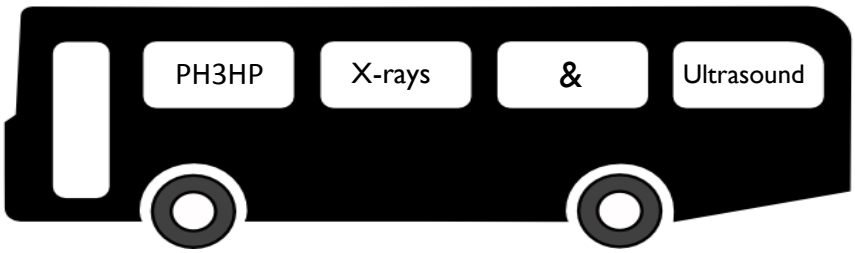
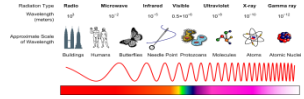


P3.1a Medical applications

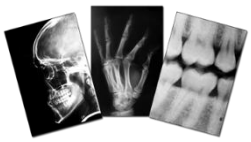
physicsline

X-rays are members of the *electromagnetic spectrum*. Their *wavelength* is very small and of the same order of magnitude as the *diameter of an atom*. X-rays are *ionising* (they knock electrons off other atoms).



X-rays are not used to take images of an unborn child as the X-rays would kill or damage cells which could lead to mutations and/or cancer.

X-rays affect photographic film in the same way as light does. They are *absorbed by dense metal and bones* but *transmitted by soft tissue*. This is why they are used in medicine to *diagnose and treat conditions*. Radiographers wear *lead aprons* to protect themselves from the ionising radiation.



X-rays are used to *check luggage* at the airport, *destroy tumours*, *find bone fractures* and identify dental problems. With *charge-coupled devices (CCDs)*, devices that convert X-rays to light, the X-ray can be converted into an *electronic image* that can be seen on a screen.

CT Scanner
(computerised tomography scanner)

In a CT scan *many X-rays* taken from different positions are combined to produce a *3-D image* of an organ. The organ can be observed from different directions (X-ray images are only 2D).

The *human hearing range is 20Hz to 20000Hz*. *Ultrasound* waves are waves that have a frequency of *above 20000Hz* which cannot be detected by humans.

Ultrasound waves have many *uses*: scanning foetuses, breaking up kidney stones and cleaning delicate jewellery

Cleaning jewellery

The jewellery item is placed into some *cleaning fluid*. Pulses of ultrasound are send through the fluid which makes the *fluid particles vibrate and knock off dirt particles*.

Ultrasound scans

Because ultrasound waves *partially reflect at the boundary between two media*, they are used to scan foetuses to check up on their development. *The time it takes for a narrow beam of ultrasound to return to a detector is measured* and used to produce an image. The *narrower the beam, the more detail is shown*. As different tissues have *different densities*, ultrasound travels at *different speeds*. Any ultrasound waves not reflected are absorbed and transmitted.

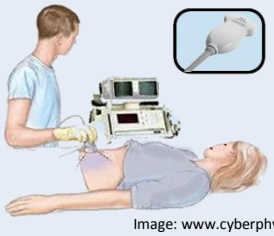


Image: www.cyberphysics.co.uk

A gel is applied to the skin so that the ultrasound pulses don't reflect off the air and skin boundary. Ultrasound waves are non-ionising and therefore do not harm the foetus.

Distance to a material boundary

Using the equation *distance = speed x time*, the distance to a boundary and back is calculated to produce an ultrasound image.

The distance to the boundary (m) =
½ x speed (m/s) x time (s)

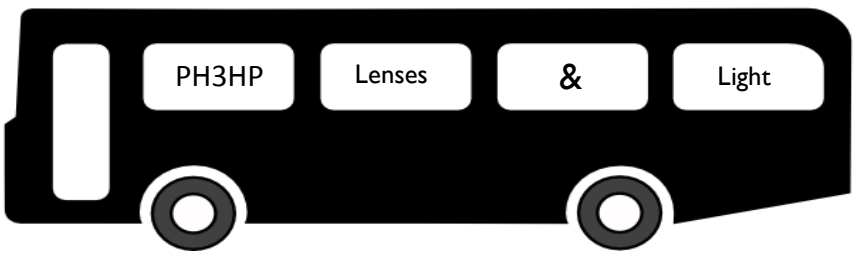
The speed of ultrasound in different materials is known.

