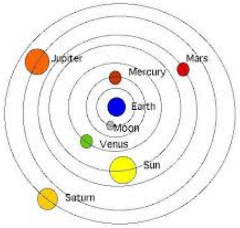
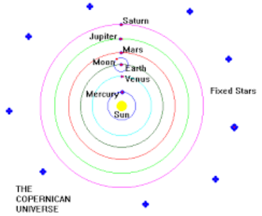
SOLAR SYSTEM



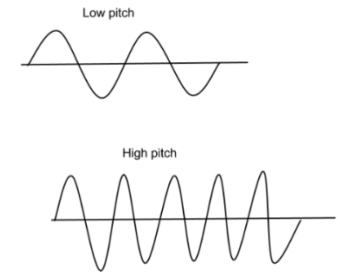
- History
- The early Greek astronomer Ptolemy thought the Earth was in the centre of everything, with the Sun and the planets circling (moving in orbits) around it – the geocentric model.
- Over 1000 years later, the Polish astronomer Nicolaus Copernicus suggested a different model in which the Sun is at the centre of the Solar System, and the Earth and other planets orbit around it – the heliocentric model (note that the model also shows that the moon orbits round the Earth).



- The telescope was invented at the end of the 16th Century, allowing scientists to see objects in space in much greater detail than with the naked eye.
- Galileo Galilei utilised the telescope to discover four of Jupiter's moons. He plotted the movements of the four moons and found they orbited round Jupiter, and NOT round the Earth. This led him to support Copernicus's heliocentric model of the Solar System (and reject Ptolemy's geocentric model).

- As telescopes improved, more and more discoveries were made, including the planets Uranus and Neptune and the dwarf planet Pluto.
- The heliocentric model's principal idea of planets orbiting round the sun is accepted today, but we now know that the orbits are ellipitical (oval) rather than circular.

INFRASOUND



Sound waves are longitudinal vibrations that must travel through a medium (i.e through a solid, liquid or gas and cannot pass through a vacuum).
Frequency of a sound wave determines its pitch:

High frequency waves →high pitch   low frequency waves →low pitch

Sounds with frequencies below 20Hz are called infrasound (humans can't hear these low frequencies of sound, but we can detect them using microphones)

Infrasound is used by animals to communicate

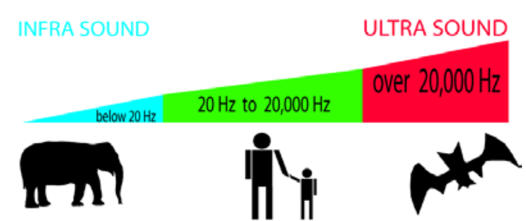
Infrasound waves travel further in air (before they become too faint to detect) than sound waves of higher frequencies. Infrasound is used by whales and other animals to communicate over long distances. Using microphones, biologists can pick up infrasounds to study the movement of animals in remote locations.

Using infrasound for the detection of volcanic eruptions

Natural events such as volcanic eruptions produce infrasound waves which can be detected by sensors a long way from the volcano, allowing scientists to predict when eruptions are going to happen.

Using infrasound for the detection of meteors

Meteors are rocks that fall into the atmosphere from space. Most meteors burn up in the atmosphere and some explode, however some survive and hit the ground – potentially very dangerous (meteors that hit the ground are called meteorites). Scientists use infrasounds to detect the passage of meteors through the atmosphere and also detect any that explode.



Questions on the Solar System

- Explain Ptolemy’s theory of the Solar System.
- How did Copernicus’ theory differ from Ptolemy’s?
- What do the words heliocentric and geocentric mean?
- What was invented at the end of the 16^{th} century?
- What did Galileo see through the telescope and which theory did he end up supporting –Ptolemy’s or Copernicus’s?
- What is an elliptical orbit?

Questions on Infrasound

- Can sound waves travel through a vacuum? Why?
- What frequency are infrasound waves?
- What is the normal hearing range of a human?
- Can humans hear infrasound?
- Describe two uses of infrasound.

WAVES

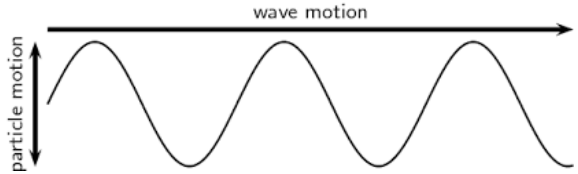
Luminous objects in space give out visible light that travels as waves of energy. Many objects in space don't give out much visible light but give out other types of energy-carrying waves, like radio waves and microwaves.

Transverse waves – e.g electromagnetic waves, sea waves

Waves in which particles vibrate at right angles to the direction that the wave is going are called transverse waves.

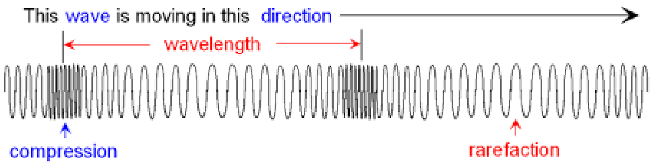
Transverse waves do not need a medium in which to travel (so can travel through space) – e.g. electromagnetic waves (visible light, radio waves, microwaves).

Sea waves are also examples of transverse waves. When waves hit a cliff/shore, energy is transferred and wears the cliff away. This happens without transferring matter (i.e water particles move up and down as the wave passes abd they aren't carried to the shore). Note: this is true for longitudinal waves as well



Longitudinal waves - e.g sound waves

Sound waves are not transverse – they are longitudinal. In a sound wave, the particles vibrate back and forth in parallel with the direction that the wave is going, forming areas where air particles are spread out and areas where they are pushed together. Longitudinal waves need a medium in which to travel, which is why sound cannot travel through a vacuum (i.e can't travel in space).

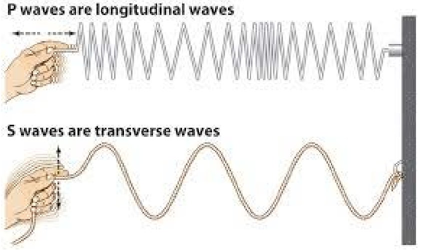


Seismic waves

Earthquakes and explosions produce seismic waves that travel through the earth.

Seismic waves can be either longitudinal or transverse.

- Longitudinal - rock material is pushed and pulled
- Transverse - rock material is moved up and down or side to side



ULTRASOUND

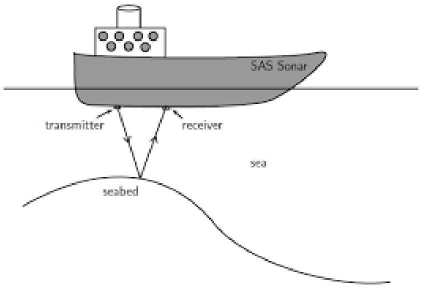
Sounds with frequencies above 20,000Hz are called ultrasounds. Some animals, e.g. dolphins, use ultrasound to communicate with each other.

Sonar

Bats emit ultrasound waves that are reflected by things around them and listen for the echoes in order to locate obstacles and objects in their environment.

Using a similar method, humans use sonar on ships to find out the depth of the sea. A loudspeaker on the ship emits a pulse of ultrasound which spreads through the water, and some is reflected off the sea bed. A microphone on the ship detects the echo and the sonar equipment measures the time between the sound being sent out and the echo returning.

The distance travelled by the sound wave can then be calculated using the equation: distance (m) = speed (m/s) x time (s)



Ultrasound scans

Ultrasound can also be used to make images of unborn babies so that doctors can monitor the development of the foetus. A probe is used to emit and receive ultrasound waves and a gel is used to stop the ultrasound just reflecting off the skin. When ultrasound waves pass from one medium to another (e.g fat or bone), some sound is reflected. The time between the pulse being sent out and the echo returning is detected by an ultrasound machine. The display shows where the echoes come from and create an image.

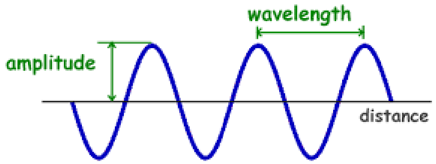
Questions on Waves

- What is a transverse wave?
- Give an example of a transverse wave.
- Can a transverse wave travel through space? Why?
- What type of wave is a sound wave? What does this mean?
- Describe what will happen to rock if longitudinal and transverse waves occur during an earthquake.

