SP2h
BRAKING DISTANCES AND ENERGY

Brakes ‘do work’ by transferring kinetic energy to thermal energy

When the vehicle stops, it has no more kinetic energy. Energy is conserved (All the kinetic energy has been converted to thermal energy)

The work done to bring a vehicle to rest is equal to its initial kinetic energy

- i.e the greater the initial velocity of the vehicle, the greater its initial kinetic energy (recall: $KE = \frac{1}{2} \times m \times v^2$), so the more work that needs to be done to bring the vehicle to rest
- This explains why the faster a vehicle is travelling, the longer its braking distance

SP2h Questions on Braking

- What energy transfer occurs with braking?
- How much kinetic energy does a car have when at rest?
- Why does moving at a higher speed increase the braking distance?

SP4d Waves Crossing Boundaries

- Waves are absorbed, transmitted and reflected at boundaries.
- When a wave meets a boundary between two materials (a material interface), three things can happen:
- 1. the wave may be absorbed by the second material transferring energy to the materials energy stores. This is how a microwave works.
- 2. The wave may be transmitted-it carries on travelling through the new material often at a different speed (velocity) which can lead to refraction.
- 3. The wave may reflect off the boundary. This is where the incoming ray is neither absorbed or transmitted, but ‘sent back’ away from the second material .
- Sound waves can be affected in the same way as light waves.

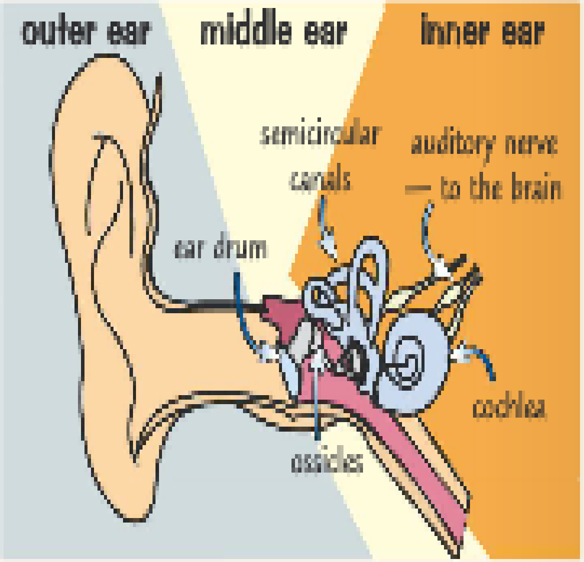
SP4d Waves Crossing Boundaries Questions

- What three things can happen to a wave at a boundary between materials?
- Why don’t you get a clear reflection from a rough surface?

SP4e Ears and Hearing

You Hear Sound When Your Eardrum Vibrates

1) Sound waves that reach your eardrum cause it to vibrate.
2) These vibrations are passed on to tiny bones in your ear called ossicles, through the semicircular canal and to the cochlea.
3) The cochlea turns these vibrations into electrical signals which get sent to your brain.
4) The brain interprets the signals as sounds of different pitches and volumes, depending on their frequency and intensity. A higher frequency sound wave has a higher pitch.
5) Human hearing (audition) is limited by the size and shape of our eardrum, and the structure of all the parts within the ear that vibrate to transmit the sound wave.
6) Young people can hear frequencies ranging from about 20 Hz (low pitch) up to 20 000 Hz (high pitch). As you get older, the upper limit decreases, and sounds may need to be louder for you to hear them. This is mainly due to wear and tear of the cochlea or auditory nerve.



SP4e Ears and Hearing Questions

- List the parts of the ear in the order that vibrations affect them.
- Which part of the ear converts vibrations in to nerve impulses?
- In which parts of the ear are the vibrations occuring in a solid, a liquid or a gas?

SP4f ULTRASOUND

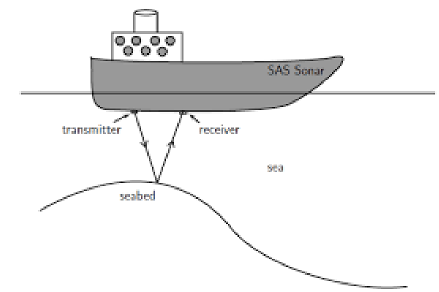
Sounds with frequencies above 20,000Hz are called ultrasounds. Some animals, e.g. dolphins, use ultrasound to communicate with each other.

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)



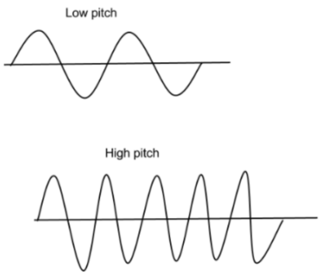
Ultrasound scans

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.

SP4f 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.

SP4g 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

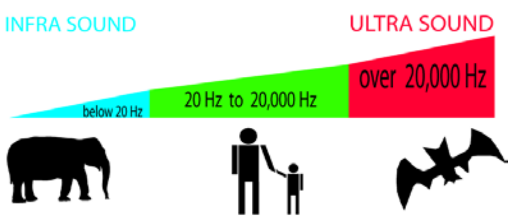
Infrasound waves travel further in air (before they become too faint to detect) than sound waves of higher frequencies. Infrasound is used by whales and other animals to communicate over long distances. Using microphones, biologists can pick up infrasounds to study the movement of animals in remote locations.

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.



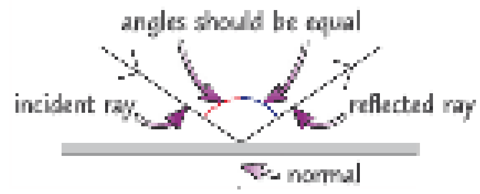
SP4g Questions on Infrasound

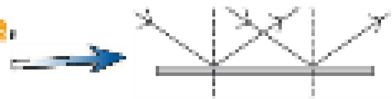
- Can sound waves travel through a vacuum? Why?
- What frequency are infrasound waves?
- What is the normal hearing range of a human?
- Can humans hear infrasound?
- Describe two uses of infrasound.

SP5a Ray Diagrams

You Need to Be Able to Draw Ray Diagrams for Reflection

1) Draw a normal to your surface and a light ray that meets the normal at the surface — this is your incident ray.
2) Now draw the reflected ray, remembering that the angle of incidence must always equal the angle of reflection.
3) If there are multiple rays which are parallel (e.g. the light source is distant) and they're reflecting off a smooth surface, then the reflected rays will also all be parallel to each other.

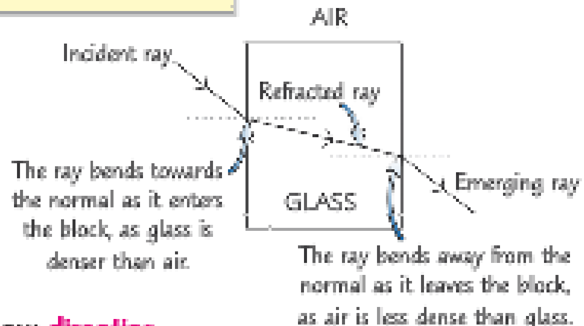




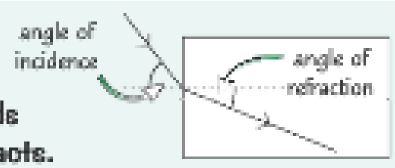
4) Remember to use a ruler (and protractor if required) and always put arrows on your rays.

