violently. Suggest one similarity and one difference between how this is achieved in a microwave oven and in a conventional thermal oven.
3. Group the uses listed in (1) under the headings:
   a. 'Electromagnetic waves used to communicate'.
   b. 'Electromagnetic waves used to cause a change in a material'.
   c. 'Electromagnetic waves used to gather information'.

WAVES Dangers of Electromagnetic Waves

When electromagnetic radiation is absorbed by the body, it deposits its energy. The more energy deposited, the greater the potential for damage. This depends on the type of radiation, its intensity, and time for which the body is exposed to it.
To reduce the hazard from electromagnetic waves you can reduce the time of exposure, reduce the intensity (for example by moving away from the source or using a lower power source), or by the use of a physical barrier to absorb the radiation.

Type of radiation	Hazard	How to reduce hazard
Non-ionizing. These are a lower hazard		
Radiowaves	Minimal. These generally pass straight through the body and carry little energy	
Microwaves	Low intensity radiation from mobile phones and their transmitter masts may be a health risk, but the evidence is inconclusive Microwaves used in ovens causes a heating effect in water, which would therefore damage water-containing cells	*Reduce time of exposure:* reduce phone usage *Reduce intensity:* use a hands free kit to reduce exposure *Physical barrier:* microwave ovens have metal case and grille over the door to prevent microwaves escaping
Infrared	Absorbed infrared can lead to cell damage, which we call a burn	*Reduce time of exposure and intensity:* the body has a natural defence mechanism of instinctively moving away from sources of infrared that are uncomfortably hot
Visible light	Only laser light presents a significant hazard	*Reduce exposure:* never look into the beam *Physical barrier:* most laser products, especially if high intensity, have the beam shielded
Ionizing – able to break molecules into smaller parts (ions) which may go on to be involved in further (possibly harmful) chemical reactions. If these molecules are in the cells of the body the ions can cause changes to the DNA of the cell causing it to divide and grow incorrectly. This is called *cancer*		
Ultraviolet	Absorption may cause cell mutations (particularly in skin) which can lead to cancer Sunburn	*Physical barrier:* sun cream and sun block contain chemicals that strongly absorb ultraviolet providing a barrier between the radiation and the skin Wear clothing *Reduce time of exposure:* avoid excessive sunbathing or tanning treatment
X-rays	Some absorbed and some transmitted. Absorbed radiation may cause cell mutations leading to cancer	*Reduce time of exposure:* limit number of X-rays you are exposed to (but sometimes the medical benefits outweigh the potential risks) *Physical barrier:* health workers use lead shielding to reduce their exposure
Gamma rays	High enough energy to directly kill cells (radiation burns), or to cause cancerous cell mutation	*Physical barrier:* gamma rays from nuclear power plants are shielded from the outside by thick layers of lead, steel, and concrete *Reduce time of exposure:* nuclear industry workers have their exposure times carefully monitored and controlled

Questions

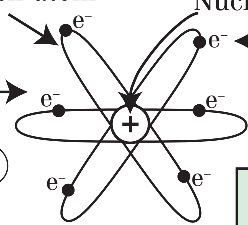
1. Suggest three ways that exposure to harmful electromagnetic waves can be reduced.
2. What is the difference between ionizing and non-ionizing radiation?
3. A parent is worried about the possible health risks of a child using a mobile phone while sunbathing in swimwear on a very sunny day. What advice would you give them?

ELECTRICAL ENERGY Static Electricity

The positively charged nucleus is orbited by negatively charged electrons. These do not escape because opposite charges attract.

All materials are made of atoms

Normally the number of positive and negative charges is equal in each atom



Nucleus – has positive charge

Electrons – have negative charge

Measured in Coulombs, C.

Like charges repel

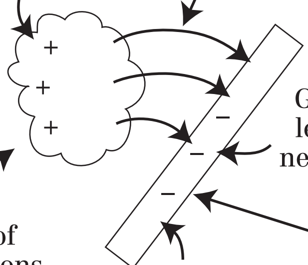
Unlike charges attract

Static electricity is formed when electrical charges are trapped on an insulating material that does not allow them to move. You can charge up a material by . . .

1) Friction

Wool duster

Electrons (negative charge) rubbed off the wool onto the polythene rod.



Gain of electrons leaves an overall negative charge.

Loss of electrons leaves an overall positive charge.

Polythene rod

Clothing and aircraft can be charged by friction.

In all charging processes, it is always electrons that move as they can be removed from or added to atoms.