Questions on Ultrasound

- What frequency of wave is an ultrasound?
- How do bats use ultrasound waves?
- How is this similar to how humans on ships use ultrasound?
- Explain how you would calculate how deep the water was beneath a ship using sound waves.
- Describe one other use of ultrasound and explain how an image forms.

Properties of Waves



Frequency - is the number of waves passing a point each second and is measured in Hertz (Hz). 1 Hz means 1 wave passing per second.

Wavelength - distance from a point on one wave to the same point on the next wave (measured in metres).

Amplitude -maximum distance of a point on the wave from its rest position (measured in metres). The top of the wave is called the crest, the bottom the trough.

Wave speed

The wave speed refers to how fast the energy in a wave travels.

1. Wave speed (metre/second, m/s) = $\frac{\text{distance (metre, m)}}{\text{time (second, s)}}$

   e.g. a wave carries a surfer 52 metres in 8 seconds

   wave speed =52/8 = 6.5 m/s

<u>2.</u> Wave speed is also linked to the wave frequency and wavelength.

Wave speed (m/s) = frequency (Hz) x wavelength (m)

e.g. if waves of 13m wavelength have a frequency of 0.5 Hz

Wave speed = 0.5 x 13 = 6.5 m/s

SEISMIC WAVES

Movements inside the Earth, such as earthquakes, cause waves to be transmitted through the Earth – these are called seismic waves which reach the surface of the Earth causing the ground to shake.

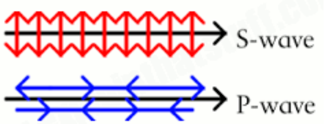
Seismometers are instruments that can detect seismic waves, helping scientists to model the structure of the Earth's interior.

The Earth's interior

Focus: place inside the Earth where rock suddenly moves

Epicentre: point on the surface of the Earth directly above the focus

3 layers of the Earth: the outermost surface of the Earth is called the crust/The middle layer is the mantle/The innermost layer is the core (liquid on the outside, solid on the inside).



P and S waves

An earthquake causes two types of seismic waves within the Earth.

P waves – longitudinal waves: Push and pull on the rock as the wave passes and travel faster than S waves

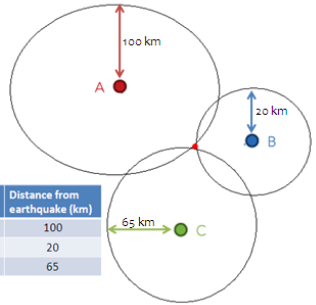
S waves – transverse waves: Move the rock particles from side to side as the wave travels down and travel slower than P waves.

The properties of rocks gradually change with depth (due to increasing heat as you get closer to the Earth's core). As seismic waves travel deeper towards the Earth's core, their speed increases and they gradually refract upwards and travel on a curved path. At the boundaries between the different layers, there is a sudden change in rock properties and seismic waves are refracted sharply. Some of the waves may get reflected (back to the surface).

DETECTING EARTHQUAKES

Scientists use a network of seismometers to detect earthquakes. In a seismometer trace, the P waves arrive first because they travel faster than S waves. The time difference between the arrival of the P and S waves is used to work out how far away from a seismometer an earthquake has occurred (the closer together the P and S waves, the closer the earthquake is to the seismometer). To work out the precise location of the earthquake's epicentre (point where the earthquake originated), data from 3 or more seismometers is required. The epicentre of the earthquake is where the three circles meet up.

Seismometer	Distance from earthquake (km)
A	100
B	20
C	65



Questions on Properties of Waves

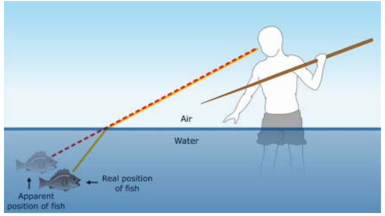
- Draw a wave and label the amplitude and wavelength on it.
- Define wavelength and amplitude.
- Draw a wave with twice the amplitude of the first one and then draw a wave with half the wavelength.
- Define frequency of a wave. What unit is frequency measured in?
- Calculate the speed of a wave if its frequency is 50Hz and its wavelength is 10m. Which equation did you use?

Questions on Seismic Waves

- What is a seismic wave?
- Explain what the focus and epicentre of an earthquake mean.
- Describe the difference between S and P waves and the effect they have on rocks.
- Why do seismic waves get refracted as they travel through the Earth’s core?
- How do scientists use seismometers to find the epicentre of an earthquake?

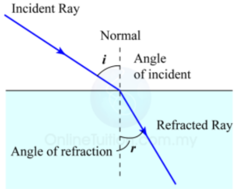
REFRACTION

Light travels in straight lines, however it can change direction when it moves into a different material (e.g from air into water). This is called refraction and happens at the boundary ('interface') between two materials ('mediums').The 'normal' line is at a right angle to the interface



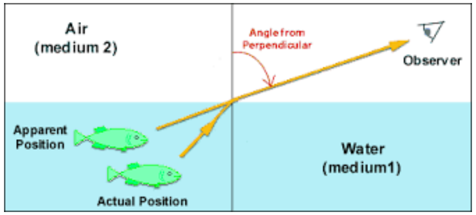
Why does refraction occur?

Refraction occurs because light travels at different speeds in different mediums – fastest through air, slower through glass and water. When moving from air to water/glass (or from deep water to shallow water), light slows down and refracts towards the normal. The wavelength of the wave also decreases.



Note: the amplitude and frequency of the light wave does not change.

When moving from water/glass to air (or from shallow water to deep water), light speeds up and refracts away from the normal. The wavelength of the wave also increases.

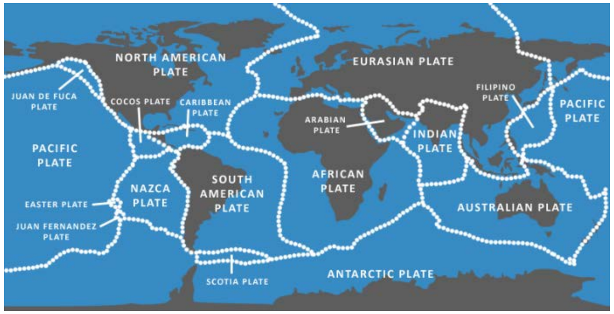


Note: the amplitude and frequency of the light wave does not change.

Predicting Earthquakes

The outermost layer of the Earth - the crust – is made up of tectonic plates which are pushed by slow moving convection currents (‘heat cycles’) in the mantle. This cause the plates to move relative to each other. Friction forces between the edges of the plates stops them moving and as the forces on the plates build they are suddenly big enough to overcome the friction. Once friction is overcome, the plates move with a sudden jerk, causing an earthquake.

Most earthquakes occur at boundaries between plates so scientists can study these areas to predict where earthquakes are likely to happen. However, it’s not possible to measure the forces acting on the plates so it’s difficult to predict when a sudden movement will happen.



Predicting tsunamis

If the earthquake happens under the sea, the movement of the sea floor may cause a huge wave called a tsunami. Scientists can’t tell whether or not a tsunami will happen from seismometer traces however, pressure sensors detecting tsunami waves can give people at risk several hours’ warning.

Questions on Refraction

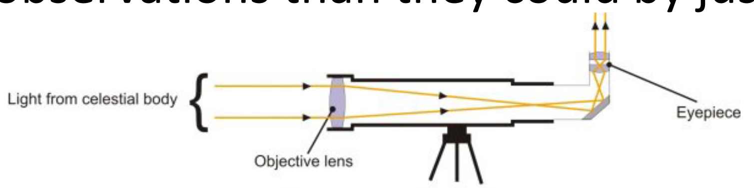
- Define refraction.
- Why does refraction occur?
- What is meant by ‘medium’?
- What is the normal?
- When light goes from a less dense to more dense medium what happens?
- When light goes from water to air what happens?
- What happens to the frequency and amplitude of the wave in the above?

Questions on Predicting Earthquakes

- What is the Earth's crust made from?
- What makes them move relative to one another?
- What can happen at the boundary between two plates?
- How does a tsunami occur?