X-ray video

ultrasound video

Exam question

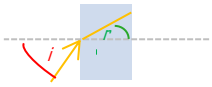
Exam answers



P3.1b Medical applications

physicsline

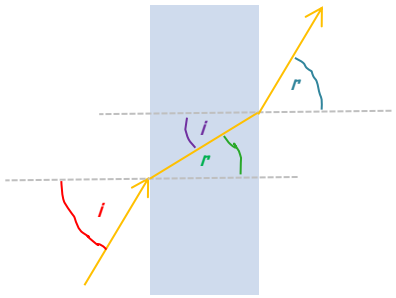
When light passes from one material to another (for example from air to glass), it changes direction. This is called *refraction*.



Different materials refract light rays by different amounts. The refractive index (n) of the material is a measure of how much the material refracts a light ray. It is calculated in the following way:

n= sin *i* / sin *r*

i – angle of incidence; *r* = angle of refraccton

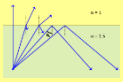


When light travels *from air into a transparent material* (such as glass or plastic), the light ray is refracted towards the normal and **n = sin *i* (angle in air) / sin *r* (angle in glass)**

When light *travels from the transparent material into air*, the light ray is refracted away from the normal and **Sin *r* (angle in air) = n x sin *i* (angle in glass)** first equation rearranged

When the angle of incidence is equal to or greater than the **critical angle**, the light ray is reflected instead of refracted. The critical angle c depends on the refractive index of the material:

n = 1/sin c or sin c = 1/n



Once you have found the value for sin c, use the $\sin^{-1}$ button on your calculator to find the value for c (e.g. if sin c = 0.7, press '$\sin^{-1}$', enter the value 0.7, then press '='. The answer is c = 44.4°)

Optical fibres are thin glass fibres which transmit light or IR-radiation. Light enters the optical fibre at the critical angle and is **totally internally reflected** every time it hits the fibre boundary.

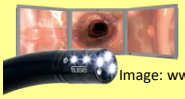


Image: www.gallay.com.au

In medicine, **endoscopes** use optical fibres and a camera to produce an image of the inside of the body. In addition, laser light can be used in an endoscope to cauterise leaking blood vessels, burn away diseased tissue or carry out eye surgery on the retina.

Lenses

Lenses form an image by refracting light.

There are two types of lenses, *concave* and *convex* lenses.

Concave lenses are called *diverging* lenses as they spread light out. Convex lenses are called *converging* lenses as they bring light rays together. Converging lenses are used as magnifying glasses.

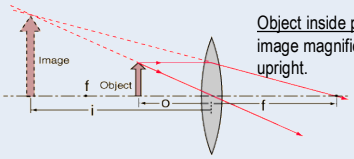
Magnification

The magnification produced by a lens is calculated in the following way:

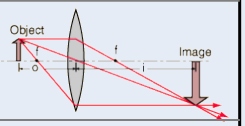
Magnification = image height / object height.
(note: the magnification value can be <1)

There are 2 types of images: **real and virtual**. Real images form on a screen where the light rays meet. Virtual images form where the rays appear to come from (on the same side of the lens as the object).

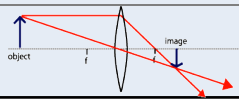
Convex lens



Object inside principle focus F; image magnified, virtual and upright.

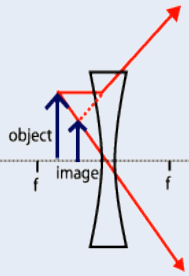


Object between F and 2F; image real, magnified, inverted.



Object outside 2F; image real, diminished, inverted.

Concave lens



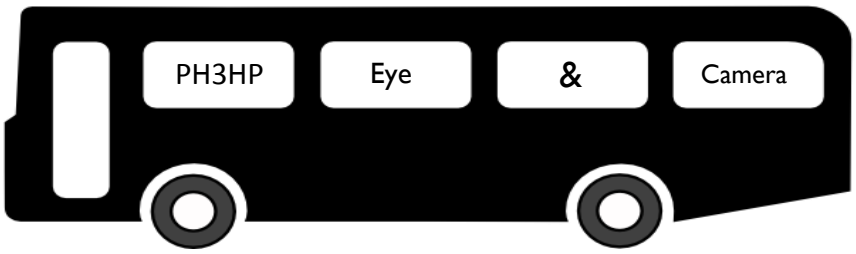
Diminished, virtual and upright image

If the object moves outside the focal point, the size of the image produced diminishes more.

