PHYSICS REVISION NOTES

FOR AQA GCSE (9–1)

SIMPLE, CLEAR & MEMORABLE

PAPER 2

Ronaldo Butrus

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USING THIS BOOK

This is **Higher Tier** only material – this means you will only need to revise this if you are sitting the higher tier Physics paper.

This is **Physics (separate science)** only material – this means you will only need to revise this if you are sitting the triple award separate science Physics paper (**8463**).

This is **Higher Tier <u>and</u> Physics (separate science)** only material – this means you will only need to revise this if you are sitting the higher tier Physics paper (**8463**).

THIS IS A SPECIFICATION CHAPTER

1.1 THIS IS A SPECIFICATION TOPIC

1.1.1 This is a specification subtopic

1.1.1.1 This is a section of a specification subtopic

5 FORCES

5.1 FORCES AND THEIR INTERACTIONS

5.1.1 Scalar and vector quantities

- Scalar quantities have magnitude only.
- Vector quantities have magnitude and an associated direction.

- A vector quantity may be represented by an arrow where:
  - the length of the arrow represents the magnitude
  - the direction of the arrow represents the direction of the vector quantity

5.1.2 Contact and non-contact forces

- A force is a push or pull that acts on an object due to the interaction with another object.
- Force is a vector quantity.

- All forces between objects are either:
  - **contact forces:** the objects are physically touching
    - e.g. friction, air resistance, tension and normal contact force
  - **non-contact forces:** the objects are physically separated
    - e.g. gravitational force, electrostatic force and magnetic force

5.1.3 Gravity

- Weight is the force acting on an object due to gravity.
- The force of gravity close to Earth is due to the gravitational field around the Earth.
- The weight of an object depends on the gravitational field strength at the point where the object is.
- Weight is measured using a calibrated spring-balance (a newtonmeter).

weight (N) **= mass** (kg) **x gravitational field strength** (N/kg)

W = m g

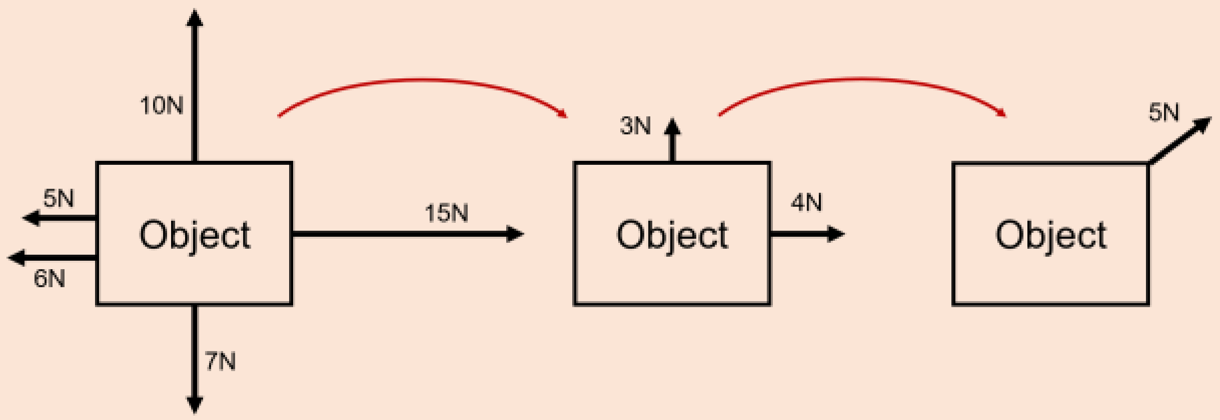
- An object's centre of mass is a single point where the its weight is considered to act.

- How to find an object's centre of mass:
  - suspend object from a point using a stand
  - suspend a plumbline (string with weight on the end) from that point
  - use plumbline to draw a vertical line on the object
  - repeat from different points of suspension
  - the centre of mass is where the lines cross

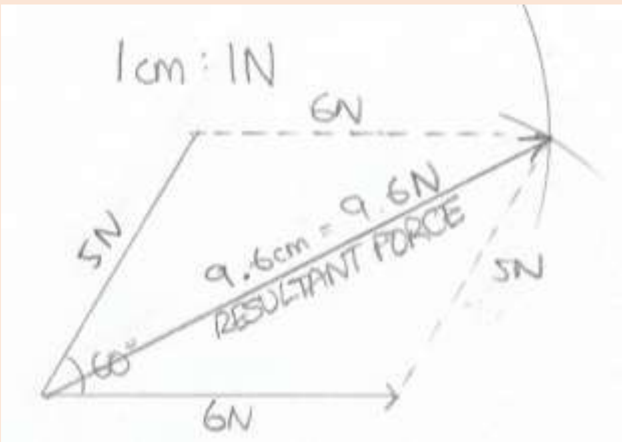
5.1.4 Resultant force

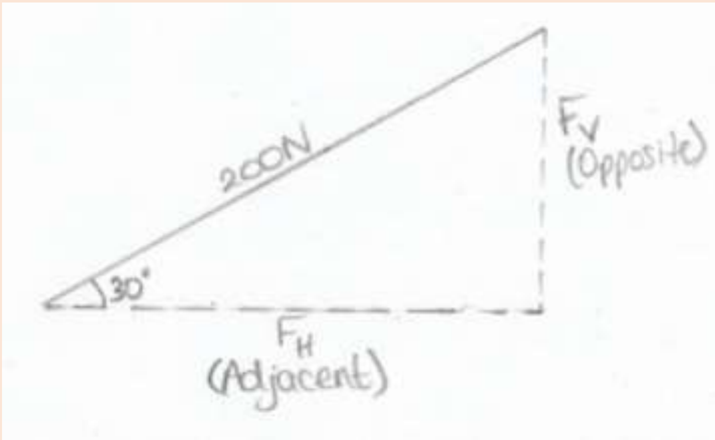
- A resultant force is a single force that has the same effect as all the forces acting on an object.

- Free body diagrams can be used to represent this:



- A single force can be resolved into two components acting at right angles to each other.
- The two component forces together have the same effect as the single force.





5.2 WORK DONE AND ENERGY TRANSFER

- When a force causes an object to move through a distance work is done on the object.
- This means a force does work on the object when the force causes a displacement of the object.

work done (J) **= force** (N) **x distance** (m)

W = F s

- One joule of work is done when a force of one newton causes a displacement of one metre.
- 1 joule = 1 newton-metre

- Work done against the frictional forces acting on an object causes a rise in the temperature of the object.

5.3 FORCES AND ELASTICITY

- The extension of an object, such as a spring, is directly proportional to the force applied, provided that the limit of proportionality is not exceeded.

force (N) **= spring constant** (N/m) **x extension** (m)

F = k e

- An elastic deformation is a change in shape that is reversed when the force is removed.
- An inelastic deformation is not reversed when the force is removed.

- When an object's shape is changed (by stretching, bending or compressing), more than one force has to be applied because a single force would only displace the object.

- A force that stretches (or compresses) a spring does work and elastic potential energy is stored in the spring.
- Provided the spring is not inelastically deformed, the work done on the spring and the elastic potential energy stored are equal.

- In a linear relationship, the highest exponent is 1, and the graph of force and extension is a straight line. If it passes through the origin, they are directly proportional.
- In a non-linear relationship, the highest exponent exceeds 1, and the graph of force and extension is a curve.