Telescopes and Lenses

Different types of telescopes are used today to detect these 3 different types of waves (visible light, radio waves, microwaves).The data collected helps scientists make conclusions about our Universe. Also, the invention of photography has allowed astronomers to make more detailed observations than they could by just making drawings



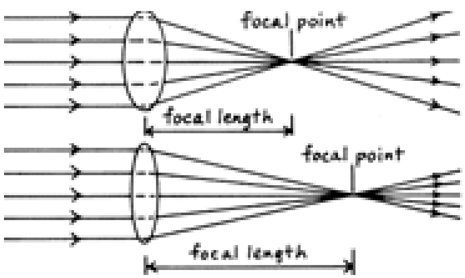
Convex Lenses

A lens is a transparent block capable of changing the directions of parallel light waves. Convex lenses are curved on both sides and are thicker/fatter in the middle. Convex lenses Converge light rays (i.e brings them together) and focusses them onto a 'focal point'.

The distance between the focal point and the lens is called the focal length of the lens .

The thicker the lens, the greater the converging power of the lens and the shorter the focal length.

The focal length of a convex lens can be found by focusing the image of a distant object onto a piece of paper and measuring the distance from the paper to the lens.



Renewable Energy

Renewable energy resources are resources that will not run out and most don't cause pollution or produce greenhouse gases. Using renewable sources of energy also reduces reliance on fossil fuels so we can conserve stocks of fossil fuels .

Solar energy

Solar cells can convert solar energy directly into electrical energy. Solar energy is dependent on sunlight and isn't available all the time.

Hydroelectricity

Hydroelectricity is generated by falling water. Water is trapped in high reservoirs and as long as the reservoir doesn't dry up, hydroelectricity is available all the time.

Wind turbines

With the right wind speed (not too high or too low), wind turbines can generate electricity however if it's not windy then no energy is produced. Many turbines are needed to produce the same amount of energy as fossil-fuelled power stations and some people think they spoil the landscape.

Geothermal energy

In some places, rocks are hot enough to turn underground water into steam so the steam can turn turbines in power stations to generate electricity. Some gases in the steam can cause pollution.

Tidal power

Turbines can generate electricity from tidal currents and although not available all the time, tidal power is available at predictable times. Unfortunately, not many places are suitable for installing turbines, and they may affect birds and other wildlife that live or feed on tidal mudflats.

Wave power

Wave power can generate electricity when floating electrical generators move up and down. In coastal power stations, ocean waves can force air up pipes in the power station, and the moving air turns turbines to generate electricity

Questions on Telescopes and Lenses

- Which three types of waves can be detected by telescopes today?
- What is a lens? What does a convex lens do to light rays?
- Define focal length.
- What effect does a thinner lens have on the converging rays?
- Describe a simple way to find the focal length of a lens.

Questions on Renewable Energy

- Define renewable energy.
- State a disadvantage of solar energy.
- How is hydroelectricity generated?
- Give an advantage and disadvantage of wind turbines.
- What is geothermal energy?
- Explain the difference between tidal power and wave power.

Refracting Telescopes

In a refracting telescope the light rays pass through a convex lens known as the objective lens, focusing the image (at the 'focal point') inside the tube. The image formed inside the microscope is smaller (than the original object) and is upside down.

Another lens known as the eyepiece lens is used to magnify this image.

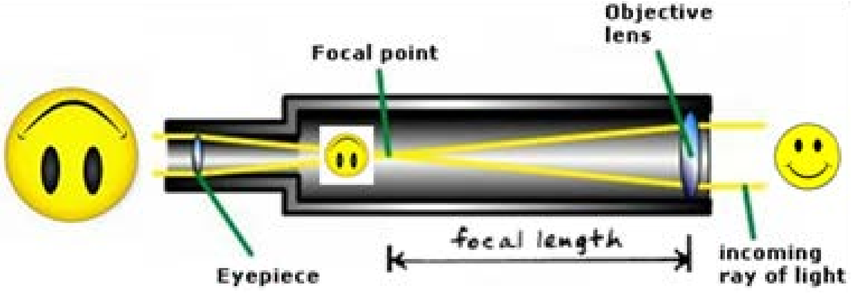
Note the image is still upside down – not a problem when viewing space.

PROBLEMS OF REFRACTING TELESCOPES

1. When light waves reach a boundary between two different materials, not all the light refracts and passes through the material. Whenever light passes through a lens, some is reflected making the image fainter.

2. Refracting telescopes need to be very long to have large magnifications to make the object many times bigger. Large lenses can be used to improve the magnification but they're heavy and are difficult to make into perfect shape so images have distorted colours

These problems of refracting telescopes are overcome by reflecting telescopes.



Non-Renewable Energy

Most of our electricity is generated using non-renewable resources (e.g. fossil fuels such as oil, coal, natural gas) which will eventually run out.

Fossil fuelled power stations produce waste gases:

Carbon dioxide - contributes to climate change

Sulphur dioxide and nitrogen oxides - can cause acid rain

Nuclear power

Nuclear power stations use radioactive metals such as uranium or plutonium as their energy source. These metals will also run out one day so nuclear power is also non-renewable.

Nuclear power stations don’t emit any carbon dioxide or other gases however, the waste they produce is radioactive and it must be sealed into concrete or glass and buried safely so that the radioactivity cannot damage the environment.

A nuclear power station also needs to be dismantled carefully when closing down so that no radioactive materials escape into the environment. These safety considerations make nuclear power stations more expensive to build and dismantle than fossil-fuelled power stations.

There aren’t many accidents as the stations are designed to contain any radioactive leaks however, when major accidents occur, they have very serious consequences (e.g. Chernobyl, 1986).

Advantages of fossil fuels and nuclear power (compared to renewable resources)

At the moment there is still good supply of both fossil fuels and nuclear fuel and they produce electricity more cheaply.

They don’t depend on the weather or the tides and electricity is available all the time.

Questions on Refracting Telescopes

- Describe the difference between the objective and eyepiece lens in a refracting telescope.
- The image is still upside down. Is this a problem?
- Why is the image always fainter when the light has passed through a lens?
- What is the problem with very large lenses?
- What type of telescope will eliminate these problems?

Questions on Non- Renewable Energy

- Define non-renewable.
- What is a fossil fuel and give 3 examples?
- Fossil fuelled power stations emit gases. Name them and the problems that they can cause.
- Can nuclear power run out?
- Give one advantage and one disadvantage of a nuclear power station.
- Are there any advantages to using non-renewable energy resources?

REFLECTING TELESCOPES

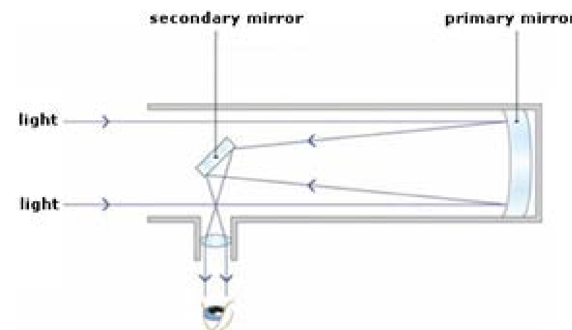
How they work

Reflecting telescopes use <u>two mirrors</u> to focus the light rays.

When parallel light rays hit the curved primary mirror they reflect back into the tube (no refraction) where they hit a flat secondary mirror.

The image is subsequently focused inside the tube.

The eyepiece lens then magnifies the image.



Comparison with refracting telescopes

The concept of focusing the image inside tube and then magnifying it using the eyepiece lens is the same as in the refracting telescope.

However, the use of two mirrors instead of an objective lens means the image is <u>less faint</u> (because rays are reflected back into the telescope, they're not lost) and allows the telescope to be <u>smaller</u>.

Reflecting telescopes are mostly used nowadays because of the need to view very faint, distant stars

GENERATING ELECTRICITY

Electrical current is a flow of charged particles. Current is the rate of flow of charge in a circuit and is measured in Amps(A).

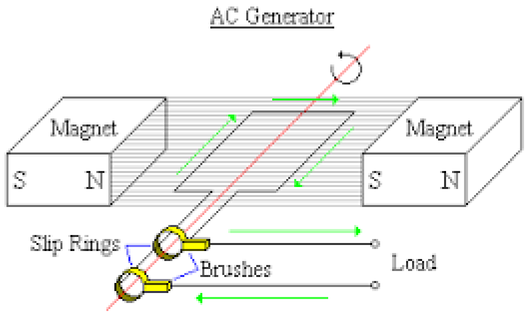
Voltage is a measure of the amount of energy transferred by the electrons to an electric component.