Refractive index video

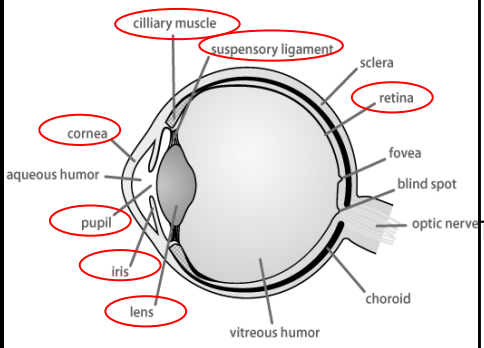
Exam question

Exam answers



P3.1c Medical applications

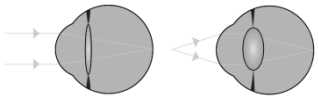
physicsline



The *iris/pupil* changes size to ensure the correct amount of light enters the eye.
The function of the *ciliary muscles* is to change the size and curvature of the lens.
If the muscles contract, they shorten and make the lens thicker.
The *ligaments* connect the lens to the muscles.
The function of the converging *lens* is to focus the light rays onto the *retina* which contains light sensitive cells.
The *cornea* helps to focus the light and protects the eye.

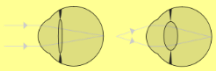
Range of vision

The human eye has a range of vision from 25cm (the *near point*) to infinity (the *far point*). This means that the eye can focus on objects that are 25cm or more from the eye.



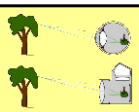
Focusing on distant or far away objects

To focus the light rays from a nearby object onto the retina, the lens has to become thicker. The ciliary muscles and ligaments contract to shorten and squeeze the lens.



To focus the light rays from a distant object onto the retina, the lens has to become longer and thinner. The ligaments and ciliary muscles relax.

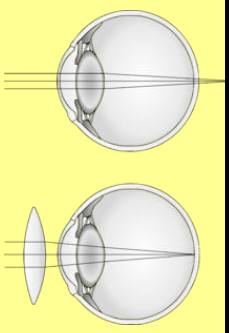
Eye vs Camera



Similarities: both use a converging lens and both form a real, diminished and inverted image.
Differences: the image is projected onto the retina inside the eye but by a photographic film or CCD in cameras. To focus the lens, the muscles inside the eye contract whereas the camera adjusts the lens position instead. The iris controls how much light enters the eye. The same role is carried out by the aperture inside the camera.

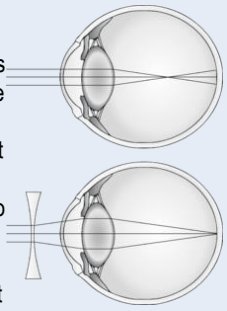
Correcting vision: long sight

If you are long-sighted, the lens focuses the light rays from nearby behind the retina as the eye ball is too short or the lens cannot focus the light rays.
A converging lens is used to converge the light from the nearby object. The lens now focuses the light rays onto the retina.



Correcting vision: short sight

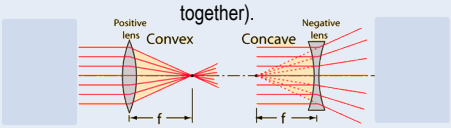
If you are short-sighted, the lens focuses the light rays from far away objects in front of the retina as the eye ball is too long or the lens cannot focus the light rays.
A diverging lens is used to spread the light from the distant object out. The lens now focuses the light rays onto the retina.



Prescription glasses

The power P of a lens = 1/focal length f (m)

The focal length is the distance between the lens and the principal focus (the point where the light rays come together).



The power of a lens is measured in **Dioptres, D**. Converging lenses have a positive value. The higher the value, the shorter the focal length of the lens. Diverging lenses have a negative Dioptre value.