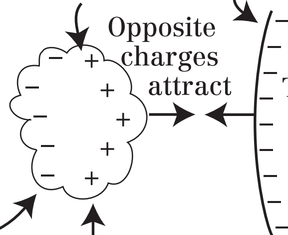
2) Induction

Overall neutral particle, e.g. dust.

Negatively charged surface (e.g. a TV screen).

Electrons repelled away.

Opposite charges attract

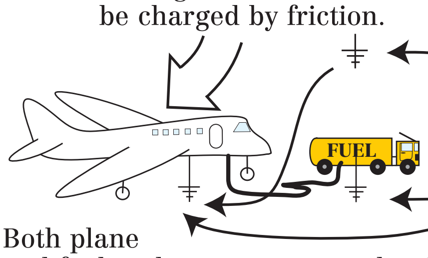


This explains why TV screens tend to get very dusty.

Surplus of positive charges on this surface

E.g. polish

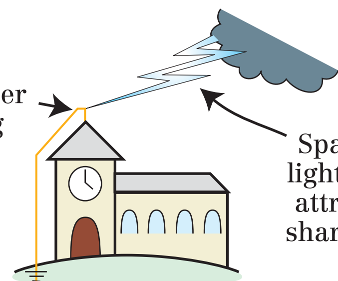
Antistatic sprays contain a conducting chemical to avoid the build up of charge.



Static electricity will flow to Earth if a conducting path is provided, as the charges can get further apart by spreading over the Earth.

Both plane and fuel tanker are connected to Earth before fuelling to prevent any sparks.

Copper lightning conductor



Sparks like lightning are attracted to sharp points.

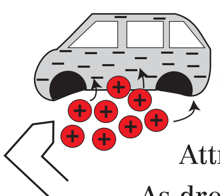
Large metal plate

E.g.

Danger of explosions – flammable vapours or dust ignited by sparks – earthing needed in these environments

Uses and dangers of static electricity

Spraying paint and pesticides

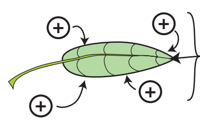


Negatively charged metal object.

Attraction

Spray gun is positively charged.

As drops all have the same charge, they repel giving a fine spray.



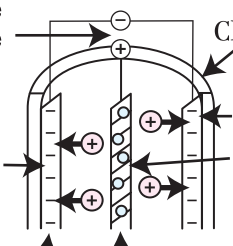
Negative charge induced on leaf by positive drops.

Positively charged droplets are attracted to leaf.

Electrostatic precipitator

Large voltage

Chimney



Negatively charged plate

Positively charged grid.

Smoke attracted and sticks to negative plates.

Smoke particles positively charged by contact with the grid.

When large particles are collected on the plates, they fall down the chimney due to their weight.

Prevents dirty smoke entering the atmosphere.

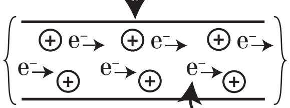
Questions

1. Complete the following sentences. Like charges ________, unlike (opposite) charges ________.
2. What is the unit of electrical charge?
3. What is the difference between an insulator and a conductor?
4. Why would it not be possible to charge a copper rod by rubbing it, no matter how furiously you rubbed?
5. Explain in as much detail as possible how a balloon rubbed on a woolly jumper sticks to a wall.
6. Make a list of all the examples of static electricity in action mentioned in this page. Divide your list into cases where static electricity is useful, where it is a nuisance, and where it is dangerous. Try to add your own examples to the list.

An electric current is a flow of charged particles.

Solids

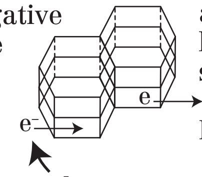
Fixed lattice of metal ions.



Metals

Electrons move from metal ion to metal ion, towards the positive end of the metal.

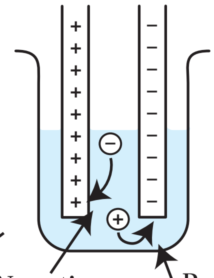
Graphite



Layers of carbon atoms arranged in hexagonal sheets.

Electrons move through the layers.

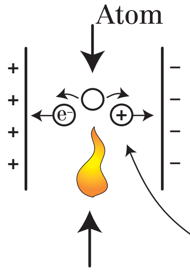
Liquids



Molten or dissolved *ionic* solids.

What do all these have in common?

Gases



Atom loses electrons due to heating (or by collision with other fast moving atoms). This is called ionization.

Current flows between plates.

Three conditions for an electric current to flow:
1. There must be charge carriers (electrons or ions).
2. They must be free to move.
3. There must be a potential difference to repel them from one side and attract them to the other.