5.4 MOMENTS, LEVERS AND GEARS

- A force or a system of forces may cause an object to rotate.
- The moment of a force is its turning effect.

moment of a force (Nm) **= force** (N) **x distance** (m)

M = F d

The distance is the perpendicular distance from the pivot to the line of action of the force.

- If an object is balanced, the total clockwise moment about a pivot equals the total anticlockwise moment about that pivot.

- A simple lever and a simple gear system can both be used to transmit the rotational effects of forces.

- A lever is used as a force multiplier as it exerts a greater force than is applied by the user:
  - it increases the perpendicular distance from the line of action of the force to the pivot
  - this increases the moment

- Low gear:
  - a small gear wheel (engine) turns a large gear wheel (output)
  - the output shaft turns slower than the engine shaft:
    - because the moment of the output shaft is greater than the moment of the engine shaft
  - low gear gives low speed and a high turning effect

- High gear:
  - a large gear wheel (engine) turns a small gear wheel (output)
  - the output shaft turns faster than the engine shaft:
    - because the moment of the output shaft is lower than the moment of the engine shaft
  - high gear gives high speed and a low turning effect

5.5 PRESSURE AND PRESSURE DIFFERENCES IN FLUIDS

5.5.1 Pressure in a fluid

5.5.1.1 Pressure in a fluid 1

- A fluid can either be a liquid or a gas.
- The pressure in fluids causes a force normal to any surface.

$$\textbf{pressure}\ (\text{Pa}) = \frac{\textbf{force normal to a surface}\ (\text{N})}{\textbf{area of that surface}\ (\text{m}^2)}$$

$$p = \frac{F}{A}$$

5.5.1.2 Pressure in a fluid 2

pressure (Pa) **= height of column** (m) **x density of liquid** (kg/m^3) **x gravitational field strength** (N/kg)

$$p = h\,\rho\,g$$

- As the height of the column increases, there is a larger weight, hence a larger force.

- Upthrust is a force where:
  - a partially (or totally) submerged object experiences a greater pressure on the bottom surface than on the top surface
  - this creates a resultant force upwards

- Factors which influence floating and sinking:
  - **shape:** an object with a smaller bottom and larger top sinks faster
  - **density:** smaller contact area causes larger pressure downwards

5.5.2 Atmospheric pressure

- The atmosphere is a thin layer (relative to the size of the Earth) of air round the Earth.

- The atmosphere gets less dense with increasing altitude:
  - air molecules colliding with the surface create atmospheric pressure
  - the number of air molecules (and so the weight of air) above a surface decreases as the height of the surface above ground level increases
  - as height increases there is always less air above a surface than at a lower height
  - so atmospheric pressure decreases with an increase in height

5.6 FORCES AND MOTION

5.6.1 Describing motion along a line

5.6.1.1 Distance and displacement

Distance:
- how far an object moves
- scalar quantity (magnitude only – no direction)

Displacement:
- how far and object moves in a straight line from start to finish
- vector quantity (magnitude and direction)

5.6.1.2 Speed

speed (m/s) = $\frac{\textbf{distance}\text{ (m)}}{\textbf{time}\text{ (s)}}$ speed is a scalar quantity

$$\mathbf{v = \frac{s}{t}}$$

- Typical values of speed:
  - walking ~ 1.5 m/s
  - running ~ 3 m/s
  - cycling ~ 6 m/s
  - car ~ 20 m/s
  - train ~ 56 m/s
  - plane ~ 250 m/s
  - sound ~ 330 m/s

- As speed involves **distance**, speed is a scalar quantity.

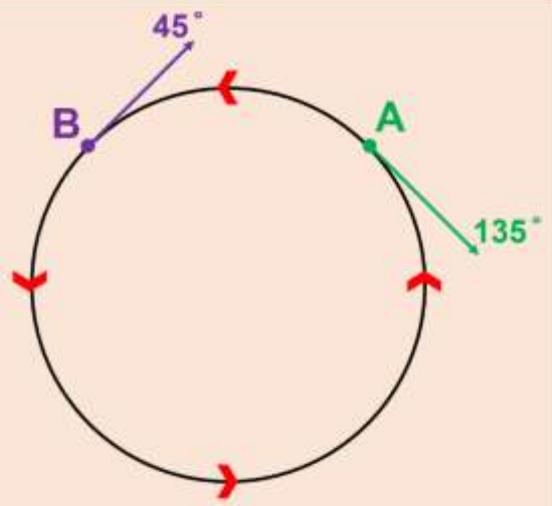
5.6.1.3 Velocity

velocity (m/s) = $\frac{\textbf{displacement}\text{ (m)}}{\textbf{time}\text{ (s)}}$ velocity is a vector quantity

$$\mathbf{v = \frac{s}{t}}$$

- As velocity involves **displacement**, velocity is a vector quantity.

- Motion in a circle involves constant speed but changing velocity as the direction (and displacement) of motion constantly changes.



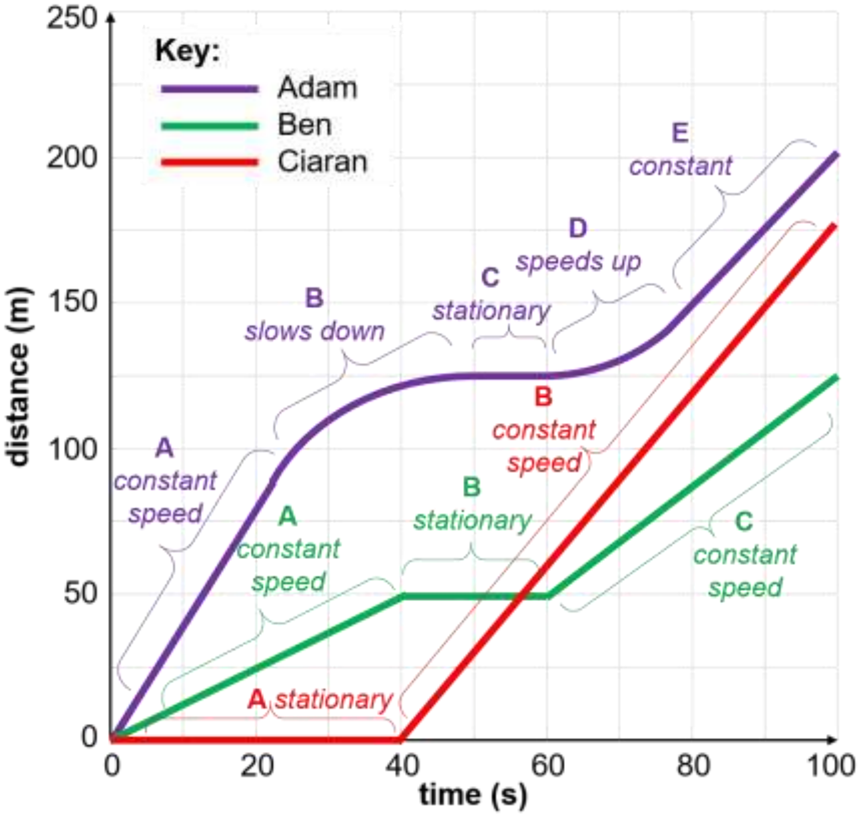
At point A, the direction of motion is 135˚ from the vertical.

At point B, the direction of motion is 45˚ from the vertical.