Focal length

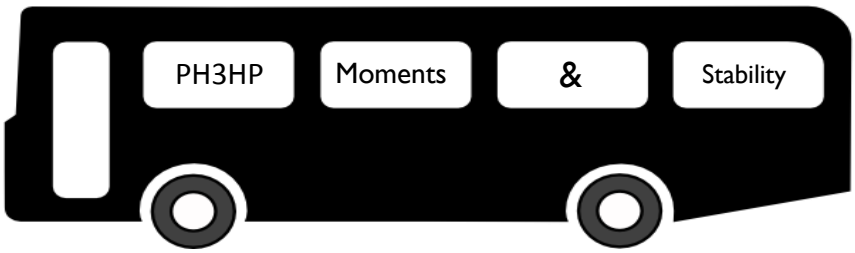
The focal length of a lens depends on the *refractive index* of the lens material and the curvature of the two lens surfaces. To make thinner lenses with the same power, opticians have to use a lens material with a high refractive index so that the *curvature of the lens* can be reduced.

Eye video

Lens power video

Exam question

Exam answers



P3.2a Making things move

physicsline

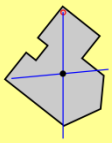
Centre of mass

By definition, the centre of mass of an object is *the point at which the mass of the object may be thought to be concentrated*.

If the object is freely suspended, it will come to rest with its centre of mass directly below the point of suspension.

The centre of mass of a symmetrical object is along the axis of symmetry.

Finding the centre of mass

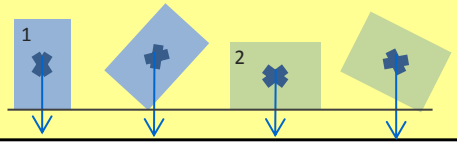


Make a hole in one corner and freely suspend the object. Use a plumb line to draw a vertical line downwards starting at the hole. Repeat at another corner. Where the two lines meet is the centre of mass.

Stability

If the centre of mass does not lie over the base of an object, the object will topple (box 1). Stable objects have a low centre of mass and a wide base (box 2). The line of action of weight falls inside its base.

(Top tip: put all your heavy items at the bottom of your suitcase where the wheels are.)

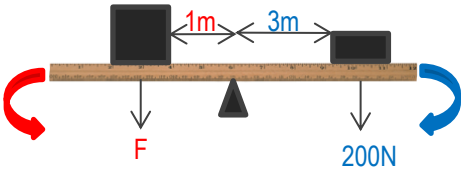


Moments

Forces can make objects turn. This turning effect of a force is called the moment.

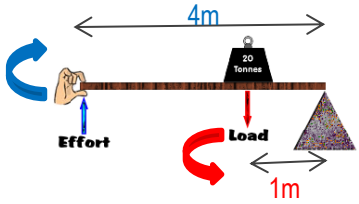
The pivot is the point around which an object turns and the size of the moment is

Moment (Nm) =
Force (N) x distance to pivot (m)



The ruler will not move if the anticlockwise moment = clockwise moment.

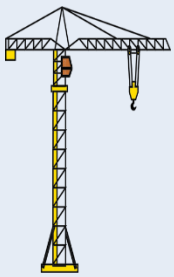
F x 1m = 3m x 200N
If F = 600N, the ruler will not turn.



In this example, both the load and the effort are on the same side of the pivot. The ruler will remain balanced as long as the anticlockwise moment = clockwise moment.

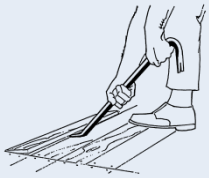
The large block of concrete behind the operator's cabin is there to ensure that the clockwise moment = anticlockwise moment so that the crane does not topple over and the centre of mass remains above the base.

The mass or positionof the concrete block can be adjusted depending on the mass of the load lifted by the crane.

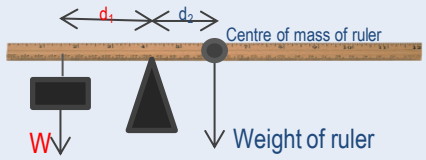


To *increase the turning force* when using a spanner or lever, either apply a *larger force* or use a *longer spanner/lever* because:

Moment = Force x distance to pivot.