You Need to Be Able to Draw Ray Diagrams for Refraction

1) Draw a normal where any ray meets a boundary.
2) If the light ray is travelling into a MORE dense material, it will slow DOWN, making it bend TOWARDS the normal.
3) If the light ray is travelling into a LESS dense material, it will speed UP, making it bend AWAY from the normal.
4) If a light ray is travelling through a rectangular block, the emerging ray and the incident ray will be parallel.
5) Remember to use a ruler and add arrows to your rays to show direction.



1) The angle of incidence is between the incident ray and the normal.
2) The angle of refraction is between the refracted ray and the normal.
3) The angle of refraction varies with the angle of incidence. It also depends on the light's wavelength — the shorter the wavelength, the more it refracts. And it depends on the materials either side of the boundary, e.g. glass refracts light more than water.



SP5a Ray Diagrams Questions

- Light hits a mirror with an angle of incidence of 30°, what is the angle of reflection?
- Describe what happens to the direction of a light ray when it goes from water into air.
- You can see your reflection in a window when it is dark outside, why?
- Explain why total internal reflection does not occur when light goes from air into glass.

SP5b Colour & More on Reflection

- Reflection can be specular or diffused. Specular reflection is when waves are reflected in a single direction by a smooth surface. Scattering or diffused reflection is when waves are reflected by a rough surface, e.g paper and the waves are reflected in all directions.
- The colour something appears to be is all about what wavelengths of light we are seeing when we look at it.
- Colour and transparency depend on absorbed wavelengths.
- White light is a mixture of all the colours of light which all have different wavelength. White light can be can be separated into the visible colours of the spectrum using a prism.

SP5b Colour & Filters Questions

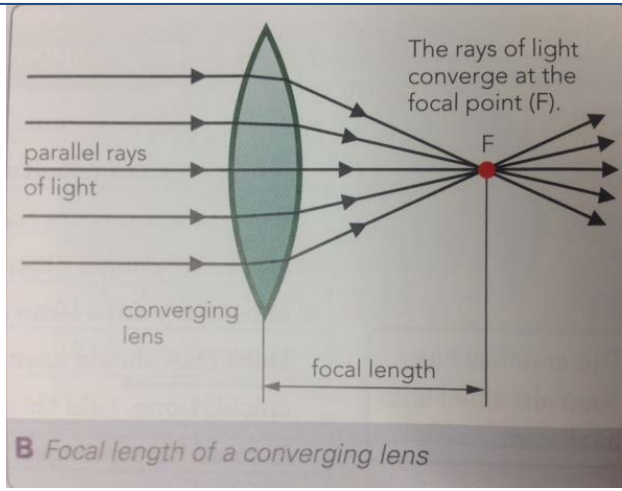
- Filters are pieces of transparent material that absorb some of the colours in white light. For example a blue filter transmits (allows through) blue light and absorbs all the other colours.

- Draw a diagram showing specular reflection.
- Explain why a white shirt looks white and why a black object looks black.
- Explain which colours in white light are transmitted and absorbed by the kind of glass used to make house windows and the different coloured glass in the windows of the Academy Hub.

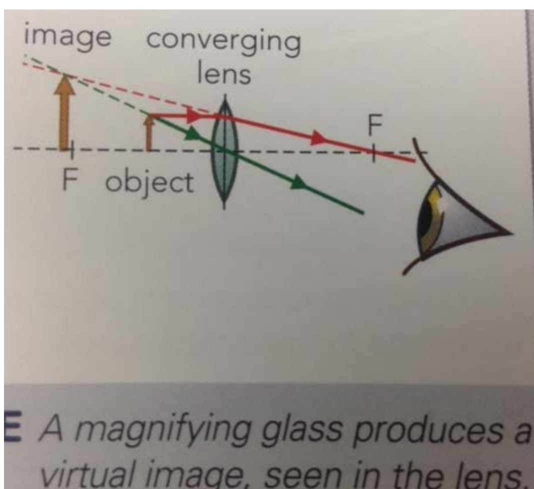
SP5c Lenses

Power of a lens = $\frac{1}{\text{Focal length (metre, m)}}$
(dioptre, D)

- **Converging** lens – parallel rays refracted and **meet** at focal point
- Lens to focal point = **focal length**



B *Focal length of a converging lens*

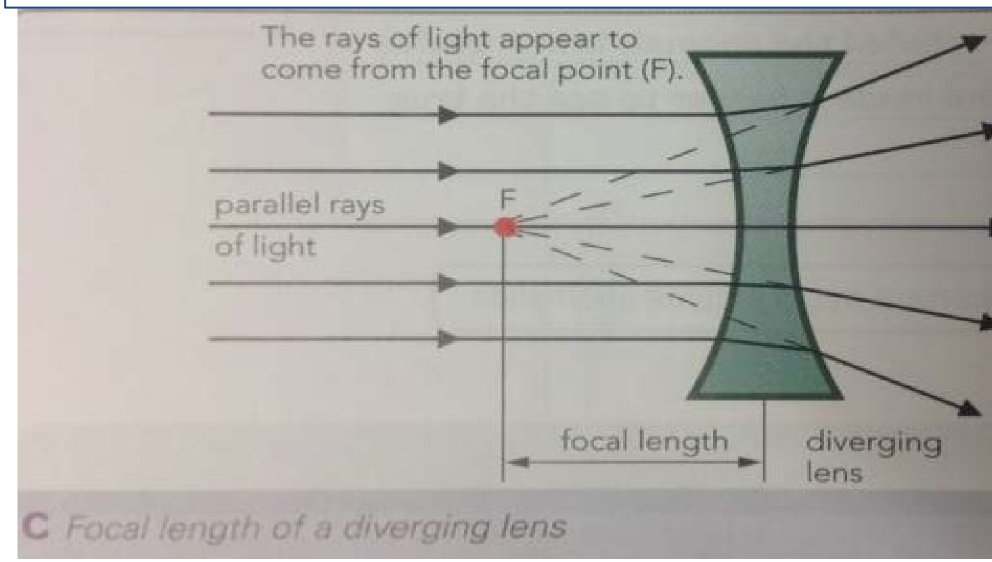


E *A magnifying glass produces a virtual image, seen in the lens.*

Keywords

- **Dioptres** – Unit for measuring the power of a lens
- **Real Image** – An image that can be projected onto a screen
- **Virtual Image** – An image that cannot be projected onto a screen

- **Diverging** lens – focal point is point rays seem to **coming from**
- Focal point to lens = **focal length**



C *Focal length of a diverging lens*

Lens Equation – links the <u>object distance</u> (u), the <u>image distance</u> (v) and the <u>focal length</u> (f)

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$$

SP5c Lenses

1. Define the term focal length.
2. Where is the focal point in a diverging lens
3. How is the power of a lens measured?
4. What unit is used to measure the power of a lens.
5. What is the lens equation
6. What factors are linked in the lens equation?
7. Define a ‘real image’.
8. Define a ‘virtual image’.

SP5g Radiation and temperature

- The intensity (amount) of radiation emitted by an object increases as its temperature increases. The wavelengths of the radiation emitted also change with temperature – the higher the temperature the shorter the wavelength.
- The amount of energy transferred in a certain time is the power it is measured in watts (W) (1W= 1J /s) For a system to stay at a constant temperature it must absorb the same amount of power as it radiates.
- The earths surface absorbs about half the radiation that reaches it from the sun. It re-radiates this energy as infrared radiation, which can warm up the atmosphere. For the temperature of the earth to stay the same it must radiate energy in to space at the same average rate it is absorbed.