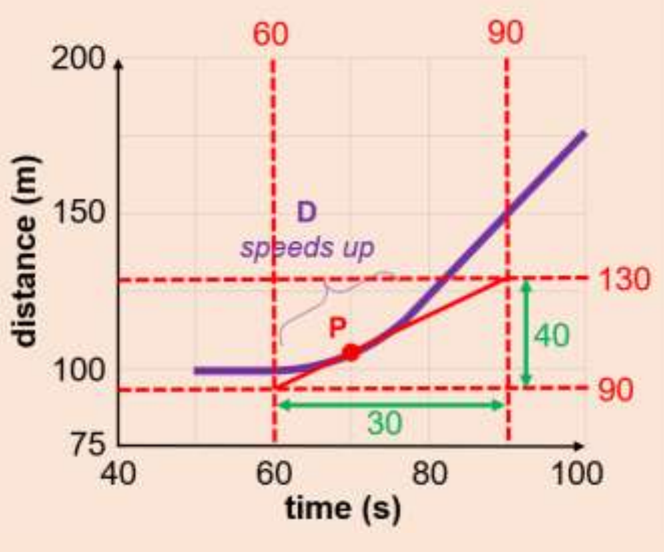
While speed is constant around the circle (as speed does not involve direction), displacement is continuously changing (as direction changes from 0˚ to 360˚.

5.6.1.4 The distance-time relationship

A graph showing distance covered in a 100-second race



- The speed of an object can be calculated from the gradient of its distance time graph:
- e.g. in Ciaran's section B, he ran 175m (y-axis) in 100-40s (x-axis)
- so distance = 175m, time = 60s
- and speed = 175 ÷ 60 = 2.9 m/s



If an object is accelerating, its speed can be determined by drawing a tangent to the curve and measuring its gradient:

E.g. at point P, we draw a tangent to the curve and measure its length on the x and y axes.

Speed at P = 40 ÷ 30 = 1.3 m/s

5.6.1.5 Acceleration

acceleration (m/s²) = $\frac{\textbf{change in velocity (m/s)}}{\textbf{time (s)}}$

$$a = \frac{\Delta v}{t}$$

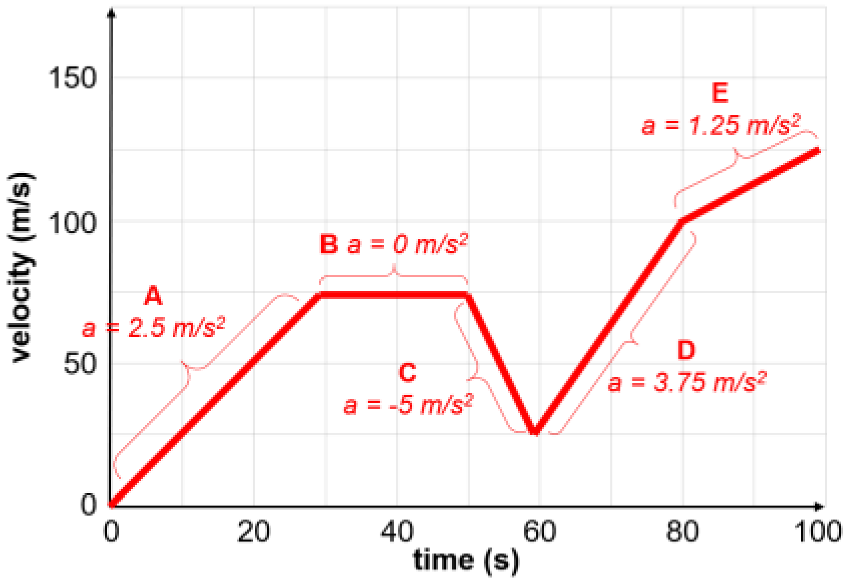
acceleration (m/s²) = $\frac{\textbf{final velocity – initial velocity (m/s)}}{\textbf{time (s)}}$

$$a = \frac{v - u}{t}$$

- The acceleration of an object is the change in velocity per second.

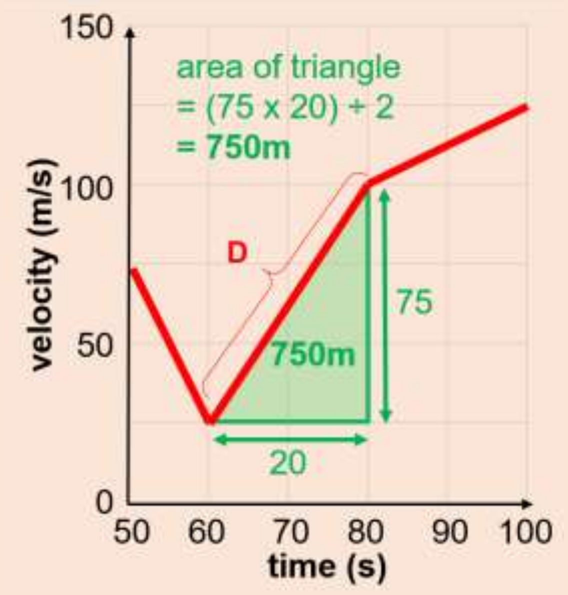
- An object with a positive acceleration is said to be accelerating.
- An object with a negative acceleration is said to be decelerating, or accelerating in reverse.

- Typical acceleration values:
  - car ~ 4 m/s^2
  - train ~ 0.2 m/s^2
  - plane ~ 3 m/s^2



- The acceleration of an object can be calculated from the gradient of its velocity-time graph, e.g.:

  at **A**: velocity changes from 0 to 75 m/s in 30 s, so 75 ÷ 30 = 2.4 m/s^2



The distance travelled by an object can be calculated from the area under a velocity-time graph.

On this velocity-time graph, the area of the triangle (for section **D**) represents the distance travelled between 60 and 80s.

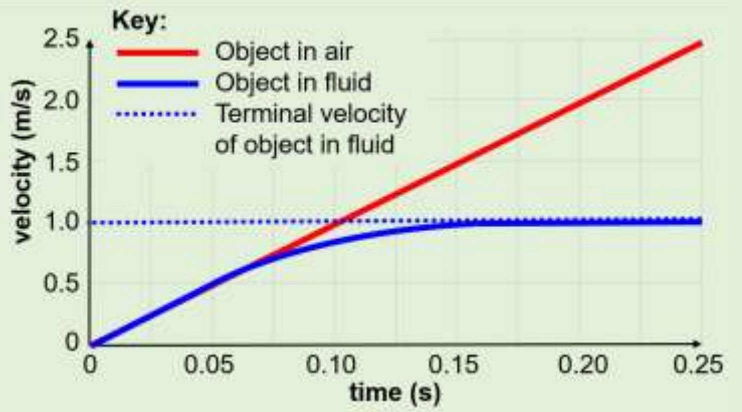
Alternatively, you can count the squares, where each square represents 250m (10 x 25):
3 squares x 250m = 750m

For objects in uniform acceleration (i.e. where acceleration is constant):

(final velocity)^2 (m/s) **– (initial velocity)^2** (m/s) **= 2 x acceleration** (m/s^2) **x distance** (m)

$v^2 - u^2 = 2\,a\,s$

- Near the Earth's surface a freely falling object has an acceleration of 9.8 m/s^2 due to gravity.
- An object falling through a fluid initially accelerates at 9.8 m/s^2 due to gravity then, when the resultant force eventually gets zero, it moves at its terminal velocity (maximum speed).