Induced current

If you move a piece of wire in a magnetic field, an electric current will flow in the wire and this process is called electromagnetic induction and the current produced is called an induced current.

The size of the induced current can be increased by:

- Putting more turns on the coil of wire
- Using an iron core inside the coil of wire
- Using stronger magnets
- Moving the wire faster



The direction of the current can be changed by:

Changing the direction of movement of the wire

Changing the direction of the magnetic field (i.e by swapping the poles of the magnet)

To create a continuous induced current, you must keep the magnet moving relative to the coil of wire.

Questions on Reflecting Telescopes

- What does a reflecting telescope use instead of an objective lens?
- What happens to the reflected rays after they have hit the second mirror?
- What is the advantage of using mirrors over lenses?
- Are reflecting telescopes longer or shorter than refracting telescopes?

Questions on Generating Electricity

- Define current.
- Define voltage.
- If a wire is moved in a magnetic field what is created inside the wire?
- State 4 ways you can increase the induced current.
- How could you change the direction of current flow?

Electromagnetic waves

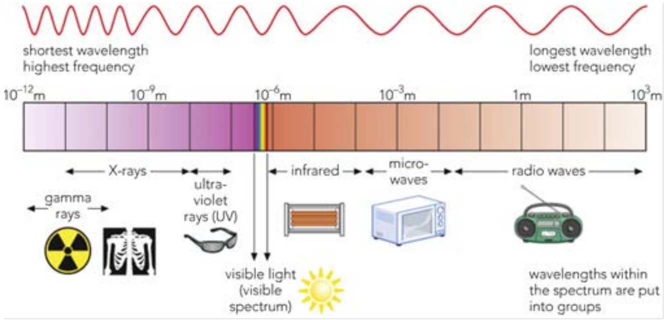
Visible light, IR and UV are all types of electromagnetic radiation. The electromagnetic vibrations are at right angles to the direction in which the energy is being transferred by the wave as they are transverse waves.

THE ELECTROMAGNETIC SPECTRUM

Electromagnetic waves can travel without any particles to vibrate so can travel through a vacuum, such as space. All electromagnetic waves travel at 300,000,000 m/s (3×10^8 m/s)in a vacuum which is the fastest speed anything can move.

Since v=fʌ and V, the speed of waves is always the same, if frequency goes up the wavelength, ʌ, must decrease. The full range of electromagnetic waves is called the electromagnetic spectrum. Although continuous, the spectrum is conveniently divided into 7 major according to the wavelength and frequency of the waves.

Gamma rays (shortest wavelength, highest frequency)→x-rays→UV→ visible light (violet, indigo, blue, green, yellow, orange, red)→IR→ microwaves→radio waves (longest wavelength, lowest frequency). So, compared to visible light UV has a shorter wavelength and higher frequency waves. IR has a longer wavelength and lower frequency waves. Visible light waves are the only ones visible to the human eye.



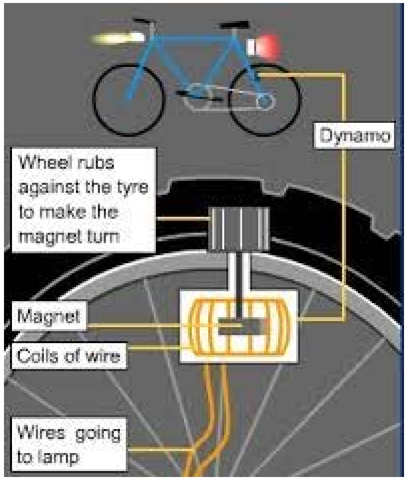
Modern astronomy tries to observe stars and galaxies by detecting various parts of the electromagnetic spectrum they give off - the Hubble Space telescope can detect visible light, UV and IR.

Direct Current, Alternating Current and Generators

Direct current – current always flows in the same direction.
Alternating current – current changes direction many times per second.

Dynamos and Generators

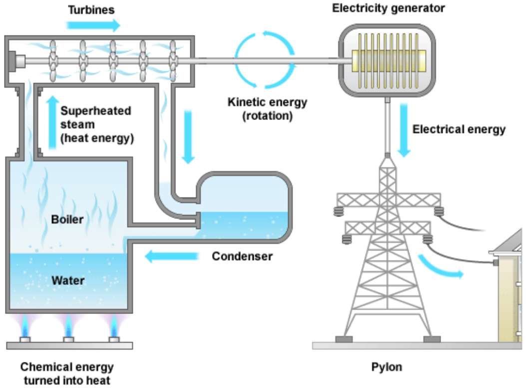
Simple dynamos (used in bicycle lights and wind-up torches and radios) produce direct current.



Generators are used to produce electricity on a larger-scale:

- Electricity induced in the coil of wire is transferred to a circuit through slip rings and connected carbon brushes
- The slip rings and carbon brushes allow electricity to flow without the wires becoming twisted
- Each side of the coil goes up through the magnetic field and then down again and the direction of the induced current changes.
- Generators produce alternating current.

Generators in power stations need to induce a very high voltage so use electromagnets. Electromagnets are able to create much more powerful magnetic fields than permanent magnets.



Questions on Electromagnetic Waves

- Electromagnetic waves are transverse waves – explain what this means.
- What speed do all electromagnetic waves travel at?
- Write down the equation that links speed to frequency and wavelength.
- If the wavelength increases what must happen to the frequency – why?
- Calculate the frequency of a wave in the electromagnetic spectrum that has a wavelength of 500m.

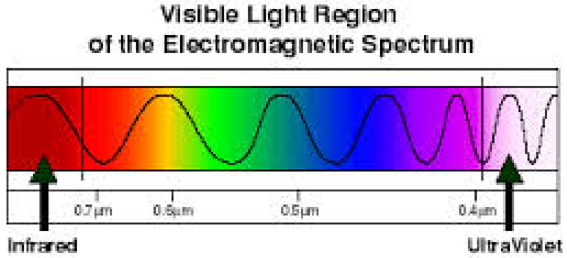
Questions on Direct Current, Alternating Current and Generators

- What is the difference between an alternating current and a direct current?
- Where might you find a simple dynamo generating a direct current?
- Why is a slip-ring needed?
- Why do generators in power stations using electromagnets rather than permanent magnets?

Infra Red and Ultra Violet

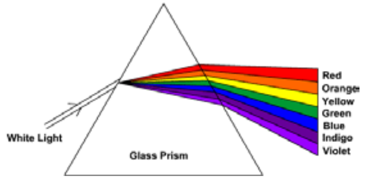
Spectrum of visible light in order

Red →orange→yellow→green →blue→indigo→violet (shortest wavelength, highest frequency). Use 'Richard Of York Gave Battle In Vain' to remember the order.



The discovery of infrared

The astronomer William Herschel put coloured filters on his telescope to observe the Sun safely and he noticed that different coloured filters heated up his telescope to different extents hence he wondered whether different colours of light contained different amounts of heat. To test this, Herschel used a prism to split sunlight into a spectrum and then put a thermometer in each of the colours. He found that as he changed the colour from violet→indigo→blue→ green→yellow→orange→red, the temperature increased. Herschel then measured the temperature just beyond the red end of the spectrum, where there was no visible light, and found this gave the highest temperature. This band of invisible light beyond the red spectrum is called infrared radiation (IR).



Going beyond violet

Johann Ritter found out about Herschel's work and set about trying to find 'invisible rays' at the other end of the spectrum (i.e violet end). He used silver chloride, a chemical that breaks down to give a black colour when exposed to light and it was already known that silver chloride turned black more quickly in violet light than in red light.

Ritter showed that silver chloride turned black even faster when exposed to 'invisible rays' just beyond violet and these 'invisible rays' were later called ultraviolet waves (ultraviolet radiation, UV).