SP5g Questions- Radiation and temperature

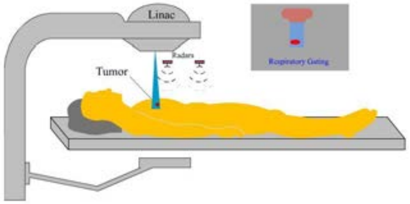
- 1. Explain which emits more radiation, a cup of tea at 75° C or a bowl of soup at 50°C.
- Explain why astronomers think that blue stars are hotter than yellow stars.
- Blacksmiths heat iron before hammering it into a new shape. Explain how looking at the colour of the heated iron can tell them whether its hot enough.

SP6h USES OF RADIATION

Diagnosis of cancer:

- A tracer solution containing a source of gamma rays is injected into the body and it collects on the cancer cells. A gamma ray detector is used to find the cancer cells. Why gamma rays are used:
  - Gamma rays are used for this because they are weakly ionising, most penetrating and so pass straight through the body, allowing them to be detected

Treatment of cancer:



- Radiotherapy – a beam of gamma ray radiation is fired at cancer cells, killing them

Sterilisation of equipment:

- It is important to have clean surgical instruments to use in hospitals
- The usual method is to heat them (as microorganisms are killed by the heat)
- Some instruments, e.g plastic syringes, cannot be sterilised using heat (as they would melt), they can be irradiated with gamma rays to kill any micro-organisms present

Irradiating food:

- All foods contain bacteria – these bacteria are what eventually cause all food to decompose (i.e to go off)and cause food poisoning
- Some types of foods (fruit, vegetables, fish and poultry) are irradiated with gamma rays to kill bacteria:
  - This makes the foods safer to eat and also means that they can be stored for longer before going off
  - Irradiating the food also kills any pests (e.g insects) that may be in it

Smoke alarms:

- A smoke alarm contains a source of alpha particles – usually a radioisotope called americium-241. If the radiation detector is blocked by smoke then a circuit is broken and the alarm triggered.

Checking thicknesses:

- The thickness of the paper is controlled by a detector, which counts the rate at which beta particles pass through the paper

Tracers in the environment:

- To detect leaks in water pipes underground, a gamma source is added to the water. A GM tube follows the path of the pipe, measuring the levels of radiation

SP6h Uses of Radiation - Questions

- How is radiation used to find and treat cancer?
- Suggest two applications for the ability of radiation to kill microbes and why is better than other methods
- How the properties of radiation which make measuring the thickness when manufacturing paper

SP6j Radiation in Medicine

Keywords

- **Ionising Radiation** – radiation that can cause charged particles by knocking electrons from the atom. Causes tissue damage and may cause mutations.
- **Intensity** – the strength of a wave defined as power of incident radiation/area.
- **Diagnosis** – identifying a medical condition by its signs and symptoms or from a medical imaging scan
- **Non-ionising radiation**– radiation that does not cause formation of charged particles.
- **Incident radiation**– falling of striking of radiation on something.

Facts:

- **Intensity** is an example of a compound measure (its units are determined by the units used in the calculation)
- Standard units = W/m^2

- Visible light - example of radiation (**energy** carried by waves from a source)
- Different types used to identify and **treat medical** problems.
- Produce **images** that show features inside the body.
- Non-ionising = lasers used in eye surgery; ultrasound to treat swelling.
- Intensity decreases with distance from source. (Different tumours treated with different intensities)
- Denser medium to move through = weaker radiation.

Intensity (I) = power of incident radiation in Watts (P) / area in Metres squared (A)
W/m²

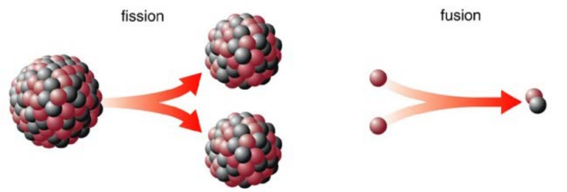
$$I = \frac{P}{A}$$

Visible light	Light **reflects** to form an image	**Endoscopes**
X-ray	**Absorbed** by some material but not others. **Negative image** produced	**X-ray photography and CAT scanners**
Gamma Rays	**Movement** of a substance producing Gamma rays is detecting and observed	**PET scanners**
Ultrasound	High frequency **sounds waves reflect** off internal features	**Ultrasound scanners**

SP6j Radiation in Medicine

1. Which medical techniques use harmful, ionising radiation?
2. What is ionising radiation?
3. What type of image do x-rays form?
4. What radiation is used in PET scans?
5. Give two examples of ionising radiation using in medicine
6. State the equation for calculating the intensity of radiation.
7. State 2 types of non-ionising radiation used in medicine

SP6k Nuclear energy



The process of radioactive decay releases energy

- when alpha and beta particles are emitted from unstable nuclei at high speeds, kinetic energy is released
- when gamma rays are emitted from unstable nuclei at the speed of light, the energy released is in the form of electromagnetic radiation

Some large unstable nuclei can split into two smaller nuclei called daughter nuclei – this process is called nuclear fission.

When a uranium-235 absorbs a neutron it becomes unstable and immediately splits it into two smaller daughter nuclei, and two or more neutrons are released.

Nuclear fission releases a huge amount of energy. Most energy released is in the form of kinetic energy because both daughter nuclei and neutrons are moving at high speeds. Some thermal energy is also released

SP6k   Nuclear Energy Questions

- How does the process of nuclear decay release energy?
- What element is used in nuclear fission?
- Does nuclear fission release a lot of energy?
- What form is this energy in?

SP6K Advantages/Disadvantages of nuclear power

Advantages of nuclear power:

- Nuclear power stations themselves don’t directly produce carbon dioxide so nuclear power doesn’t contribute to global warming
  - However, energy is needed to make some components of nuclear reactors therefore indirectly some carbon dioxide may be produced
- Nuclear power is produced consistently (i.e not dependent on weather conditions)
- Nuclear power won’t run out for many years and it’s a very efficient process

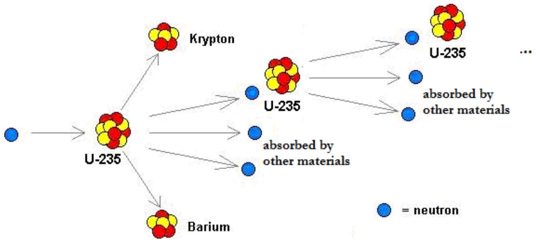
Disadvantages of nuclear power:

- Nuclear waste has to be stored for tens of thousands of years (i.e until the radioactivity has decreased to ‘LLW’) before it can be disposed
  - During this time, if any of it leaks into the environment it can have serious effects on health – e.g tissue damage, cancer
- Some people think that nuclear power is unsafe because of the risk of accidents:
  - E.g in Chernobyl, 1986 - a nuclear power station exploded, spreading radioactive material across Europe

SP6k Advantages/Disadvantages of nuclear power - Questions

- Do nuclear power stations contribute to global warming?
- Is nuclear power dependent on the weather?
- Is there a limited time which nuclear power can supply our energy needs?
- Is it easy to close a nuclear power plant?
- Are nuclear power plants safe?