This is a velocity-time graph for an object falling through a fluid.

1. Initially it accelerates downwards due to gravity.
2. Eventually, weight and drag force are equal and opposite, with no resultant force.
3. It reaches its terminal velocity at 1.0 m/s after about 0.15 s.

5.6.2 Forces, accelerations and Newton's Laws of motion

5.6.2.1 Newton's First Law

- If the resultant force acting on an object is zero it remains stationary or in uniform motion.
- A vehicle travelling at a constant speed has a zero resultant force by balancing the driving and resistive forces.
- Therefore, the velocity (speed and/or direction) of an object will only change is there is a resultant force on the object.

- Inertia is an object's tendency to continue in their state of rest or of uniform motion.

5.6.2.2 Newton's Second Law

force (N) **= mass** (kg) **x acceleration** (m/s^2)
F = m a

- Where you write an approximate answer, use the following symbol:
  ~ weak approximation, e.g. ~ 2 m/s where the true value is 2.4
  ≈ strong approximation, e.g. ≈ 6 m/s where the true value is 6.01

$$\textbf{inertial mass}\ (\text{kg}) = \frac{\textbf{force}\ (\text{N})}{\textbf{acceleration}\ (\text{m/s}^2)}$$

$$m = \frac{F}{a}$$

- Inertial mass is a measure of how difficult it is to change the velocity of an object.

5.6.2.3 Newton's Third Law

- Whenever two objects interact, they exert equal and opposite forces on each other.

5.6.3 Forces and braking

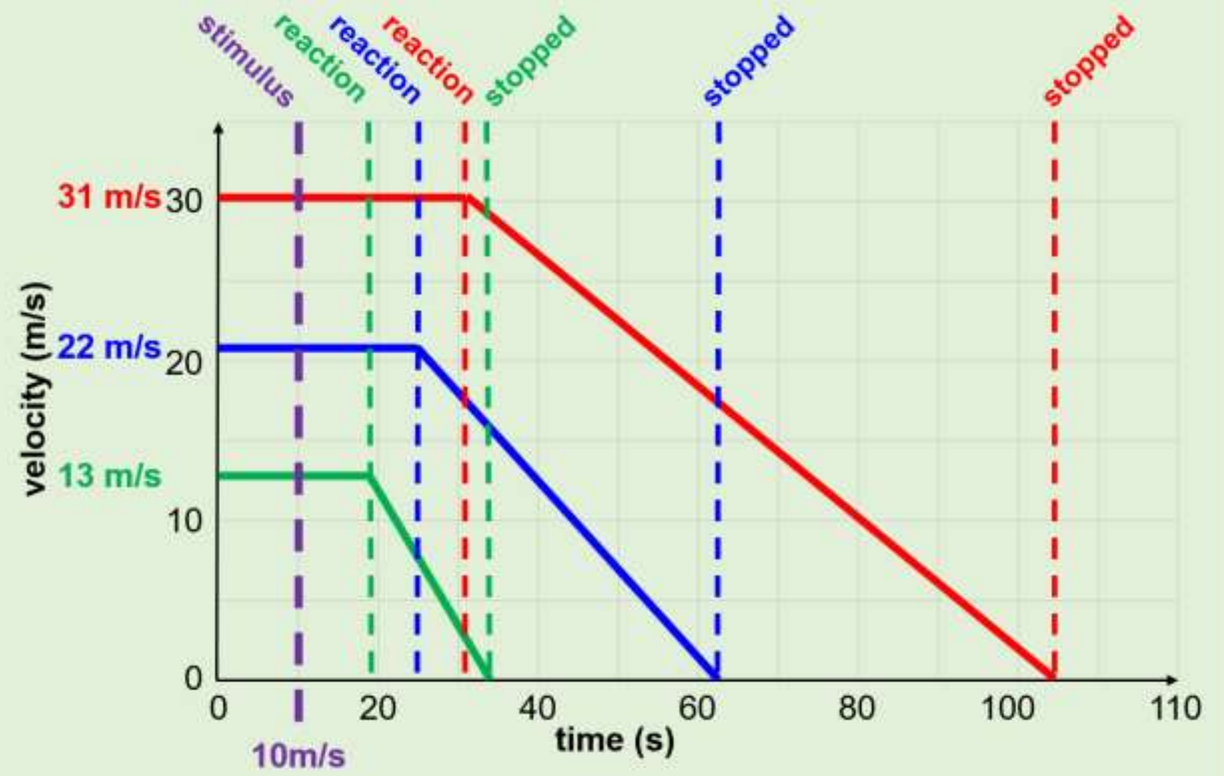
5.6.3.1 Stopping distance

stopping distance = thinking distance + braking distance

- Thinking distance is the distance travelled during the driver's reaction time.
- Braking distance is the distance travelled under the braking force.

- For a given braking force, the greater the speed of a vehicle, the greater the stopping distance.

- Typical braking distances:
    - 30mph: 22.5m
    - 50mph: 52.5m
    - 70mph: 96m



5.6.3.2 Reaction time

- Typical reaction time is 0.2 to 0.9s.

- Factors affecting reaction time:
    - tiredness
    - drugs
    - alcohol
    - distractions

- Ways to measure reaction time:
    - dropping a ruler between forefingers and thumb and seeing how far the ruler travels at an acceleration of $9.8 m/s^2$
    - pressing a button when you see a letter or number on a screen

5.6.3.3 Factors affecting braking distance 1

- Factors affecting braking distance:
    - adverse road and weather conditions (wet/icy)
    - poor vehicle condition (worn out brakes/tyres)

5.6.3.4 Factors affecting braking distance 2

- The greater the speed of a vehicle the greater the braking force needed to stop the vehicle in a certain distance.
- The greater the braking force the greater the deceleration of the vehicle.

- Large decelerations may lead to:
    - brakes overheating (sparks)
    - loss of control

- When the brakes are applied:
    - work is done by the frictional force between the brakes and the wheel
    - this reduces the vehicle's kinetic energy
    - energy is thereby transferred to the brakes' thermal energy store
    - large decelerations may lead to brakes overheating

5.7 MOMENTUM

5.7.1 Momentum is a property of moving objects

momentum (kg m/s) **= mass** (kg) **x velocity** (m/s)

p = m v

5.7.2 Conservation of momentum

- The law of conservation of momentum states:
- In a closed system, the total momentum before an event is equal to the total momentum after the event.

5.7.3 Changes in momentum

- Momentum changes when a force acts on a moving object.