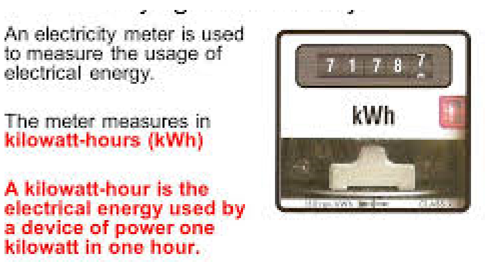
PAYING FOR ELECTRICITY

- Energy is measured in Joules (J)
- Power is the amount of energy that is used by a working appliance each second.
- Unit of measurement for power is joule/second (J/s) or Watt (W)

2 equations

$$\text{Power} = \frac{\text{Energy}}{\text{time}} \quad P=\frac{E}{t}$$

(watt, W) = (joule, J) / (second,s)



Power = current x voltage P=IxV

(watt,W) = (Amps, A) x Volts (v)

Many electrical appliances need a lot of power and usually their 'power rating' (showed on the appliance) is given in kilowatts (kW)

1 kW = 1000W

- Electricity companies charge for electrical energy by the kilowatt-hour (kWh).

  1 KwH is the amount of energy that's transferred by a 1 kW device in 1 hour.

- The cost of electricity is worked out using the formula:

  Cost (pence, p) = power (kilowatt, kW) x time (hour, h) x cost of 1 kWh (p/kWh)

  e.g an electric heater has a power rating of 2kW. What is the cost of using the fire for 3 hours if 1 kWh of electricity costs 12 p?

  Cost = 2 x 3 x 12 = 72 p

Questions on Infra Red and Ultra Violet

- List the colours of light in the visible spectrum starting with Red – the longest wavelength.
- Which of these has the highest frequency?
- Why does the wave with the longest wavelength have the shortest frequency?
- How did Herschel discover Infra red light?
- How did Ritter discover Ultra Violet?

Questions on Paying for Electricity

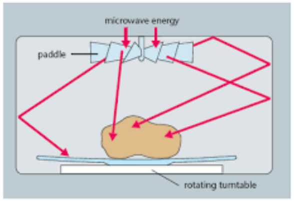
- Complete this table

Device	Power (in kW)	Time of use (in hours)	Energy transferred (in kW h)
Computer	0.4	3.0	1.2
Heater	2.0	2.0	
Kettle	3.0	0.2	
Lamp	0.1	5.0	
Microwave oven	1.0	2×0.2	
Television	0.2	2.0	

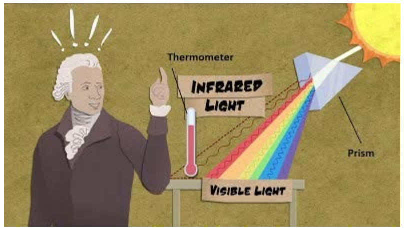
- Calculate the cost of each appliance running for the time stated if a unit of electricity costs 12p.
- Calculate the power of a kettle that transfers 240,000 Joules in 120 seconds.

DANGERS OF ELECTROMAGNETIC WAVES

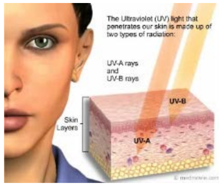
Microwaves: The microwave frequency that can heat water is used in microwave ovens. Humans are mostly water so microwaves can cause internal heating of body cells which is potentially dangerous. This is why microwave ovens have shields in them to stop the waves escaping. Mobile phones signal using microwaves, but use different frequencies so do not pose a health risk.



IR radiation: Our skin absorbs IR, which we feel as heat (remember from Herschel's experiment that IR had higher temperature than visible spectrum). Too much IR can damage or destroy cells and cause burns to skin. All waves transfer energy however, higher frequency waves transfer more energy (have greater <u>penetration)</u> so are potentially more dangerous.



UV radiation: Sunlight contains UV, which carries more energy than visible radiation and the energy transferred by UV to our cells can damage their DNA. Too much exposure to sunlight (UV) can cause skin cancer. UV in sunlight can also damage eyes leading to cataracts which cloud the lens, reducing vision. To protect yourself from UV radiation, you should put sun cream on and wear sunglasses.



X-rays and gamma rays: These waves have higher frequency than UV, carrying even more energy and excessive exposure to x-rays or gamma rays may cause genetic mutations in DNA leading to cancer.

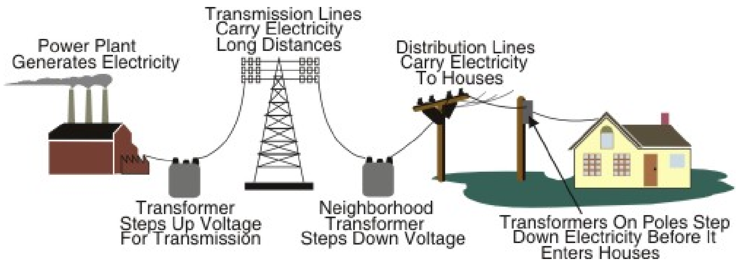
TRANSMITTING ELECTRICITY

Electricity is sent from power stations to homes, schools and factories by a system of wires and cables called the National Grid.

The National Grid

1. Power stations produce alternating currents with voltages around 25,000V
2. Before the electricity is sent around the country, step-up transformers are used to increase the voltage to 400,000V. Why?
   - When electricity passes through wires (along transmission lines), energy is lost as heat
   - Increasing the voltage of the electricity passing along transmission lines reduces the current (current = power / voltage) hence less energy is wasted as heat and efficiency is improved.

3. After passing along transmission lines, step-down transformers in local sub-stations reduce the voltage to about 230V for homes and schools – this is necessary for safety reasons



Transformer calculations

Transformers consist of two coils of insulated wire wound onto an iron core and the voltage produced or the number of turns required by a transformer can be calculated by:

$$\frac{\text{Voltage (primary coil)}}{\text{Voltage (secondary coil)}} = \frac{\text{turns (primary coil)}}{\text{turns (secondary coil)}}$$

e.g radio runs off mains supply (230V) but only needs 23V supply. If the transformer has 100 turns of wire on primary coil, how many turns are needed on the secondary coil?

- 230V – voltage (primary coil) and 23V – voltage (secondary coil) =230/23 =10
- 100 turns (primary coil) / 10 turns (secondary coil) =10
- Both sides equal

Questions on Dangers of Electromagnetic Waves

- What molecule is heated by microwave radiation?
- Why is this dangerous to humans?
- Where does IR radiation come from? What damage could it cause to humans?
- If the skin is exposed to too much UV what may happen? What can you do to protect yourself from UV rays?
- What dangers are associated with X-rays and Gamma rays? Why are these rays so dangerous?

Questions on Transmitting Electricity

- What is the National grid?
- What is the voltage of the electricity produced by the power stations?
- Why is this voltage increased to 400,000 volts before it is sent around the country?
- What needs to happen to this voltage before it comes into our homes?
- How many turns are needed on a secondary coil if there are 40 on the first and the voltage needs to come down by a factor of 5?

USES OF ELECTROMAGNETIC RADIATION

Illumination, vision and photography: Visible light is necessary for illumination, vision and photography e.g .the EURion pattern on banknotes (prevents digital copying) can be seen when illuminated because it reflects certain wavelengths of visible light.

Security UV: Some materials absorb UV radiation and re-emit it as visible light – this is called fluorescence which is used to check banknotes – real banknotes fluoresce when UV light is shone onto them.

Some security lights use fluorescent lamps – these produce UV waves and use a fluorescent material on the inside of the bulb glass.

X-ray: X-ray scanners are used in airports to detect objects hidden on the body as well as in luggage. Both x-rays and gamma rays can penetrate the body, but x-rays transfer less energy than gamma rays so are safer. X-rays are used in hospitals to detect broken bones.

IR radiation: All warm objects give off some heat as IR radiation so CCTV cameras that detect IR are used to watch people at night – this is called thermal imaging. IR radiation can pass through fog so it's useful in daytime too

Communications: Both radio waves and microwaves carry TV signals. Wi-fi wireless connections for computers use radio waves and mobile phone signals use microwaves.

IR radiation carry signals a short distance from remote controls to devices like TVs and are also sent down optical fibre cables for telephone and internet communications.

Food and medicine: Gamma rays transfer a lot of energy which can kill cells (including those of bacteria/ microorganisms) so are used to sterilise food and surgical instruments. They are also used also to kill cancer cells in radiotherapy (gamma rays are <u>aimed</u> at the cancer cells so damage to normal cells is limited). They can also detect cancer: A chemical that emits gamma rays is injected into the blood. The chemical is designed to collect inside cancer cell so a scanner then locates the cancer by finding the source of the gamma rays

UV radiation: UV radiation can kill bacteria so is used to disinfect water and sewage.