SP6L Nuclear fission



Uncontrolled chain reactions:

When a uranium-235 nucleus splits, neutrons released are absorbed by other uranium-235 nuclei:

- These other uranium-235 nuclei will split into two smaller daughter nuclei and release more neutrons
- These neutrons can then be absorbed by yet more uranium-235 nuclei..
- In these ‘uncontrolled chain reactions’, lots of energy is released (through nuclear fission) in a very short time – this occurs in an atomic bomb

Controlled chain reactions:

If some of the neutrons released during nuclear fission are absorbed by other materials, then chain reactions can be controlled

- when a uranium-235 nucleus splits, all neutrons except for one are absorbed by other materials
- only one neutron from each fission event can be absorbed by another uranium-235 nucleus
- The chain reaction is now ‘controlled’ because the chain reaction continues at a constant rate, the amount of energy produced through nuclear fission is regulated

Controlled chain reactions occur in nuclear reactors.

SP6K Nuclear Fission Questions

- How does the chain reaction from Uranium 235 continue?
- What is the difference between controlled and uncontrolled chain reactions?
- Which type of reactions occur in nuclear reactors?

SP6L Nuclear fission in nuclear reactors

Nuclear reactors in nuclear power stations convert (nuclear) energy contained in the nuclei of uranium and plutonium ions into thermal energy using nuclear fission.

The rate at which nuclear energy is transferred to thermal energy is kept constant by controlling the fission chain reaction

- This is done by ensuring that only one of the neutrons released by the decay of a uranium nucleus is absorbed by another uranium nucleus
- To achieve this, the extra neutrons that are released have to be absorbed – this is done by control rods in the reactor core.

Control rods contain elements that absorb neutrons

- If the rate of fission needs to be decreased, more control rods are moved into the core, more neutrons are absorbed by control rods, fewer neutrons can be absorbed by other uranium nuclei (and vice versa)

When the control rods are fully lowered into the reactor core, they absorb all the neutrons the chain reaction stops and the reactor shuts down

Neutrons emitted from the fission of a uranium-235 nucleus are moving very fast

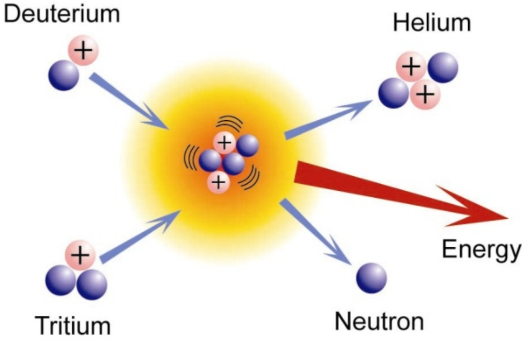
To make them more likely to be absorbed by other uranium-235 nuclei, they need to be slowed down – this is done by moderators in the reactor core

SP6k Fission in Nuclear Reactors Questions

- What kind of energy do nuclear reactors use?
- What is a control rod? What does it do?
- How does a reactor shut down?
- What do moderators do?

SP6m NUCLEAR FUSION

- Nuclear fusion occurs when small nuclei combine to form larger nuclei
- E.g when hydrogen nuclei fuse to form helium:
  - There are two isotopes of hydrogen:
    - Hydrogen-2 called deuterium (1 proton, 1 neutron)
    - Hydrogen-3 called tritium (1 proton, 2 neutrons)
  - When tritium and deuterium nuclei fuse, helium is formed:
    - Helium has 2 protons and 2 neutrons
    - One neutron is freed from the nucleus, releasing a huge amount of energy
- So much energy is released in nuclear fusion reactions that they are the energy source for stars, including our Sun
- Nuclear fusion is being investigated by scientists as a possible energy source for the future:
  - Unlike nuclear fission, nuclear fusion doesn't produce any radioactive waste products so would be a better alternative



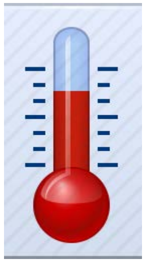
SP6m Nuclear Fusion - Questions

- Define nuclear fusion
- Why is nuclear fusion better than nuclear fission as an energy source?
- Given an example of nuclear fusion energy source in nature
- Why are isotopes useful in nuclear fusion?

SP6m Conditions for fusion:

- Nuclei of both deuterium and tritium are positively charged (due to presence of 1 proton in each nucleus) as a result they repel - ‘electrostatic repulsion’
- So in order for deuterium and tritium nuclei to overcome the electrostatic repulsion and collide, the conditions must be right:

- **1. High pressure:**
  - For nuclei to fuse, they need to get very close to each other
  - The Sun has a very strong gravitational field, which creates high densities (i.e lots) of nuclei at its centre so making collisions more likely to happen
  - These conditions are not naturally present on Earth, but very high pressures can be produced inside fusion reactors



- **2. High temperature:**
  - If nuclei are travelling fast enough, some can overcome their electrostatic repulsion and collide
  - The higher the temperature, the faster the nuclei move so the more likely they are to overcome their electrostatic repulsion and collide
- Unfortunately, the conditions that are required for nuclear fusion (very high temperature and pressure) are difficult to achieve and are very expensive so it will be some time before fusion energy will become a viable energy source

***Note* - Cold fusion:**

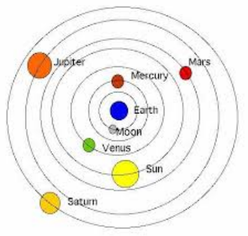
- Scientists 20 years ago claimed to have carried out nuclear fusion at 50°C – this became known as ‘cold fusion’
- The possibility of carrying out nuclear fusion at low temperatures was exciting at the time because it would be more convenient and less expensive
- However, attempts to repeat the original findings have failed as a result most scientists do not believe cold fusion can happen

SP6m Conditions for Fusion - Questions

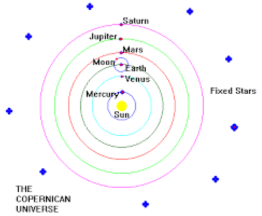
- What is the name of the force which keeps nuclei apart in normal conditions?
- Describe the two conditions are needed to allow nuclear fusion to occur?
- Explain how the two conditions provide the opportunity for fusion
- Why is nuclear fusion not a common source of energy on Earth?
- What is the name of the potentially exciting development in nuclear fusion which has yet to be proven in the laboratory?

SP7a

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.

SP7a 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 16th 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?

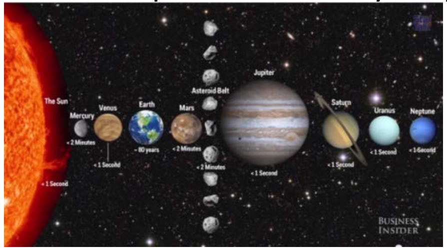
SP7a THE UNIVERSE

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.

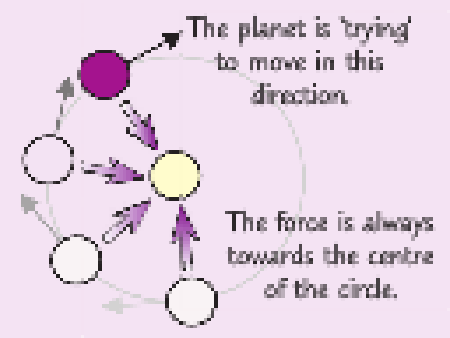
SP7a Questions on The Universe

- 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?

SP7b Gravity and Orbits

- Gravity provides the force that causes orbits.