F = ma where $a = \frac{\Delta v}{t}$

$\therefore F = \frac{m\,\Delta v}{\Delta t}$

$\therefore F = \frac{\Delta p}{\Delta t}$ **or** **impact force** (N) = $\frac{\textbf{change in momentum (kg m/s)}}{\textbf{change in time (s)}}$

∴ **impact force = rate of change of momentum**

- Safety features typically work as follows:
  - increase impact time, Δt
  - ∴ decrease rate of change of momentum (to zero – stationary)
  - ∴ decrease force on colliding person on object and vice versa

- Safety features include:
  - air bags
  - seat belts
  - gymnasium crash mats
  - cycle helmets
  - cushioned surfaces for playgrounds

6 WAVES

6.1 WAVES IN AIR, FLUIDS AND SOLIDS

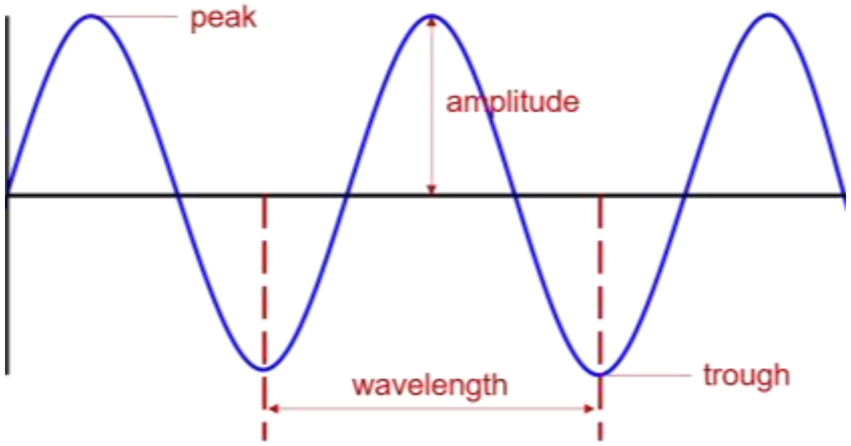
6.1.1 Transverse and longitudinal waves

- Transverse waves:
    - oscillations perpendicular to direction of energy transfer
    - e.g. ripples on water surface

- Longitudinal waves:
    - oscillations parallel to direction of energy transfer
    - show areas of compression and rarefaction
    - e.g. sound waves in air

- Why the wave, not the medium travels:
    - for ripples on a water surface, a floating object will not have a net movement
    - for sound waves in air, a vibrating tuning fork and air don't move, but vibrate

6.1.2 Properties of waves



- Properties of a wave:
    - **amplitude:** maximum displacement of a point on a wave away from its undisturbed position
    - **wavelength:** distance from a point on one wave to equivalent point on adjacent wave
    - **frequency:** number of waves passing a point each second

$$\textbf{period}\text{ (s)} = \frac{1}{\textbf{frequency}\text{ (Hz)}}$$

$$T = \frac{1}{f}$$

- Wave speed is the speed at which energy is transferred through the medium.
- All waves obey the wave speed equation:

wave speed (m/s) **= frequency** (Hz) **x wavelength** (m)

v = f λ

- Measuring speed of sound waves in air:
    - two people stand on opposite sides of field
    - friend bangs two cymbals together
    - time interval between seeing and hearing cymbals crash using a stopwatch
    - speed = distance ÷ time
    - repeat experiment to calculate a mean

- Measuring speed of ripples on a water surface:

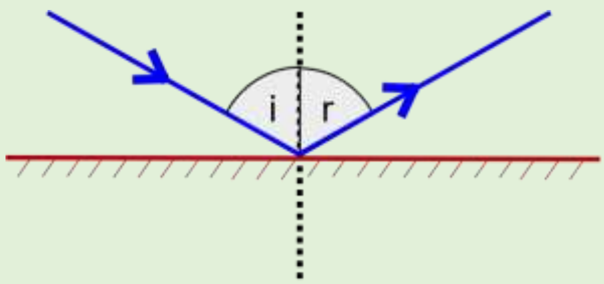
    <u>Measuring wavelength</u>
    - set up ripple tank above plain surface with stroboscope above
    - connect oscillator (on water surface) to oscilloscope
    - set stroboscope and oscilloscope to same frequency so as to make a 'still' image on the surface below
    - place a relatively thin transparent ruler in the ripple tank
    - on the reflection, count the number of strokes on the ruler the wavelength takes up

    <u>Measuring frequency</u>
    - for 10 seconds, count how many waves pass a point (mark this using a label)
    - divide this by 10 to obtain the frequency

    <u>Calculating wave speed</u>
    - use the wave speed equation (v = f λ) to calculate wave speed

6.1.3 Reflection of waves

- Waves can be reflected, absorbed or transmitted at the boundary between two different materials:
    - **reflection:** wave reflected at same angle as that of incidence
    - **absorption:** some wave energy absorbed by medium
    - **transmission:** wave goes through to next medium



6.1.4 Sound waves

- Sound waves can travel through solids causing vibrations in the solid.

- How we hear:
  - sound waves cause ear drum and other parts to vibrate
  - this causes a sensation of sound
  - conversion of sound waves to vibrations of solids works over a limited range of frequencies
  - this restricts the limits of human hearing (20Hz to 20kHz)

6.1.5 Waves for detection and exploration

- Ultrasound waves:
  - have a frequency higher than 20kHz
  - are partially reflected when they meet a boundary line between two different media
  - time taken for reflections to reach detector can be used to determine distances
  - this allows ultrasound waves to be used for medical and industrial imaging e.g. prenatal scanning, undersea scanning

- Seismic waves:
  - produced by earthquakes
  - P-waves are longitudinal, seismic waves that travel through solids and liquids
  - S-waves are transverse, seismic waves cannot travel through a liquid
  - P-waves and S-waves provide evidence for the structure and size of the Earth's core, which are not directly observable otherwise

- Echo sounding:
  - using high frequency sound waves to:
    - detect objects in deep water
    - measure water depth

6.2 ELECTROMAGNETIC WAVES

6.2.1 Types of electromagnetic waves

- Electromagnetic waves are transverse waves that transfer energy from the source of the waves to an absorber.

- Electromagnetic waves form a continuous spectrum and all types of electromagnetic wave travel at the same velocity through a vacuum or air.

- In this order, *wavelength decreases* and *frequency increases*:
  - radio waves
  - microwaves
  - infrared
  - visible light
  - ultraviolet
  - X-rays
  - gamma rays

- Human eyes only detect visible light and so detect a limited range of electromagnetic waves.

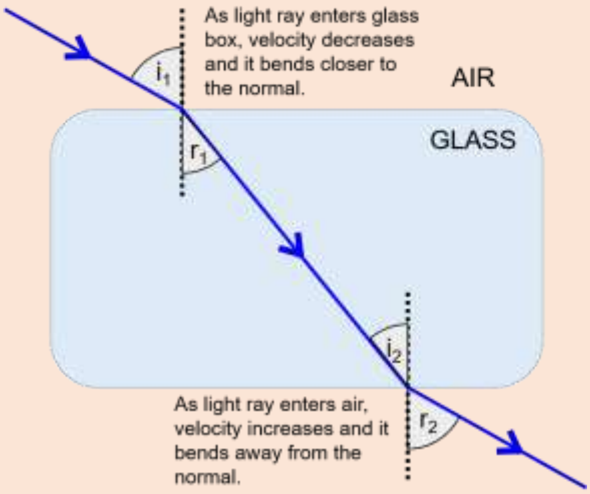
- Examples of transfer of energy by electromagnetic waves:
  - humans cool down by emitting infrared radiation
  - remote control transmits signals to TV
  - radio waves carry mobile phone signals