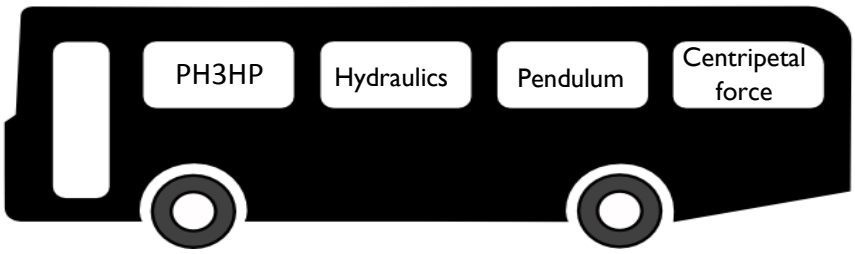
How to calculate the weight of the ruler:



Balance the ruler off-centre using a known weight W. The weight of the ruler acts at its centre of mass and the clockwise moment = weight of the ruler x d_2. The anticlockwise moment = Wxd_1.

Therefore, the weight of the ruler = Wxd_1/d_2

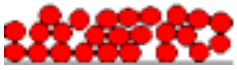
Moments video | Moments II video | Centre of mass video | Stability video | Exam question | Exam answers



P3.2b Making things move

physicsline

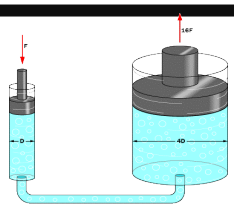
Liquids are almost completely **incompressible** as the particles are still close together.



If a force is exerted at one point on the liquid, it will be transmitted to other points in the liquid. We say that *the pressure P (measured in Pascal Pa) is transmitted equally in all directions.*

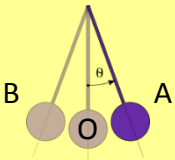
Hydraulic systems, such as a hydraulic jack, use liquids in pipes to transmit and amplify a force.

1. A force is applied to a piston
2. This exerts a pressure in the liquid
3. The pressure (P) depends on the force(F) on, and surface area(A) of the piston: P=F/A
4. The pressure is transmitted equally in all directions.
5. The force is transferred to a piston at the other end of the hydraulic system.
6. The second piston has a larger surface area which produces a larger outward force.



Because the pressure is transmitted equally in all directions, the following relationship is true:
Force 1/Surface area 1 = Force 2/Surface area 2.
The surface area is measured in m^2.

Pendulum
A pendulum is an object that swings freely from its point of suspension.



Swinging from the highest point A to B and back to A is called a cycle. The time taken to complete **1 cycle** is called the **time period T.**

The swinging of the pendulum along the same line is known as **oscillating motion.**

The **amplitude of the oscillation** is the distance from point O (the **equilibrium position**) to the highest point A (or B).

The frequency of the oscillations is the number of cycles per second or:
Frequency (Hz) = 1/time period T (s)

The length of the time period is affected by the length of the pendulum.

The longer the pendulum, the longer the time period.

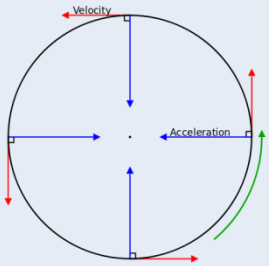
In an experiment you would measure how long it takes for the pendulum to complete 20 cycles and then divide by 20. This will give you the time period T.

Circular motion

In P2 you learnt that when a resultant force acts on an object, it causes a change in the object's state of motion. The object changes speed or direction.

When an object moves at constant speed in a circle, its direction and therefore velocity changes constantly and therefore the object accelerates constantly (acceleration = change in velocity/time).

The acceleration acts towards the centre of the circle as a result of the resultant force which acts towards the centre of the circle.
This resultant force is known as **centripetal force**.



<u>Where does the centripetal force come from?</u>

A car driving round a roundabout: **friction** force between tyres and road
Fair ground rides: **tension** in the ride's struts
Conker on a piece of string: **pull/tension** on string

<u>The centripetal force increases if the mass and speed of the object increase or the radius of the circle gets smaller</u>.