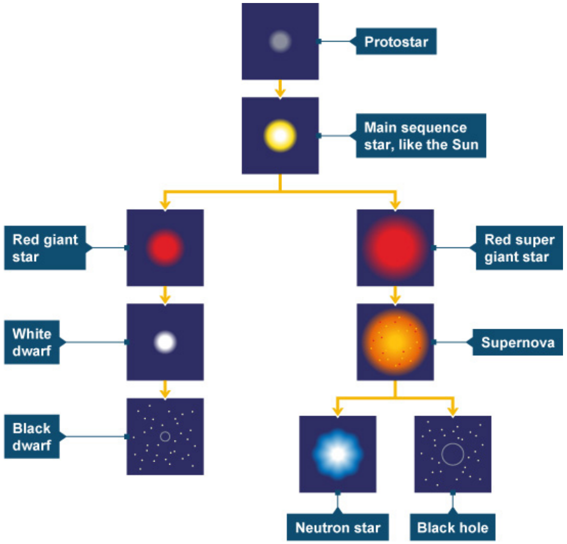
1) The orbits of the planets around the Sun, and satellites around planets, are almost circular.
2) If an object is travelling in a circle it's constantly changing direction. This means its velocity is constantly changing, so it's accelerating. (Speed doesn't have direction though, so that's not changing.)
3) For an object to accelerate, there must be a force acting on it. For an object moving in a circle, this force is directed towards the centre of the circle and is called the centripetal force.
4) For orbiting objects, this force is provided by gravity (gravitational force).
5) This force would cause the object to just fall towards whatever it was orbiting, but as the object is already moving, it just causes it to change its direction.
6) The object keeps accelerating towards whatever it's orbiting but its velocity at any given moment is always at right angles to this acceleration. This keeps it travelling in a circle.
7) For an orbit to be stable the object must be moving at just the right speed — too fast and it'd fly off into space, too slowly and it'd spiral down and crash into whatever it was orbiting.
8) If an object's speed changes, the radius of its orbit must also change for the orbit to remain stable: The closer you get to a star or planet, the stronger the gravitational force is. The stronger the force, the faster the orbiting object needs to be going to avoid falling in to what it's orbiting. So the closer you get, the faster you need to go to stay in orbit. For an object in a stable orbit, if its speed changes, the size (radius) of its orbit must do so too. If the object moves faster, the radius must get smaller. If it moves slower, the radius must get larger.



SP7b Gravity and Orbits Questions

- State two factors that affect the weight of an object on a planet.
- Give one reason why *g* on Mars is greater than *g* on the moon.
- Explain what happens to the satellite if its speed changes

SP7c 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 <u>red giant</u> 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 <u>white dwarf.</u> No fusion reactions happen inside a white dwarf and over about a billion years it gradually cools into a <u>***black dwarf***</u>

Life-cycles of massive stars:

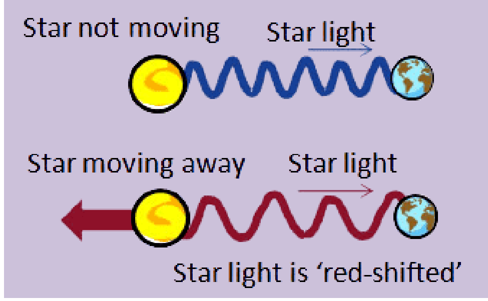
Stars with considerably more mass than the Sun are hotter and brighter and the fusion reactions in a massive star's core happen at a faster rate. Stable main sequence is <u>shorter</u> than in smaller stars.

Once hydrogen runs out and the core cools, massive stars become <u>***red supergiants***</u> 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 <u>***supernova***</u>. 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 <u>***black hole***</u>. 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 <u>***neutron star***</u>.

SP7c 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?

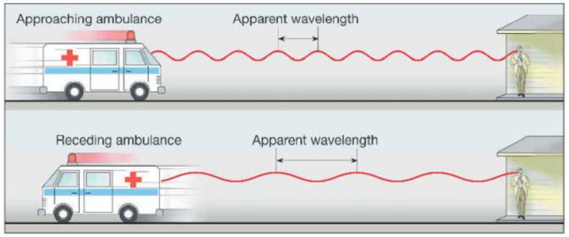
SP7d Red Shift and the Doppler Effect



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.



Doppler Effect

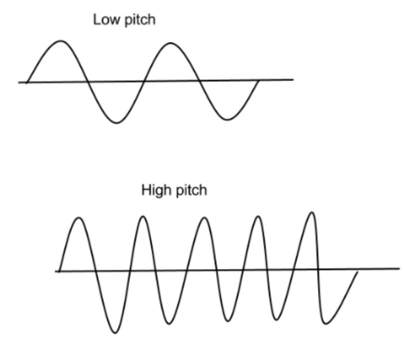
A sound with a high pitch has a high frequency. A sound with a low pitch has a low frequency.

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).

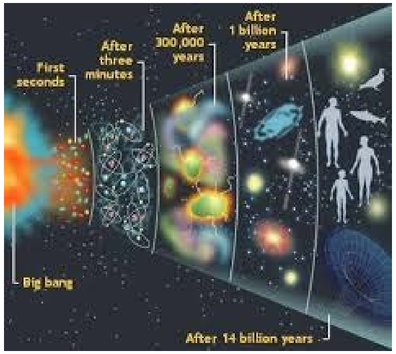
SP7d Questions on Red Shift & The Doppler Effect

- If a source of light is moving away from us what will happen to its frequency and wavelength? What is this effect called?
- 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.

SP7e Origin 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 <u>cannot</u> explain CMB radiation so there is more supporting evidence for the Big Bang theory which is accepted by most astronomers today.

SP7e Questions on Origins of the Universe

- Describe the Big Bang theory?
- How is the steady state theory different?
- Give one piece of evidence that supports the Big Bang theory.

SP9c Rotational Forces (Moments)

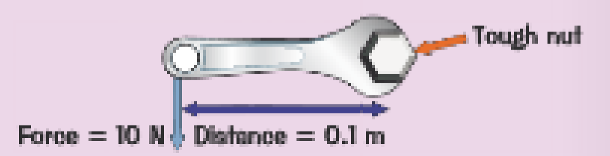
A Moment is the Turning Effect of a Force

If a force acts on an object with a pivot, it can cause the object to rotate around the pivot — like pushing open a door on a hinge. The size of the moment of the force is given by:

moment of a force (Nm) = force (N) × distance (m) or $M = F \times d$

The distance here is the normal (perpendicular) distance between the pivot and the line of action of the force (the direction of the force, see below).

1) The force on the spanner causes a turning effect or moment on the nut (which acts as a pivot). A larger force would mean a larger moment.



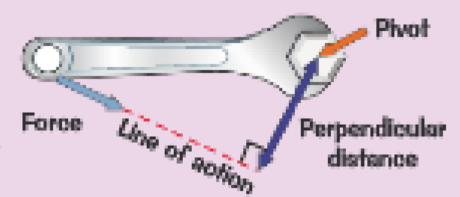
Moment = force × distance = 10 × 0.1 = 1 Nm

2) Using a longer spanner, the same force can exert a larger moment because the distance from the pivot is greater.

Moment = force × distance = 10 × 0.2 = 2 Nm

3) To get the maximum moment you need to push at right angles (perpendicular) to the spanner.

4) Pushing at any other angle means a smaller moment because the perpendicular distance between the line of action and the pivot is smaller.



A force can either cause an object with a pivot to rotate clockwise or anticlockwise. The direction of the rotation depends on the direction of the force and which side of the pivot the force is on. Just imagine the object is in front of you and you're applying the force to work out which direction the rotation is in.

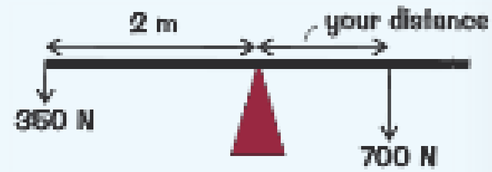
SP9c Rotational Forces (Moments)

A Question of Balance — Are the Moments Equal?