Ionising Radiation: Gamma rays are ionising radiation – i.e. they can remove electrons from atoms to form ions which are very reactive so if atoms in the cell are ionised, the reactions that follow can damage DNA (this is how gamma rays can cause cancer). Some elements naturally emit gamma radiation all the time (e.g radium) – such elements are said to be radioactive

Alpha and Beta particles : Not all substances emit gamma (ɣ) waves. Others emit alpha (α) and beta (β) particles. Some e.g plutonium give off all three types. Alpha and beta are particles of matter with a lot of kinetic energy which can ionise atoms so alpha and beta particles are also types of ionising radiation. Gamma rays, alpha and beta particles can damage DNA inside cells however, unlike gamma rays, they are not electromagnetic radiation.

Hazards Associated with Electricity Transmission

If one part of your body is at a higher voltage than another (e.g. if you fly a kite on electric cables), electric current runs through you and you get an electric shock.

Birds sitting on electricity transmission lines don't get a shock because both of their feet are on the wire at the same voltage (so no voltage or potential difference).

REDUCING ENERGY USE

Electricity is mostly generated by the burning of fossil fuels, which releases CO_2 and other harmful gases contributing to climate change and in particular global warming.

Reducing energy use reduces the amount of CO_2 (and other gases) added to the atmosphere and also saves money on electricity bills.

Reducing energy use in the home – e.g double glazing, solar panels.

Cost efficiency of these methods:

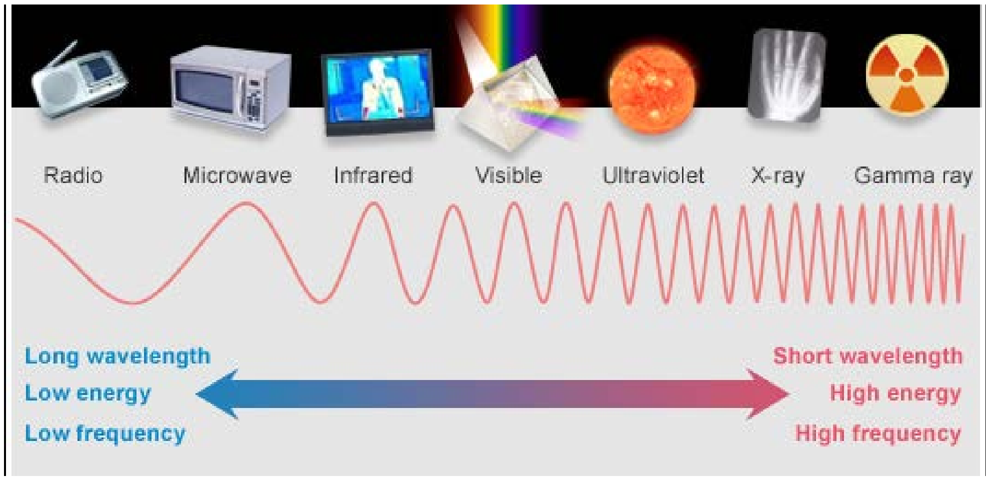
All these methods of reducing energy usage in the home cost money.

The length of time it takes you to save the amount of money it costs to buy the item is called the 'payback time'

$$\text{Payback time} = \frac{\text{cost}}{\text{saving per year}}$$

The shorter the payback time, the more cost-efficient the method (i.e lower cost and greater saving per year).

Questions on Uses of EM Waves



Give a use of each part of the electromagnetic spectrum of waves:
Radio Waves
Microwaves
Infrared
Visible
Ultraviolet
Xrays
Gamma rays

Which wave has the longest wavelength?
Which wave has the highest frequency?
Which wave has the highest energy?

Questions on Hazards of Electricity Transmission

- Why would you get an electric shock if your kite got tangled in an electricity transmission line?
- Why don’t birds get an electric shock when they sit on an electricity transmission line?
- Why should we reduce the amount of electricity we use?
- What is payback time and what is the equation you use?
- If solar panels cost £16,000 to install on your roof and they save you £4,000 every year in fuel bills – what is the payback time?

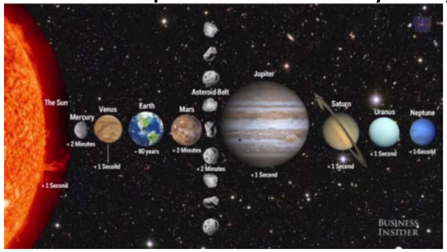
THE UNIVERSE

Early astronomers

Using only the naked eye, early astronomers believed that stars were fixed, all the same distance very far away from the Earth. Using a telescope, Galileo Galilei noted that stars were other suns and that each star was a different distance away from the Earth.

Modern day

As technology improved, telescopes with greater magnifications (i.e. that could zoom further) were invented. Building on Galileo's discoveries, we now know that the Solar System contains 8 planets orbiting round one star (the Sun), in addition to some dwarf planets (e.g. Pluto), many moons and several smaller bodies (e.g asteroids). Millions of stars make up our galaxy - the Milky Way (The Solar System is just a small part of the Milky Way galaxy).



The Milky Way is just one of billions of other galaxies (some of the nebulae seen from Earth are these other galaxies) that together make up the Universe. In other words Galaxies are made up of lots of stars and the Universe is made up of all the galaxies.

EXPLORING THE UNIVERSE

Early telescopes let people see objects that emitted visible light. The invention of photography allowed detailed pictures to be taken of even faint objects (by pointing the telescope at a fixed point for hours).As already mentioned in earlier topics, most objects give out energy in all parts of the electromagnetic spectrum.

Modern telescopes can be designed to detect almost any part of the spectrum, showing us things that can't be detected using visible light

e.g. the Hubble Space Telescope has been in orbit around the Earth since 1990, and can detect UV, visible light and IR.

ENERGY TRANSFERS

There are 9 forms of energy:

- Thermal (heat energy)
- Light
- Electrical
- Kinetic (movement energy)
- Sound
- Chemical potential (e.g. energy stored in batteries, muscles and fuels)
- Nuclear potential (energy stored in nuclei of atoms)
- Elastic potential (energy stored by things that have been stretched or squashed and can spring back)
- Gravitational potential (energy stored in things that can fall)

Energy cannot be created or destroyed it is simply changed from one form to another.

e.g a battery-powered torch has the energy transfers shown below:

chemical energy → electrical energy →light and heat energy

Conservation of Energy

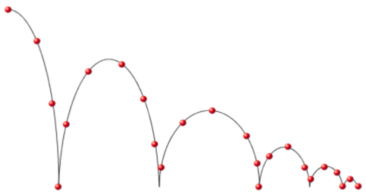
If you add up all the energy that has been transferred by a system (the output energy) and compare it with the energy put into the system (the input energy), the amounts are the same

output energy = input energy

This means energy can't be created or destroyed (it's 'conserved') and can only be transformed from one form to another: this is the law of conservation of energy.

Although energy is conserved, it's not always transferred into forms that can be used.

e.g. after a bouncy ball has bounced it gains thermal energy and loses kinetic energy which means on the second bounce the ball doesn't reach the height it was initially dropped from.



Questions on The Universe

- What did early astronomers believe about the position of the stars?
- How many planets do we now know orbit the Sun?
- The sun is our star – what do lots of stars make?
- What is the universe made from - lots of…?
- Which three types of radiation can the Hubble telescope detect?

Questions on Energy Transfers

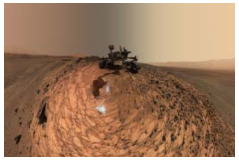
- What is the correct name for heat energy?
- Which type of energy implies movement?
- What is the name for stored energy?
- How many different types of stored energy are there?
- State the law of conservation of energy.
- Draw the energy transfer diagram for a) a washing machine b) a light bulb c) a wind up toy car

Telescopes in space

It is important for telescopes to be located outside the Earth's atmosphere because outside the atmosphere, light waves from space are not reflected or refracted by clouds and dust or even by movements of air in the atmosphere and give clearer and brighter images. Some wavelengths of electromagnetic radiation (particularly UV, IR and x-rays) are absorbed by the atmosphere so telescopes detecting these types of radiation have to be located outside the Earth's atmosphere.