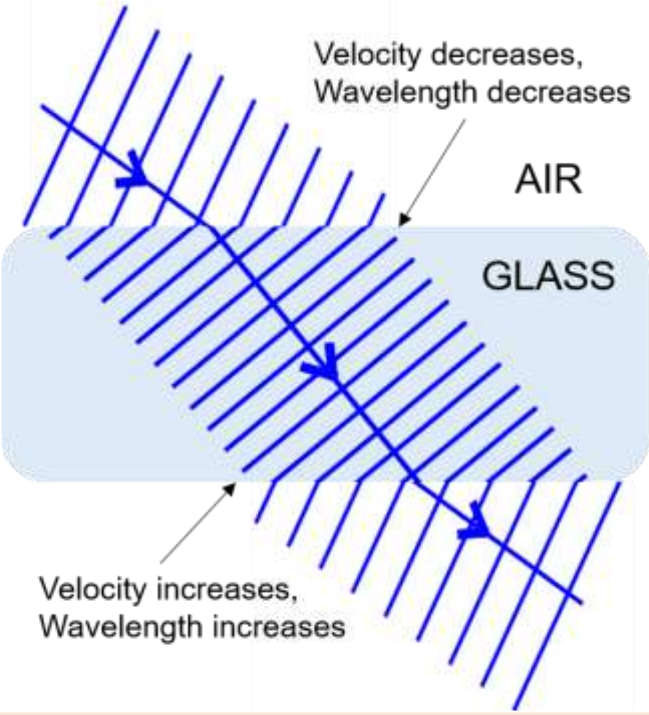
6.2.2 Properties of electromagnetic waves 1

- Different substances may absorb, transmit, refract or reflect electromagnetic waves in ways that vary with wavelength.
- Some effects are due to the difference in velocity of the waves in different substances.

- Transmission of sound waves from one medium to another:
  - light ray enters glass box
  - wavelength decreases, so velocity decreases
  - ray bends towards normal

  - light ray exits glass box
  - wavelength increases, so velocity increases
  - ray bends away from normal





- A wave front diagram shows what happens to the wavelength of an electromagnetic wave.

- In the diagram above, the light ray refracts, as light travels slower through the glass (solid) than the air (gas).

6.2.3 Properties of electromagnetic waves 2

- Radio waves:
    - can be produced by oscillations in electrical circuits
    - may create an alternating current with the same frequency as the wave itself upon absorption, so can induce oscillations in an electrical circuit

- Ultraviolet waves, X-rays and gamma rays can have hazardous effects on human body tissue, depending on the:
    - **type of radiation:** X-rays and gamma rays are ionising radiation that can cause the mutation of genes and cancer
    - **radiation dose:** a measure of the risk of harm resulting from an exposure of the body to radiation, in sieverts (Sv)

- Ultraviolet waves:
    - can cause skin to age prematurely
    - increase the risk of skin cancer

- Gamma rays:
    - originate from changes in the nucleus of an atom
    - have a wide frequency range

6.2.4 Uses and applications of electromagnetic waves

- Electromagnetic waves have many practical applications:
  - **radio waves:**
    - television (between TV masts)
    - radio (around local radio stations)
  - **microwaves:**
    - satellite communications (enough energy to travel into space)
    - cooking food (can penetrate food in microwave)
  - **infrared:**
    - electrical heaters (emit infrared radiation to transfer energy)
    - cooking food (electrical hobs emit infrared radiation to cook food)
    - infrared cameras (detect levels of infrared being emitted by objects)
  - **visible light:**
    - fibre optic communications (light rays repeatedly reflected through glass core)
  - **ultraviolet:**
    - energy efficient lamps (absorb UV light produced inside lamp and re-emit this as visible light)
    - sun tanning (skin darkens to protect from UV light)
  - **X-rays and gamma rays:**
    - medical imaging (X-rays only absorbed by denser parts of body)
    - treatment (gamma rays used to kill cancerous cells)

7 MAGNETISM & ELECTROMAGNETISM

7.1 PERMANENT AND INDUCED MAGNETISM, MAGNETIC FORCES AND FIELDS

7.1.1 Poles of a magnet

- The poles of a magnet are the places where the magnetic forces are strongest.
- When two magnets are brought close together they exert a force on each other.
- Two like poles repel each other.
- Two unlike poles attract each other.
- Attraction and repulsion between two magnetic poles are examples of non-contact force.

- A permanent magnet produces its own magnetic field.

- An induced magnet is a material that becomes a magnet when placed in a magnetic field.
- Induced magnetism always causes a force of attraction.
- When removed from the magnetic field, an induced magnet loses most/all of its magnetism quickly.

7.1.2 Magnetic fields

- A magnetic field is the region around a magnet where a force acts on another magnet or on a magnetic material (iron, steel, cobalt and nickel).

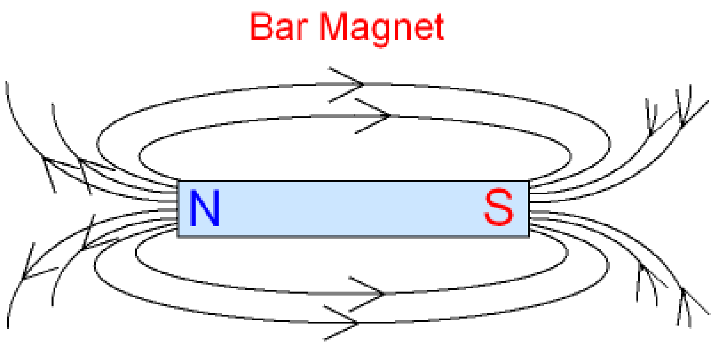
- The force between a magnet and a magnetic material is always one of attraction (induced).

- The strength of the magnetic field depends on the distance from the magnet.
- The field is strongest at the poles of the magnet.

- The direction of the magnetic field at any point is given by the direction of the force that would act on another north pole placed at that point.
- The direction of a magnetic field line is from the north(seeking) pole of a magnet to the south(seeking) pole of the magnet.

- A magnetic compass contains a small bar magnet which points in the direction of the Earth's magnetic field.

- To plot the magnetic field pattern of a magnet using a compass:
    - place the compass at different points around the magnet
    - at each point, mark the direction the compass is pointing in



- To draw the magnetic field pattern of a bar magnet:
    - closer lines mean a stronger magnetic field
    - field lines should point from north to south

- The Earth's magnetic field:
    - its outer core is liquid iron and nickel
    - this causes a magnetic field
    - when a magnet is freely suspended, the north-seeking pole of the magnet points to Earth's magnetic north pole and it aligns with the Earth's magnetic field

7.2 THE MOTOR EFFECT

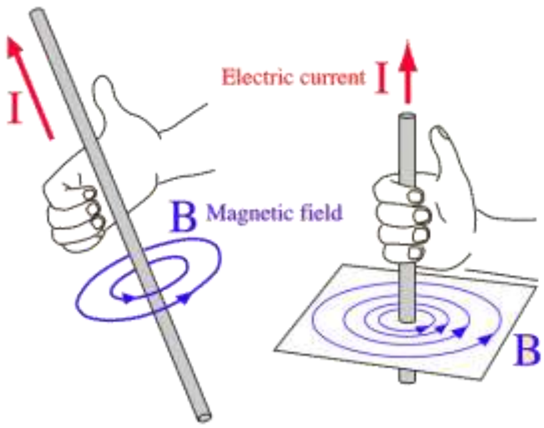
7.2.1 Electromagnetism

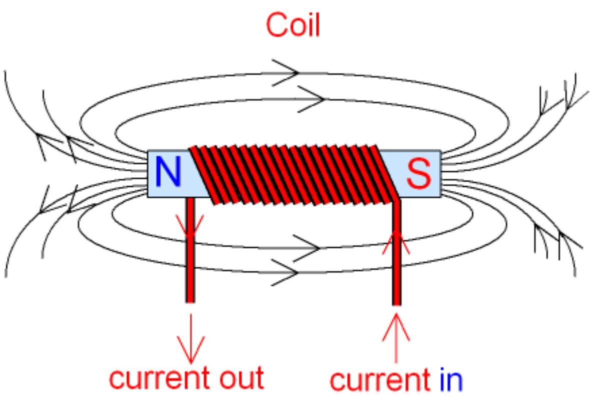
- When a current flows through a conducting wire a magnetic field is produced around the wire.
- The strength of the magnetic field depends on:
  - the **current** through the wire
  - the **distance from the wire**

- Shaping a wire to form a solenoid increases the strength of the magnetic field created by a current through the wire.
- The magnetic field inside a solenoid is strong and uniform.