If the anticlockwise moments are equal to the clockwise moments, an object won't turn. Balanced objects obey the principle of moments:

Total anticlockwise moments = Total clockwise moments

EXAMPLE: Your younger brother weighs 350 N and sits 2 m from the pivot of a seesaw. You sit on the other side of the pivot. If you weigh 700 N, how far from the pivot should you sit to balance the seesaw?



1) Put the total anticlockwise moments equal to the total clockwise moments.

anticlockwise moments = clockwise moments

$350 \times 2 = 700 \times$ your distance

2) Rearrange to find the value you don't know.

your distance $= (350 \times 2) \div 700 = 1$ m

- Three people are sat on the see-saw. Johnny weighs 360N and is sat 1.50m to the right of the pivot. Connor weighs 540N and is sat 0.75m to the right of the pivot. Evan weighs 420N. How far to the left of the pivot should Evan sit to balance out the see-saw?

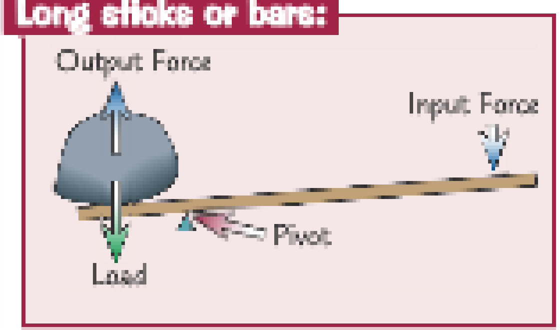
SP9c Rotational Forces(Levers & Gears)

Levers act as Force Multipliers

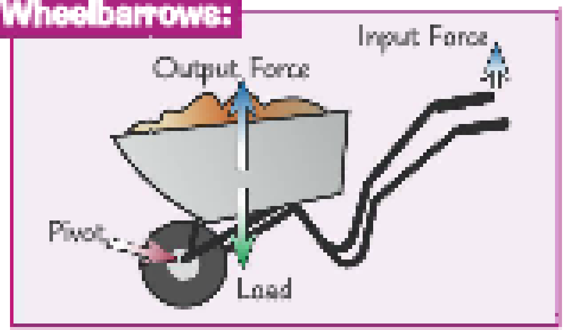
1) Levers transfer the turning effect of a force — push one end of a lever down and the rotation around the pivot causes the other end to rise.
2) You saw on p.38 that the moment due to a force depends on the distance of the force from the pivot.
3) Levers increase the distance from the pivot that the force is applied, so less input force is needed to get the same moment. This moment provides an output force to a load.
4) Levers are known as force multipliers — they reduce the force needed to get the same moment. Some examples of when levers act as force multipliers are:

Scissors use a combination of two levers.

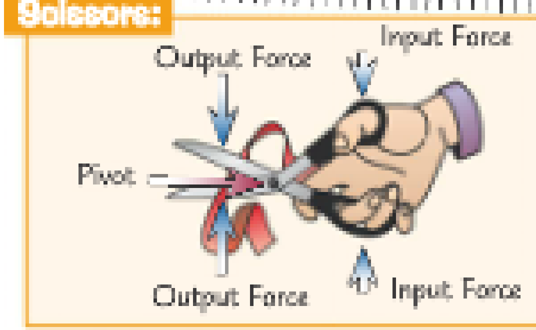
Long sticks or bars:



Wheelbarrows:



Scissors:

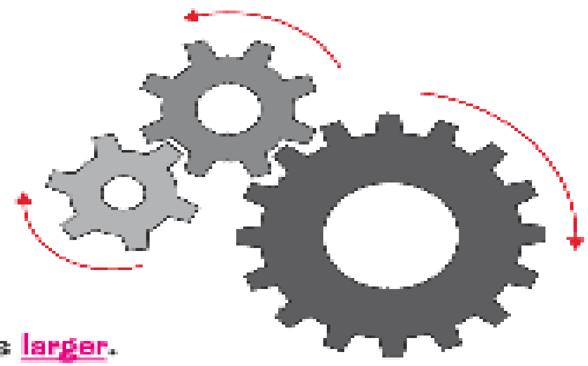


5) The moment of the input force (the force you apply) equals the moment of the output force (which is applied to the load).
Moment = force × distance,
which means you can write:

$$\frac{\text{input force}}{\text{output force}} = \frac{\text{distance of output force from pivot}}{\text{distance of input force from pivot}}$$

SP9c Rotational Forces(Levers & Gears)

Gears Fit Together to Transfer Turning Effects



1) Gears are circular cogs with 'teeth' around their edge.
2) The teeth of different gears can interlock so that turning one gear causes another to turn as well. Because of how they are linked together, a gear spinning clockwise will make the next gear spin anticlockwise. This then alternates as you go from gear to gear.
3) A force applied to a small gear creates a small moment. The small gear applies this force to the gear next to it. If this second gear is larger, the force is being applied further from the pivot (of the larger gear), so the moment of the second gear is larger.
4) A series of gears that get bigger from gear to gear will multiply the moment of the first, smallest gear.
5) Interlocked gears will rotate at different speeds, depending on their size — the larger the gear, the slower it spins. (Think of a large gear and a small gear turning together. For every complete turn of the small gear, the large gear has only turned a small amount.)

You can work out how the speeds and moments will change between gears by looking at the gear ratios. For example, look at the three gears above. The largest gear has 16 teeth and the medium gear has 8 teeth. The ratio of teeth between the largest and medium gear is 16 : 8 = 2 : 1. This means that for every 1 turn the largest gear does, the medium gear will do 2 turns.

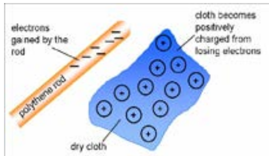
Because moment = force × distance, and the forces applied to each gear are the same, the ratio of moments of two gears is equal to the ratio of the gears' radii, and therefore equal to the ratio of teeth. For the gears above, the moment of the largest gear to the medium gear is also 2 : 1 — so the moment gets doubled.

A gear's radius is equal to the distance of the applied force from the pivot.

Cog A has 9 teeth and cog B has 6 teeth. How many times will cog B turn for one turn of cog A?

SP11a STATIC ELECTRICITY

- Static electricity is caused by an electrical (‘electrostatic’) charge building up on insulating materials – this charge could build up on a human too! All atoms contain electrically charged particles called protons (+) and electrons (-). The positive charges on the protons are balanced by the negative charges on the electrons and atoms have no overall charge.
- When two insulating materials are rubbed together, friction is generated and electrons may be transferred from one material to the other (note: protons can’t be transferred because they are fixed in the nuclei of atoms):
- The material gaining electrons now has more electrons than protons so has an overall negative charge and the material losing electrons now has more protons than electrons so will have an equal positive charge.
- Objects charged with static electricity can attract each other if the charges are opposite or repel each other if the charges are the same.



- If you rub a balloon on a jumper you can get it to stick to a wall – this process is called charging ‘by induction’ and the charge produced is an induced charge.. When the balloon is rubbed against the jumper, electrons are transferred from the jumper to the balloon to the balloon which becomes negatively charged. When the balloon is placed against the wall, the electrons in the wall are repelled by the balloon’s negative charge and move away.
- The positive charge left behind on the wall (the ‘induced charge’) attracts the negative charge on the balloon and the balloon sticks to the wall

Conductors can’t hold Static Charge

- Insulating materials (e.g a polythene rod) do not conduct electricity ‘electrons that are transferred cannot move through the material so they stay close together at the end of the polythene rod and static charge builds up at the end of the polythene rod.
- Conducting materials (e.g a metal rod) conduct electricity and electrons that are transferred spread themselves out through the metal rod and the extra static charge is difficult to detect.