ALIEN LIFE? – LOOKING FOR LIFE BEYOND EARTH

The Earth is hospitable to life mainly because of the presence of water, oxygen in the atmosphere and its optimum distance from the Sun so is an ideal temperature. When looking for life, scientists look for planets that have these characteristics (i.e. they look for planets that are similar to Earth)



Investigating the Solar System - Missions to Mars

3 ways to explore Mars:

1. Telescopes - Mars is a similar distance away from the Sun as the Earth so its temperatures may be hospitable to life.
2. Space probes orbiting Mars have photographed channels created millions/billions of years ago by flowing water and all life as we know it depends on liquid water. Rovers on Mars took photos of the soil found no evidence of life.
3. Space landers land and sample rocks and soil. Viking landers in 1976 did experiments on the soil, looking for chemical changes that could have been caused by living organisms. Despite some positive results, scientists concluded there was no evidence of life. The Phoenix lander discovered frozen water in the Martian soil in 2008 (still no direct evidence of life on Mars at present, though.)

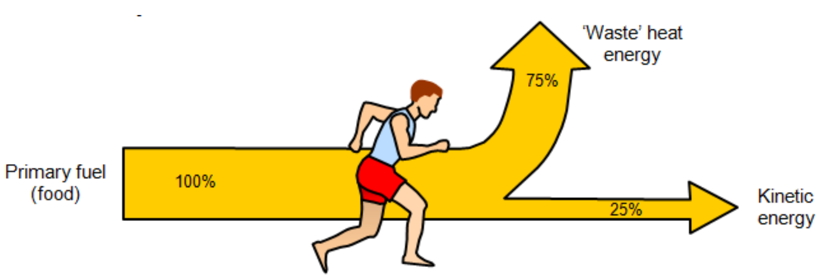
Beyond the Solar System: Scientists have discovered planets orbiting other stars (in a similar way that planets orbit the Sun in our Solar System), but they are too far away. Telescopes can't produce clear images and Space landers or space probes would take too long to get there (also, the mission would be too expensive). Scientists can sometimes find out information about the gases in the atmosphere of far away planets. The Earth's atmosphere is hospitable to life because of its high content of oxygen in its atmosphere (released by photosynthesising plants). Presence of oxygen in the atmosphere of another planet could be evidence that life may exist on that planet

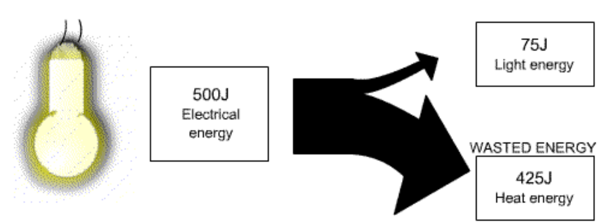
Searching for Intelligent Life (SETI): SETI analyse radio waves coming from space, looking for signals possibly produced by 'intelligent' beings. No messages have been detected so far. This is different from other projects (e.g space probes, landers) which are just looking for 'life' – i.e respiring microorganisms or plants.

Energy Conservation Diagrams (Sankey diagrams)

- These show the amount of energy converted or transferred.
- The width of the arrows represents the amount of energy in joules.

e.g. energy conservation diagram for a runner and for a light bulb



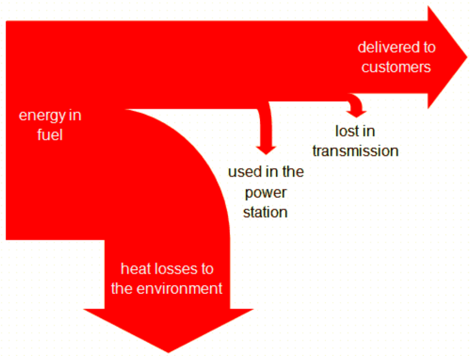


Questions on Telescopes in Space

- Why are some telescopes placed in space outside of the Earth’s atmosphere?
- Describe 3 ways that Mars has been explored.
- What problems are there with trying to explore beyond our solar system?
- What does SETI analyse to find out if there are other intelligent life forms?

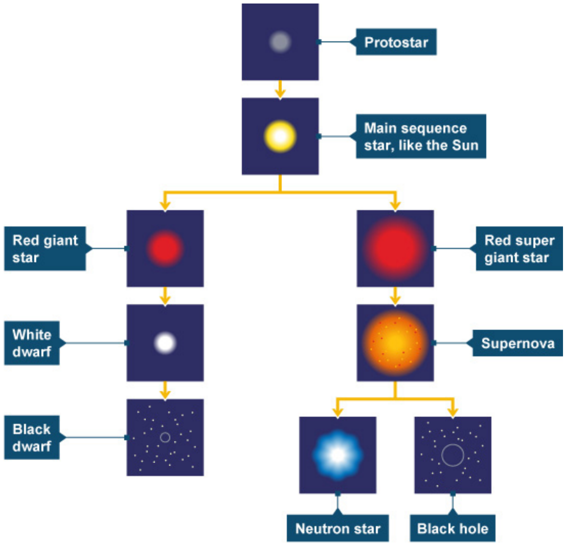
Questions on Sankey Diagrams

- Explain this Sankey Diagram for the energy released from a power station.
- Is this an efficient process?



- Construct a Sankey diagram for a washing machine that takes in 200,000 Joules of electrical energy, puts 100,000 Joules into kinetic energy, 50,000 Joules into thermal energy, 25,000 Joules into sound energy and the remaining energy is wasted. How much energy is left unaccounted for? Can you suggest what happens to it?

LIFE CYCLES OF STARS



Star formation
Nebula stage: Stars form when a nebula (cloud of dust and gases mainly hydrogen) is pulled together by gravity.
Protostar stage: The contracting cloud gets more dense and starts to glow
Main sequence stage: Eventually high temperatures and pressures in the centre of the protostar become high enough to force hydrogen nuclei to fuse together to form helium, releasing lots of energy as electromagnetic radiation. The outward pressure from the hot gases balances out the compressing action of gravity and Star enters the stable, 'main sequence' stage of its life cycle.

Life-cycles of stars like our Sun

Red giant stage: Stars of similar sizes to our Sun remain stable for about 10 billion years. After this period, most of the hydrogen has fused with helium and the core of the star is no longer hot enough to withstand gravity (i.e outward pressure from hot gases can no longer balance the compressing action of gravity). The star collapses, and the outer layers form a red giant star (much larger than the original star). Fusion reactions occur in a red giant (which balance compressing action of gravity) and stability is maintained for about a billion years.

White dwarf stage: After about a billion years, red giant throws off a shell of gas and the rest of the star is pulled together and collapses to form a white dwarf. No fusion reactions happen inside a white dwarf and over about a billion years it gradually cools into a ***black dwarf***

Life-cycles of massive stars:

Stars with considerably more mass than the Sun are hotter and brighter and the fusion reactions in a massive star's core happen at a faster rate. Stable main sequence is shorter than in smaller stars.

Once hydrogen runs out and the core cools, massive stars become ***red supergiants*** and at the end of the supergiant period, the star rapidly collapses and then explodes, casting off the outer layers of the supergiant. This explosion of a red supergiant is known as a ***supernova***. The next stage in the life-cycle depends on how big the star is. If the star is really ***massive*** then gravity will pull the remains together to form a ***black hole***. If the remains ***aren't massive*** enough to form a black hole, gravity will pull them together to form a small, very dense star called a ***neutron star***.

EFFICIENCY

The efficiency of a device is the percentage (%) of energy transferred into useful forms.
e.g. When a light bulb is switched on, most of the electrical energy supplied to it is converted into wasted thermal energy that spreads to the surroundings.

Old-style: 100 J light bulbs give out 9 J of useful light energy, 91 J is wasted thermal energy.

New :100 J light bulbs give out 45 J useful light energy, 55 J wasted heat energy.

Therefore new light bulbs transform more of the input electrical energy into light energy than older-style bulbs and are more efficient.

Equation to calculate the efficiency of a device

$$\text{Efficiency (\%)} = \frac{\text{useful energy transferred by the device}}{\text{total energy supplied to the device}} \times 100$$

e.g. for 200 J input energy, a jet pack produces 80 J of kinetic energy, 10 J of sound and 110 J of thermal energy.