- The magnetic field around a solenoid has a similar shape to that of a bar magnet.
- Adding an iron core increases the strength of the magnetic field of a solenoid.

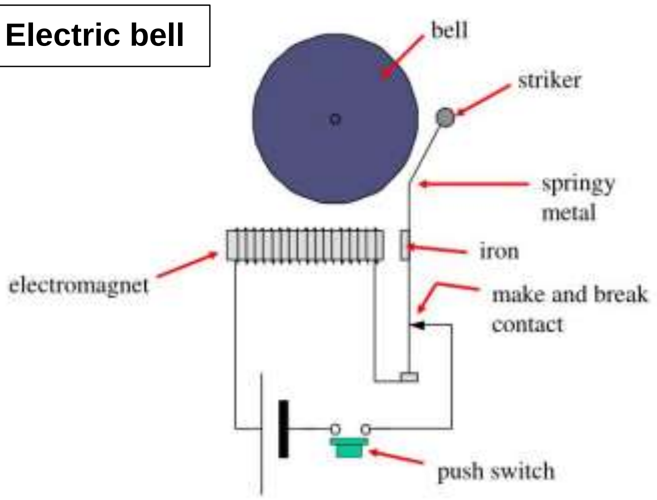
- An electromagnet is a solenoid with an iron core.



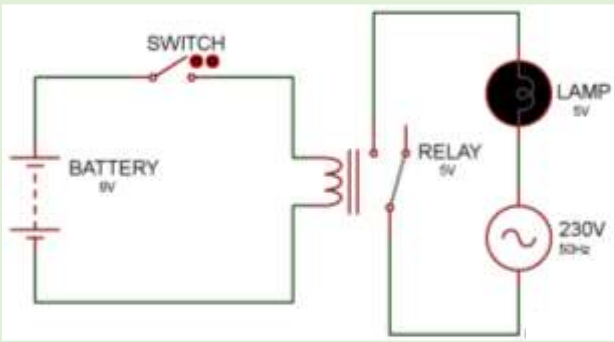


- Examples of electromagnetic devices:

Electric bell

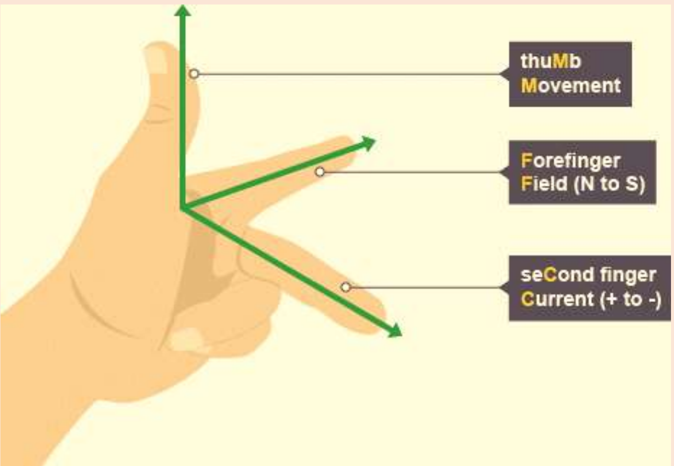


Relay



7.2.2 Fleming's left-hand rule

- **Motor effect:** when a conductor carrying a current is placed in a magnetic field the magnet producing the field and the conductor exert a force on each other.



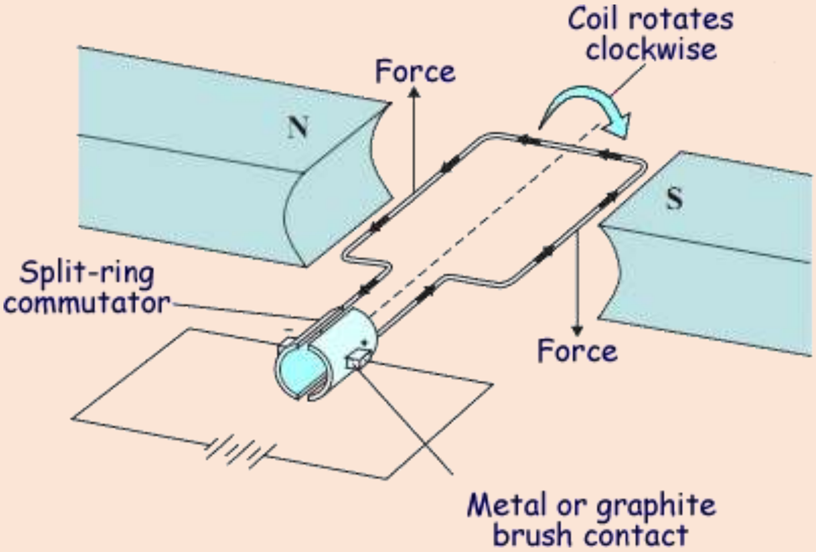
- Factors affecting the size of the force on the conductor:
    - the **size of the current** (in amperes, A)
    - the **magnetic flux density** of magnet (in tesla, T)
    - the **length of conductor** in the magnet (in metres, m)

force (N) = **magnetic flux density** (T) **x current** (A) **x length** (m)

F = $B\ I\ l$

7.2.3 Electric motors

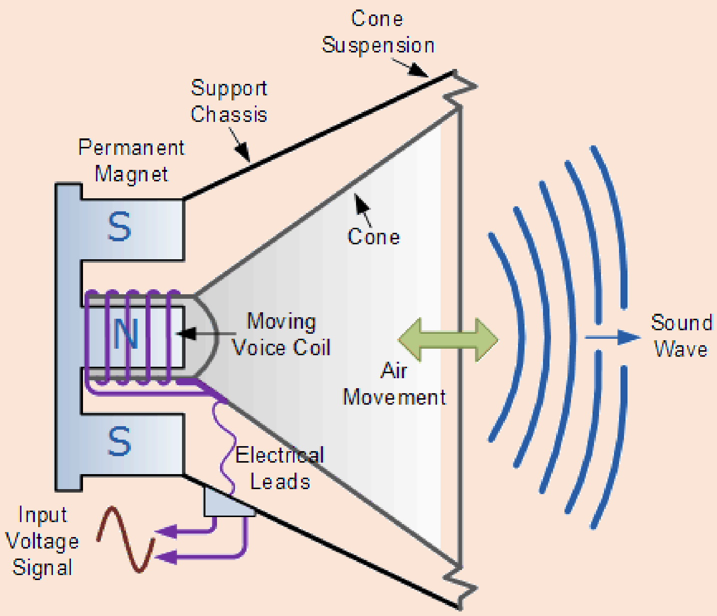
- **Electric motor:** a coil of wire carrying a current in a magnetic field tends to rotate.