SP11a Questions on Static Electricity

- When two materials are rubbed against each other which sub-atomic particle might transfer from one to another?
- Why don't protons transfer from one material to another?
- When would two materials repel? Attract?
- Why do conductors not hold onto static charge?

SP11b USES AND DANGERS OF STATIC ELECTRICITY

Electrostatic charge can build up by just by walking on a carpet. As the shoes rub along the carpet, electrons are transferred from the carpet to the person and person becomes negatively charged.. If the person then touches a conducting material (e.g metal object), the person feels a small electric shock as electrons flow from the person, through the metal object to the earth. The direction in which electrons flow depends on the charge of the object. After earthing the person is discharged so no longer has an electrostatic charge..

Lightning

Large charges of static electricity can build up on clouds, causing electrons to flow through the atmosphere between the clouds and the ground (electrons can flow in either direction from ground to clouds or from clouds to ground. This produces the huge spark that we see as lightning.

Overcoming the dangers of electrostatic charges

To reduce the dangers of the build-up of static electricity there needs to be a path between the object with electrostatic charge and the ground, through which electrons can flow for electrons to flow along it. The ‘path’ must be made of a material that conducts electricity and in most cases, it’s made of metal. This earthing process discharges the object and prevents sparks being produced

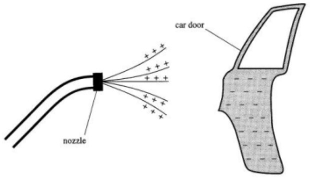
e.g refuelling aircraft

As fuel flows through a refuelling pipe, static electricity can build up and The aircraft can also build up a static charge as it flies through the air and bonding line (a metal wire) is used to connect the aircraft to the earth before it is refuelled. This discharges the aircraft of any electrostatic charge that may have built up so that no sparks are produced.

A similar problem can occur when tankers deliver fuel to filling stations: and In this case, the hose used to fill the underground fuel tanks is made of a conducting material so no sparks are produced.

Uses of static electricity

Static electricity can be used in electrostatic spray painting to make the spray spread out. The metal spray nozzle is connected to the positive terminal of an electricity supply and droplets of paint pick up a positive charge. The positively charged droplets repel each other and spread out. The object to be painted is given a negative charge and the paint droplets are attracted to the surface of the object



SP11b Questions on Uses and Dangers of Static Electricity

- Why does a charge build up simply by walking across a carpet?
- Lightning is the discharge of charge that builds up in the clouds but how does this charge build up?
- What do aircraft and petrol lorries use to ensure static charge doesn’t build up?
- Explain how spraying a car uses static electricity.

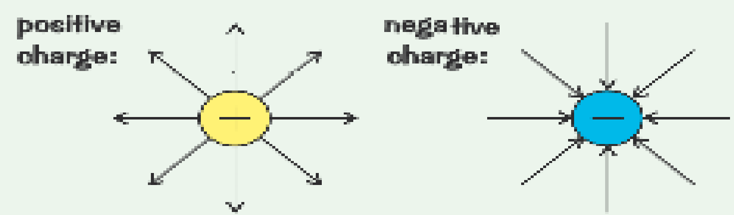
SP11c Electric Fields

Electric Charges Have an Electric Field

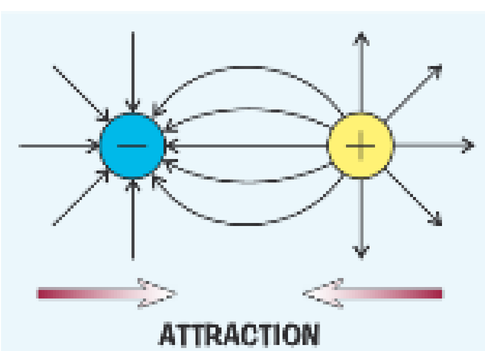
1) Like magnets have magnetic fields, charged objects have electric fields, which you can show with electric field lines.
2) Electric field lines go from positive to negative. They're always at a right angle to the surface of the object at the point where they touch the surface.
3) The closer together the field lines are, the stronger the field, and the stronger the force a charged object in the field experiences.
4) For charged spheres, like the ones on the right, field lines get further apart the further from the sphere you are, so the force another charged object feels due to an electric field decreases with distance.

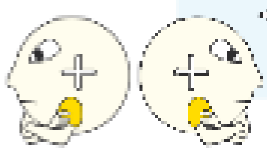
Here are the field lines around isolated, uniformly charged spheres:

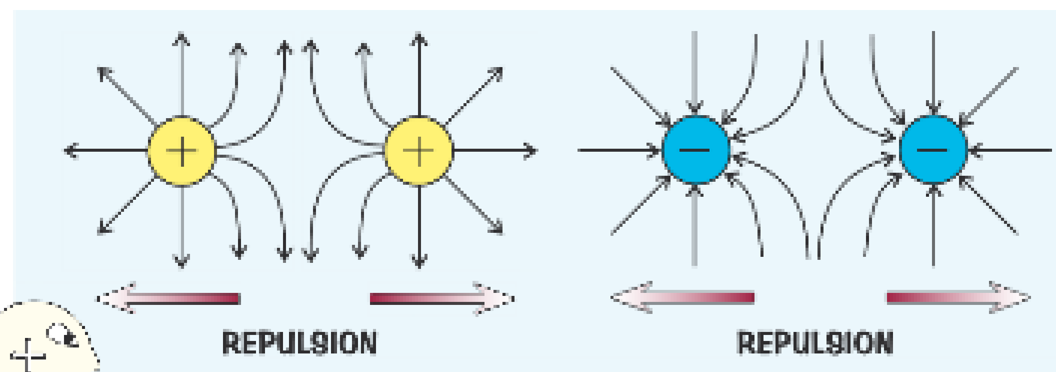
Isolated means it's not interacting with anything.



Electric Fields Cause Electrostatic Forces







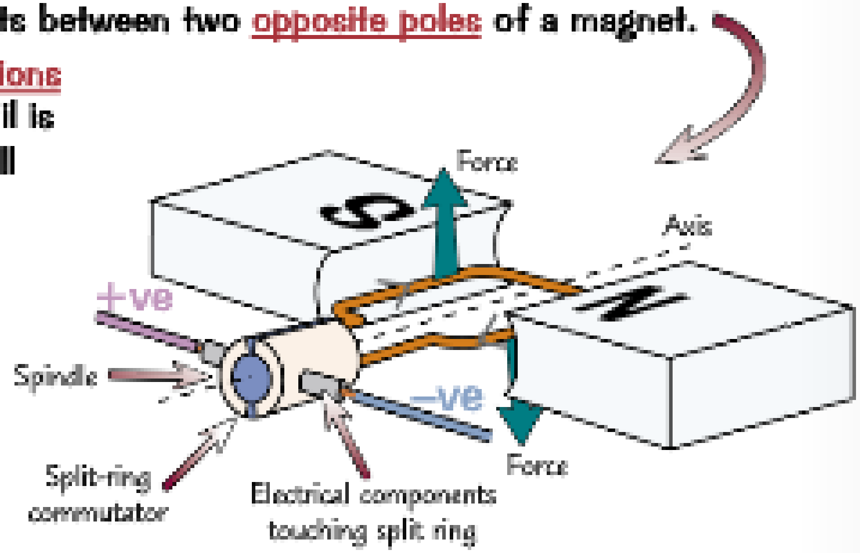
SP11c Questions on Electric Fields

- State what will happen to the strength of the electric field around a uniformly charged sphere as you move towards the sphere.
- Draw the lines surrounding an isolated, uniform, positively-charged sphere. IMPORTANT - Don’t forget the arrows on your fields lines.