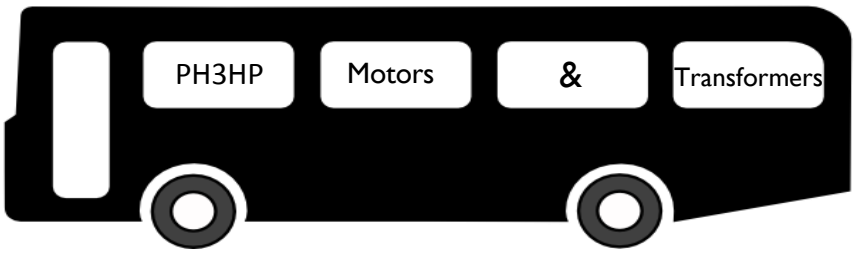
Hydraulics video

Circular motion video

Pendulum video

Exam question

Exam answers



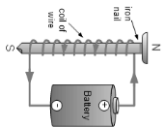
P3.3a Magnetic fields

physicsline

Electromagnetism

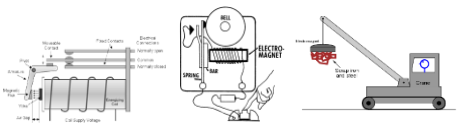
When a current flows through a wire, a magnetic field is produced around the wire.

If an insulated wire is wrapped around an iron bar (called the core), an *electromagnet* is created. When the current runs through the wire, the magnetic field created magnetises the iron bar. When the current is switched off, the iron loses its magnetism.



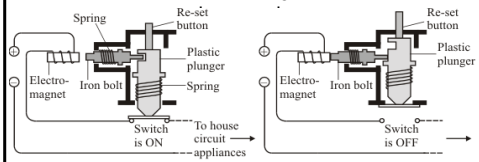
Steel is an unsuitable material for the core as steel does not lose its magnetism.

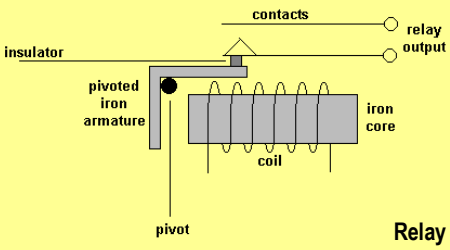
Electromagnets are used in *scrapyards cranes, electric bells, relays and circuit breakers.*



Circuit breakers

A high current flows through the circuit.
This makes the electromagnet stronger.
The iron bolt is pulled out and a plunger moves up.
This lifts the switch, breaks the circuit and stops the current from flowing.
To reset the circuit, the plunger is pushed back.



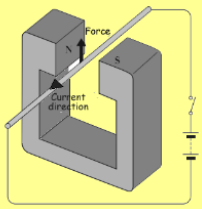


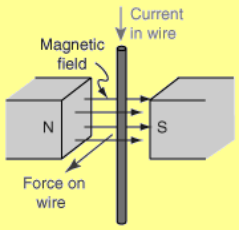
Relay

The current flows through the electromagnet which produces a magnetic field that attracts the iron bar. As a result the contacts are pushed together which closes the gap and completes the circuit.

Motor effect

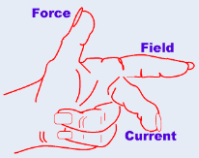
When a current flows through a wire and the wire cuts across a magnetic field, it will feel a force on it. If the wire is parallel to the magnetic field, it won't experience a force.





The *larger the size of the current* or the *stronger the magnet*, the larger the *size of the motor effect (force).*

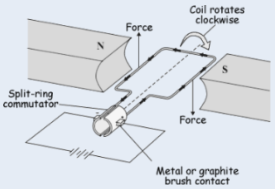
The *direction of the force* is reversed if the direction of the current or the direction of the magnetic field is reversed. Using Fleming's left hand rule, you can work out the direction of the force:



Thumb = Motion
First finger = Field
Second finger = Current

An Electric motor is

a coil through which a current flows that is placed between a permanent magnet.



Each side of the coil experiences a force (up on one side, down on the other) which makes the coil rotate.

The electric *motor can be made more powerful* by increasing the current, using a stronger magnet, increasing the no. of turns.

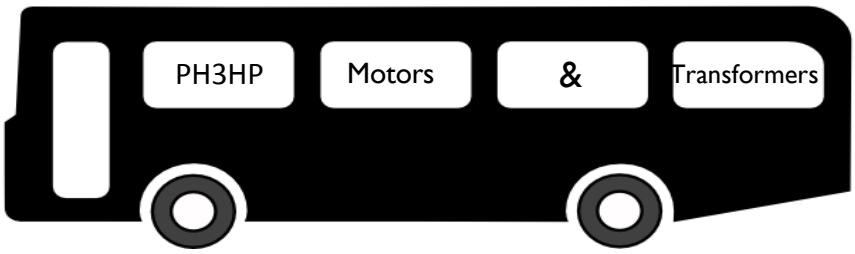
The electric motor is used in many devices, such as hair dryers, electric screwdrivers, washing machines, electric food mixers and drills, DVD players, lifts, etc.