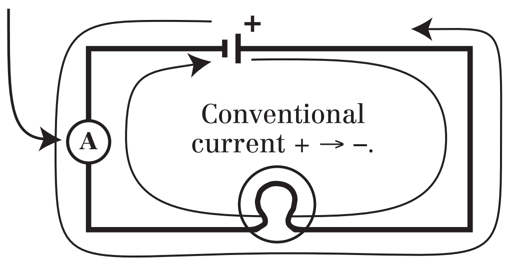
Current (in Amps) is the rate of flow of charge; the number of Coulombs of charge flowing past a point per second.

$$\text{Current (A)} = \frac{\text{Charge (C)}}{\text{time (seconds, s)}}$$

1 Amp = 1 coulomb per second

In equations we usually use I for current and Q for charge. Hence $I = {}^{Q}/_{t}$.

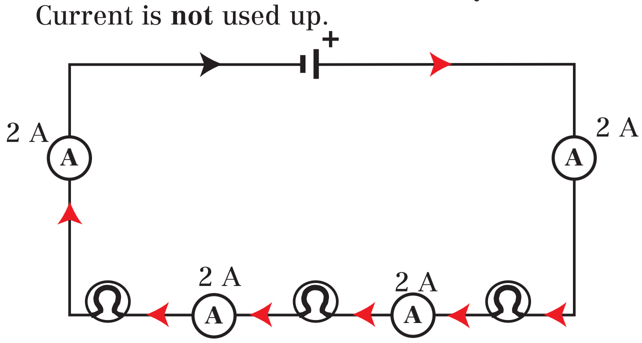
Electric current is always measured with an ammeter, always placed in series.



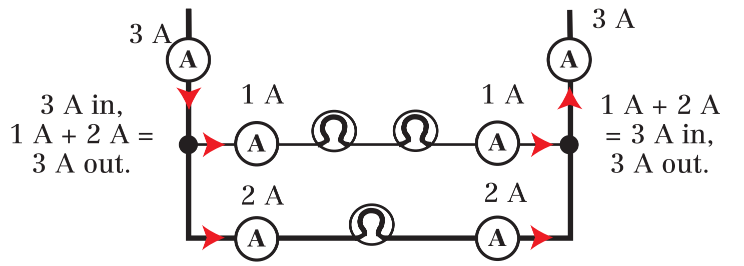
Electron current – → +.

Current rules

1. The current is the same all the way round a series circuit. Current is **not** used up.



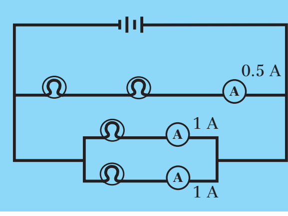
2. The current flowing into a junction = current flowing out.



These rules mean that charge is conserved. It does not 'pile up' anywhere in the circuit.

Questions

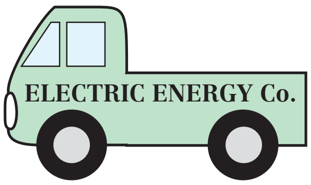
1. Why must ionic solids be molten or dissolved to conduct an electric current?
2. In a circuit 4 C of charge passes through a bulb in 2.5 s. Show that the current is 1.6 A.
3. An ammeter in a circuit shows a current of 1.2 A.
   a. The current flows for 2 minutes. Show the total charge passing through the ammeter is 144 C.
   b. How long would it take 96 C to pass through the ammeter?
4. In the following circuit, how many Amps flow through the battery?
5. The laws of circuit theory were all worked out in the 1800s. The electron was discovered in 1897. Discuss why we have conventional direct current flowing from positive to negative, when we know that the electrons actually flow from negative to positive.