SP13a Electric motors, microphones and loud speakers

A Simple Electric Motor uses Magnets and a Current-Carrying Coil

1) In a simple d.c. motor, a current-carrying coil sits between two opposite poles of a magnet.
2) Because the current is flowing in different directions on each side of the coil, and each side of the coil is perpendicular to the magnetic field, each side will experience forces in opposite directions.
3) Because the coil is on a spindle, and the forces act in opposite directions on each side, it rotates.
4) The split-ring commutator is a clever way of swapping the contacts every half turn to keep the motor rotating in the same direction.
5) The direction of the motor can be reversed either by swapping the polarity of the d.c. supply (reversing the current) or swapping the magnetic poles over (reversing the field).

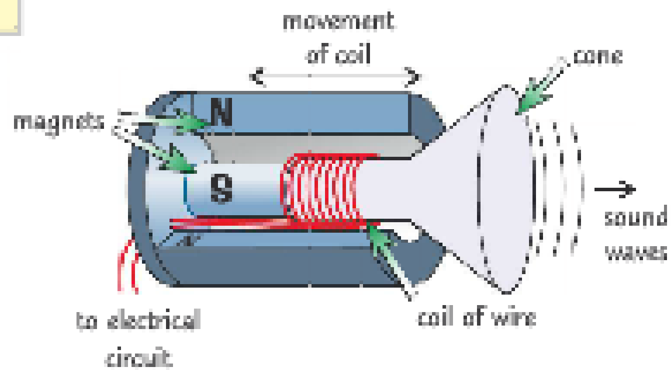


To speed up the motor, increase the current, add more turns to the coil or increase the magnetic flux density.

SP13a Electric motors, microphones and loud speakers

Loudspeakers Use Magnets and a Coil of Wire

1) As well as rotation, the force between a current-carrying coil of wire and a magnetic field can be used to make things move back and forth, like in a loudspeaker.
2) A loudspeaker contains a coil of wire which is surrounded by one magnet. Another magnet is inside the coil.
3) A.c. (alternating current) electrical signals are fed to the coil of wire, which is wrapped around the base of a cone.
4) The interaction between the magnetic field and the current in the coil forces the coil to move in one direction. As it's an alternating current, the current changes direction, forcing the coil back in the other direction. As the current continues to alternate, the coil moves back and forth.
5) These movements make the cone vibrate. This creates pressure variations in the air, i.e. sound.



The coil and cone will move more if the force acting on the coil is larger.

- Microphones work due to magnetic induction. Sound waves cause the diaphragm to move back and forth when hit by them. As the diaphragm moves the coil of wire moves inducing a p.d. across the ends of the coil of wire. The coil is part of a circuit so the induced p.d. means variations in current in the electrical circuit.

SP14e Gas Pressure and Volume

How can we calculate the pressure or volume of a gas?

Volume and Pressure

- If the volume of a gas increases at a constant temperature, the pressure decreases.
- Volume and pressure are inversely proportional
- Volume and pressure are related by this equation:

$$V_1P_1 = V_2P_2$$

V_1 and V_2 are volumes in m^3 and P_1 and P_2 are pressures in Pa.

Volume and Temperature

If the temperature of a gas is increased at a constant pressure, the volume increases.

Volume and temperature are directly proportional and are related by this equation:

$$V_1 = \frac{V_2 T_1}{T_2}$$

V_1 and V_2 are volumes in m^3 and T_1 and T_2 are temperatures in K.

- V = Volume in m^3
- P = Pressure in Pa
- T = Temperature in K

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

P = Pressure of the gas
T = Temperature of the gas
V = Volume of the gas

Combining the equations

The two equations on the left can be combined to give the one above

You will need to be able to select and use these relationships to calculate either P, V or T

SP14e Gas Pressure and Volume Questions

1. What is the link between kinetic energy of particles in a gas and the Kelvin temperature scale?
2. What are the standard units used for volume, pressure and temperature?
3. A bicycle pump compresses $0.000025m^3$ of air to a volume of $0.000010m^3$. What is the pressure of the compressed gas?

SP15c Pressure in Fluids

- Pressure can also be exerted by fluids (liquids and gases). There is pressure on you all the times from the air. At sea level this pressure from the air or atmospheric pressure is about 100,000 Pa(pascals)
- Pressure exerted by the fluid depends on the depth and density of the fluid. The deeper you are the more weight of fluid there is above you to exert the pressure.
- At sea level atmospheric pressure is at its maximum and if you go up a mountain air pressure decreases as there is less air above you.

$$\text{pressure (Pa)} = \frac{\text{force normal to a surface (N)}}{\text{area of that surface (m}^2\text{)}} \quad \text{or} \quad P = \frac{F}{A}$$

Explain what happens to the air pressure if you go down a deep mine.

Compare and contrast the pressure caused by the atmosphere and the sea

SP15 Pressure and Upthrust

Liquid Pressure Causes Upthrust and Makes Things Float

If you submerge (or partially submerge) an object in a liquid, it experiences liquid pressure from all directions due to the particles of the liquid.

This pressure increases with depth, due to the weight of the 'column' of liquid directly above the object.

Liquids can't be compressed (or not very much), so their density is the same everywhere (unlike gases).

The pressure at a given depth (i.e. below a column of liquid of a given height) is given by the equation:

pressure due to a column of liquid (Pa) = height of column (m) × density of liquid (kg/m^3) × g (N/kg)

Here g is the gravitational field strength. It's equal to about 10 N/kg.

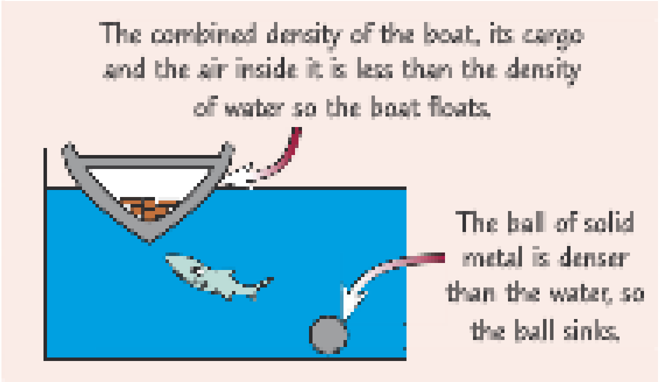
You can also use this equation to find the difference in pressure between two depths — difference in pressure = difference in depth × density × g.

As pressure in a liquid increases with depth, the force pushing upwards on the bottom of an object due to the liquid pressure is greater than the force pushing down at the top of the object.

This causes an overall upwards force, called upthrust.

The upthrust acting on an object is equal to the weight of fluid it has displaced. If this upthrust is equal to the object's weight, then the object will float. If the upthrust is less than the object's weight, it will sink.

So, to make an object float, you need to make it less dense than the liquid you're trying to float it on — so it will have displaced a volume of water with a weight equal to its own weight before it's completely submerged.



Explain why an object submerged in water will experience and upwards force