EM video

Motor video

Transformers video

Transformers II video

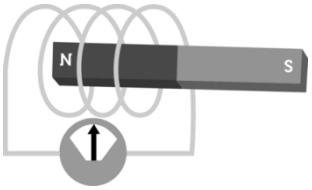


P3.3b Magnetic fields

physicsline

Producing electricity

When a magnet is pushed into a coil, the movement of the magnet causes an induced p.d. in the coil. This in turn causes a current in the coil circuit.



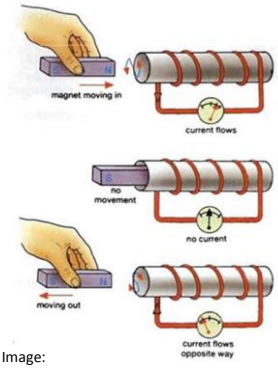


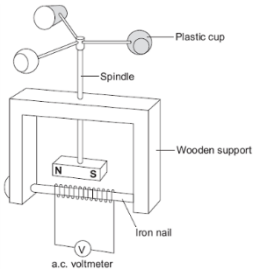
Image: www.frazerphysics.blogspot.com

If the magnet is reversed, the direction of the current is reversed.

If the magnet is moved out of the coil, the current is reversed.

Wind speed gauge

Wind causes the plastic cups to turn. This causes the magnet to spin. This induces a p.d. across the coil and the a.c. voltmeter gives a reading.



Loudspeaker

A diaphragm is attached to a coil. When a current passes through the coil, the coil moves due to the motor effect. As a result the diaphragm moves out. When the direction of the current reverses, so does the force and direction of movement. The vibrations of the diaphragm create sound waves.

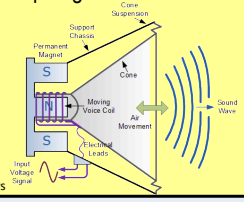
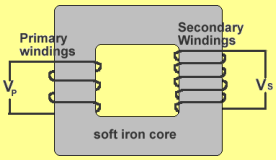


Image: www.electronics-tutorials.ws

Transformers



Transformers are used to change the voltage of an a.c. supply.

p.d. across primary / p.d.across secondary = # of turns on primary / # of turns on secondary

Transformers are used in the *National grid*. The National grid is *useful* because it means that fewer power stations are needed. Electricity can be generated remote from customers, power is available in remote areas and the supply and demand can be controlled easier.

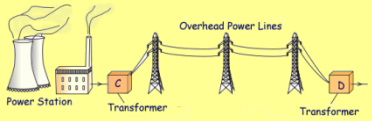
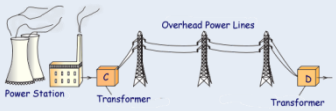


Image: www.cyberphysics.co.uk

How a transformer works

Two separate insulated coils are wrapped around an iron core (insulated so that the core does not become part of the circuit).
An *a.c. p.d.* is applied across the *primary coil* which produces a changing magnetic field. The changing magnetic field induces an a.c. p.d. across the *secondary coil*. As the number of turns is increased in the secondary coil, the a.c. p.d. is increased (and vice versa)

Transformers are *not 100% efficient* as they *become warm* when switched on.



Transformer C is a *step-up transformer* which increases the p.d. There are more turns on the secondary coil than the primary coil.

Transformer D is a *step-down transformer* with fewer turns on the secondary coil to reduce the p.d.

For a 100% efficient transformer:
$V_{primary} \times I_{primary} = V_{secondary} \times I_{secondary}$

Switch mode transformers

These transformers are used in mobile phone or laptop chargers. They are much *smaller* and *lighter* than traditional transformers working from a 50kHz-200kHz supply. They use very *little power* when they are switched on but no load is applied. They are *more efficient* than traditional transformers.

EM video | Motor video | Transformers video | Transformers II video | Exam question | Exam answers