ELECTRICAL ENERGY Potential Difference and Electrical Energy

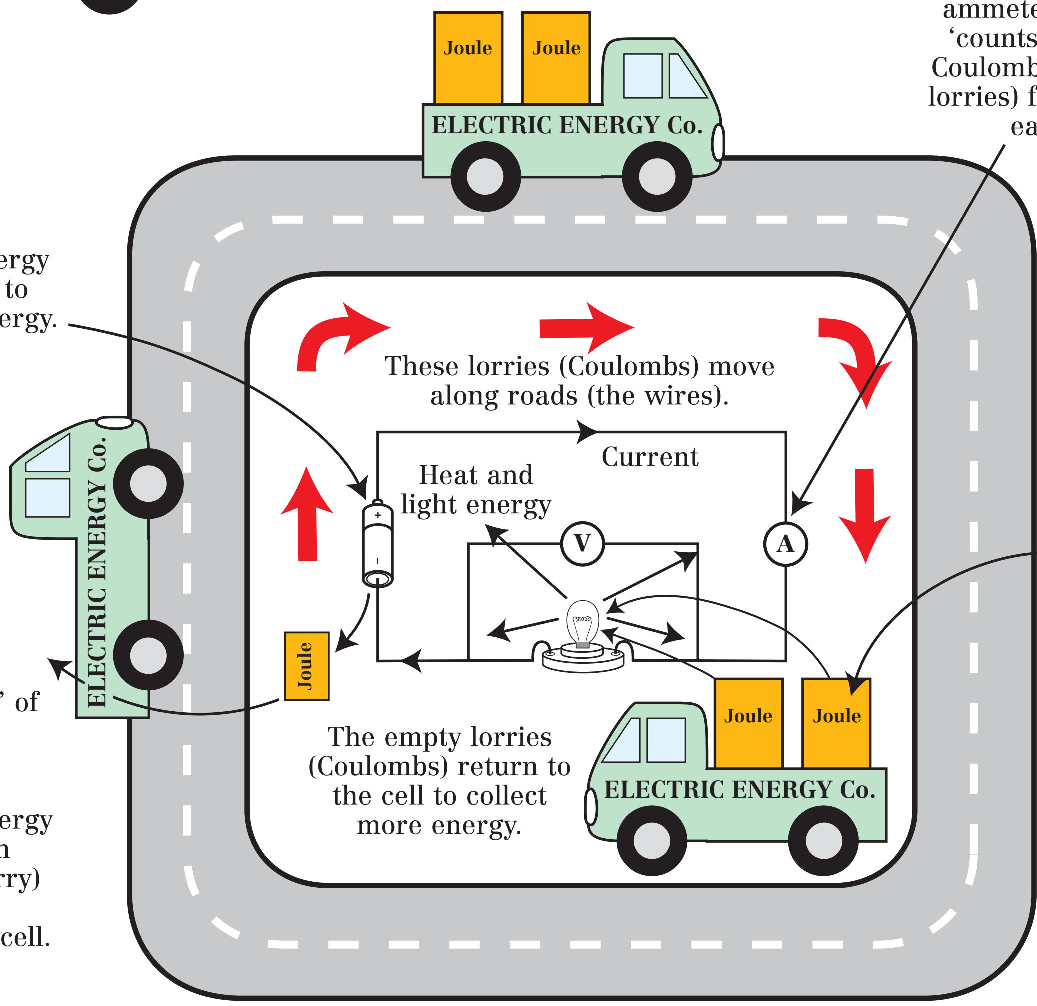
What actually happens in an electric circuit?

We can use a model to help us understand what is happening.



An electric current is a flow of charges, measured in Coulombs. We can imagine each Coulomb to be represented by a lorry.

We measure the current flowing in a circuit in Amps using a device called an ammeter. The ammeter 'counts' the number of Coulombs (the number of lorries) flowing through it each second.



In the cell, chemical energy is converted to electrical energy.

The 'voltage' of a cell is the number of Joules of electrical energy given to each Coulomb (lorry) that passes through the cell.

When the lorries get to a bulb, they unload their energy, which then comes out of the bulb as heat and light energy.

The current is the same going into the bulb as coming out of it, so electric charge (the lorries) are not 'used up' in a circuit.

We can measure the energy difference between the loaded lorries going into the bulb and the empty ones leaving it using a voltmeter. The voltmeter is connected *across* the bulb to measure how much energy has been transferred to the bulb by comparing the energy (Joules) carried by the lorries (Coulombs) before and after the bulb. *Each Volt represents one Joule transferred by one Coulomb*. The proper name of this is potential difference (because the current has more potential to do work before the bulb than after it) but is often called the voltage.

Questions Use the lorry model to explain:

1. Why the ammeter readings are the same all the way round a series circuit.
2. Why the total current flowing into a junction is the same as the total current flowing out.
3. Why all the bulbs in a parallel circuit light at full brightness.
4. Why the bulbs get dimmer as you add more in a series circuit.
5. Why the cell goes 'flat' more quickly if you add more bulbs in parallel.
6. Should a 'flat' battery be described as discharged or de-energized? Discuss.
7. This model cannot explain all the features of a circuit. Try to explain:
   a. How the lorries know to save some energy for the next bulb in a series circuit.
   b. Whether it takes time for the first full lorries to reach the bulb and make it light up.
   c. Whether there are full lorries left in the wires when you take the circuit apart.