Calculate its efficiency:

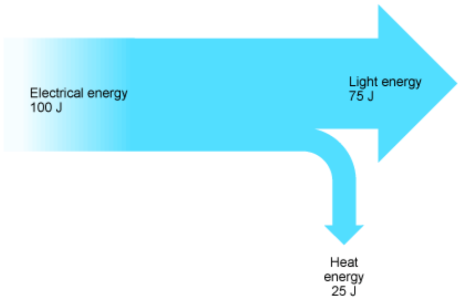
Wasted energy = sound and thermal energy = 120 J
useful energy transferred into kinetic energy = 80 J
Efficiency = 80/200 x 100 = 40%

Questions on Life Cycle of Stars

- What are stars made from?
- What force pulls all the material together to make a nebula cloud?
- What happens to turn the protostar into a main sequence star?
- What forces are balanced in the main sequence stage?
- Describe the main stages in stars that are a similar size to our sun.
- Which stages are different if the star is much heavier than the sun?

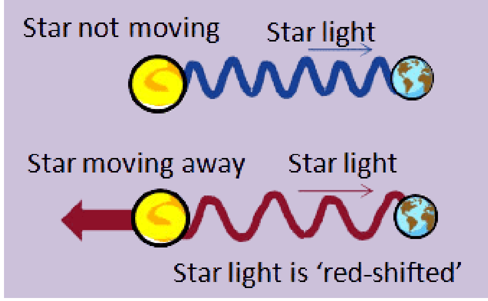
Questions on Efficiency

- Define efficiency of a device.
- Write down the equation for efficiency.
- How do you know which is useful energy and which is wasted energy?
- What is the energy efficiency of the light bulb shown in this Sankey diagram?



- What is the percentage efficiency of the washing machine described on the last card?

THEORIES ABOUT THE UNIVERSE

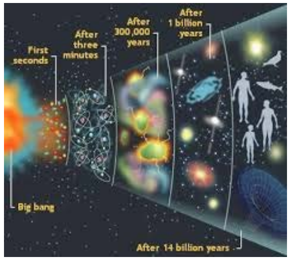


Red-shift

If a source of light is moving away from us, then its wavelength will be longer

and its frequency lower than we expect and its light is shifted towards the red end of the spectrum: this effect is called red-shift. Light from other galaxies is red-shifted so this shows that galaxies are moving away from us and this tells us that the Universe is expanding.

Note: The further away a galaxy is, the faster it is moving away from us. Astronomers use this information and other data to work out theories that explain the past and present state of the Universe.



Big Bang theory

First suggested in the 1930s, this says the whole Universe and all the matter in it started out as a tiny point of concentrated energy about 13.5 billion years ago. The Universe expanded from this point and is still expanding and the theory also claims that a huge amount of radiation was left behind after the Big bang.

Steady State theory

This alternative theory proposed in 1948 suggested that the Universe has always existed and is expanding and new matter is continuously created within the Universe as it expands.

Big Bang theory vs Steady State theory

1. Both theories state that the Universe is expanding, with new matter being created all the time and the red-shift in the light from other galaxies can be used to support both theories.

2. The Big Bang theory predicts that the radiation released after the Big Bang should still be detectable as 'cosmic microwave background (CMB) radiation' today. In 1964, two radio astronomers detected microwave signals coming from all over the sky which supported the Big Bang theory. The Steady State theory cannot explain CMB radiation so there is more supporting evidence for the Big Bang theory which is accepted by most astronomers today.

HEAT RADIATION

Black surfaces absorb and emit the most heat energy but they reflect the least heat energy. White surfaces absorb and emit the least heat energy but reflect the most heat energy.

- When wearing black clothes you feel hotter than when you wear white clothes because they absorb the most heat.
- Car radiators are designed to remove heat from the engine and have to be good at absorbing thermal energy hence car radiators are always black.

THE EARTH'S TEMPERATURE

For a system to stay at a constant temperature it must absorb the same amount of energy every second as it radiates every second (i.e. it must take in the same amount of energy as it gives out).

e.g. If a pool at 27°C radiates 1200W (Joules per second), the heating system must transfer 1200W to the pool for its temperature to remain at 27°C . If less energy is transferred then pool temperature will drop and if more is transferred the pool's temperature will rise.)

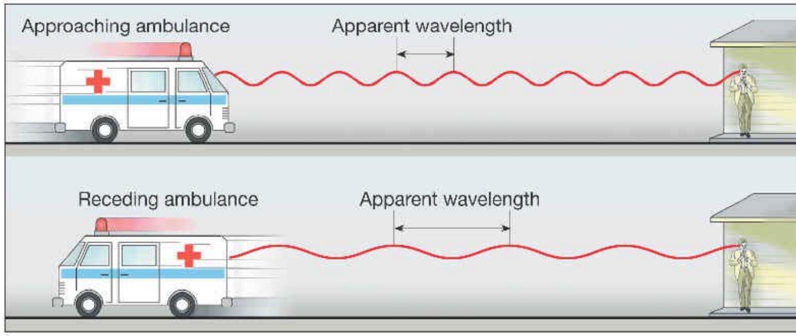
Questions on Theories of the Universe

- If a source of light is moving away from us what will happen to its frequency and wavelength? What is this effect called?
- Describe the Big Bang theory?
- How is the steady state theory different?
- Give one piece of evidence that supports the Big Bang theory.

Questions on Heat Radiation

- Which surfaces are good absorbers of infra-red radiation?
- Which surfaces are good reflectors of infra-red radiation?
- Why do people wear long white clothes in the desert?
- Why are car radiators black?

DOPPLER EFFECT



A sound with a high pitch has a high frequency. A sound with a low pitch has a low frequency. The sound waves in front of a moving vehicle are compressed so the frequency is higher and pitch is higher. The sound waves behind a moving vehicle are stretched so the frequency is lower and pitch is lower. This is called the Doppler Effect.

Therefore as an ambulance comes towards you, you hear a high pitched siren (as sound waves in front have a high frequency). As an ambulance moves away from you, you hear a low pitched siren (as sound waves behind have a low frequency).

Earth's Energy Balance

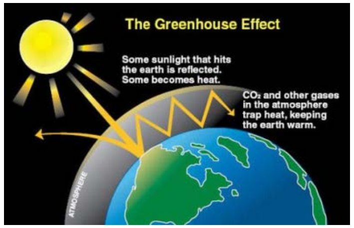
The Sun radiates energy which is either reflected back into space (by clouds, atmosphere and Earth's surface) or absorbed (by clouds, greenhouse gases in the atmosphere and Earth's surface).

The energy that is absorbed by the Earth's surface is re-radiated as infrared radiation, which can heat up the atmosphere.

For the Earth's temperature to stay the same, the energy per second absorbed by the Earth and its atmosphere must equal the energy per second radiated.

Effects of greenhouse gases on the Earth's energy balance

Greenhouse gases (such as carbon dioxide) trap heat energy so more is absorbed in the atmosphere and less is radiated back into space. This causes the temperature of the Earth to increase (global warming). To decrease the temperature of the Earth we would have to actively *remove* greenhouse gases from the atmosphere.



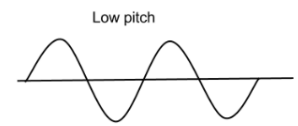
Strategies to stop the Earth's temperature rising

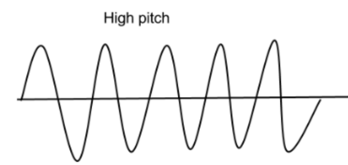
To reduce the Earth's temperature, we must reduce the amount of Sunlight that is absorbed by the Earth and its atmosphere. We can do this by increasing the amount of Sunlight that is reflected .

Possible strategies: Place huge white screens in space, about 2000km along each side or Float millions of white ping pong balls on ocean surfaces.

Questions on Doppler Effect

- Which of the diagrams opposite would represent the sound of a whistle?





- What happens to the sound waves in front of a moving vehicle?
- What is the name of this effect?
- Describe what you would hear as an ambulance approaches and then passes you.

Questions on the Earth’s Energy Balance

- How does the Sun’s energy get reflected back into space?
- Name three ways the sun’s energy is absorbed.
- If the Earth’s temperature is to stay the same then what must happen?
- Name a greenhouse gas and explain how it contributes to global warming.
- Suggest a possible strategy to reduce global warming.