- How a motor works:
  - there is a magnetic field which acts from the north to south pole of the magnet
  - a current flows through the coil
  - at the north pole, the coil experiences a force at right angles to the current and field
  - at the south pole, the coil also experiences a force (in the opposite direction)
  - the coil rotates until the force is parallel to the field lines
  - every half turn, the split ring commutator reverses the current
  - this causes the forces to reverse direction
  - the coil continuously rotates

7.2.4 Loudspeakers

- Loudspeakers and headphones use the motor effect to convert variations in current in electrical circuits to the pressure variations in sound waves.



- How a moving-coil loudspeaker works:
  - coil is wrapped around iron core and placed between poles of permanent magnet
  - input p.d. has the same frequency as the sound waves
  - varying p.d. leads to varying current in wire, and therefore a varying magnetic field around the coil
  - varying magnetic field of coil and magnetic field of permanent magnet interact, leading to a varying force being exerted on the cone
  - this vibrates the paper cone, causing compressions/rarefactions in the air, producing a sound wave

7.3 INDUCED POTENTIAL, TRANSFORMERS AND THE NATIONAL GRID

7.3.1 Induced potential

- **Generator effect:**
  - if an electrical conductor:
    - moves relative to a magnetic field **or**
    - there is a change in the magnetic field around a conductor then
  - a potential difference is induced across the ends of the conductor
  - if the conductor is part of a complete circuit, a current is induced in the conductor

- An induced current generates a magnetic field that opposes the original change, either the movement of the conductor or the change in magnetic field.

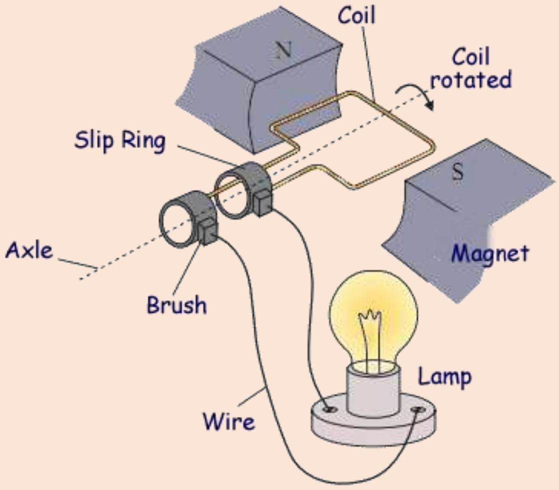
- Factors affecting the size of an induced p.d./current:
  - **speed** of movement of conductor
  - **magnetic flux density**
  - **number of loops** in solenoid (more loops mean more current flows at a given time)

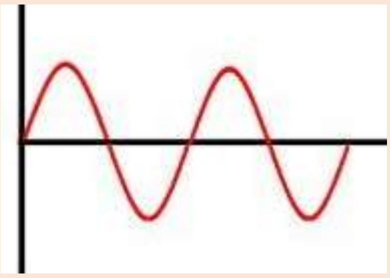
- Factors affecting the direction of the induced p.d./current:
  - **direction of motion** of the conductor
  - **direction of magnetic field**

7.3.2 Uses of the generator effect

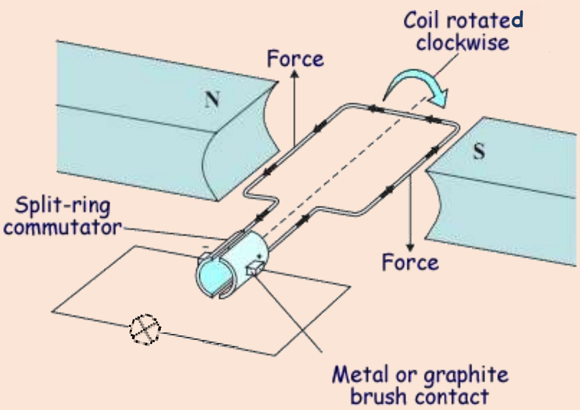
- The generator effect is used in:
  - an alternator to generate AC
  - a dynamo to generate DC

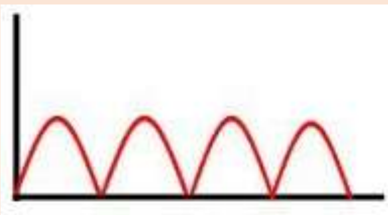
- Alternators:
  - permanent magnets produce a uniform magnetic field
  - the coil is wound on an iron core to increase the size of the current
  - the coil is turned by an external force
  - an alternating current is induced
  - brushes connect the slip rings to the ends of the coil
  - slip rings allow the coil to rotate without twisting the wires





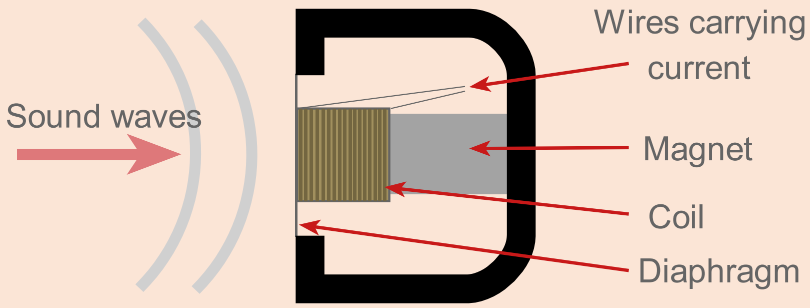
- Dynamos:
  - permanent magnets produce a uniform magnetic field
  - the coil is wound on an iron core to increase the size of the current
  - the coil is turned by an external force
  - the ends of the coil are connected to a split ring commutator
  - at each half turn, the direction of the current is reversed
  - a direct current is induced in the wire





7.3.3 Microphones

- Microphones use the generator effect to convert the pressure variations in sound into variations in current in electrical circuits.



- How a microphone works:
    - sound waves are made of compressions and rarefactions
    - these cause the diaphragm to move in and out
    - the varying force causes a varying p.d. to be induced across the ends of the conductor
    - a varying electrical current is produced
    - the varying electrical current flows through the wire to the loudspeaker to be output

7.3.4 Transformers

- A basic transformer consists of a primary coil and a secondary coil wound on an iron core.
- Iron is used because it is easily magnetised.

- The ratio of the p.d. across the primary and secondary coils of a transformer V_p and V_s depends on the ratio of the number of turns on each coil, n_p and n_s.

$$\frac{\textbf{p.d. across primary coil (V)}}{\textbf{p.d. across secondary coil (V)}} = \frac{\textbf{number of turns on primary coil}}{\textbf{number of turns on secondary coil}}$$

$$\frac{V_p}{V_s} = \frac{N_p}{N_s}$$

- In a step-up transformer, there are more turns on the secondary coil, so the p.d. across the secondary coil is greater.
- In a step-down transformer, there are less turns on the secondary coil, so the p.d. across the secondary coil is smaller.

p.d. across secondary coil x current through secondary coil = p.d. across primary coil x current through primary coil

$V_s \times I_s = V_p \times I_p$

Therefore, **power output (secondary coil) = power input (primary coil)**

- How transformers work:
  - alternating current flows through primary coil
  - alternating magnetic field is produced in iron core
  - there is a continuous change in the magnetic field around the conductor
  - this induces an alternating p.d. across secondary coil
  - an alternating current flows through the secondary coil

- Advantages of power transmission at high p.d.:
  - high p.d. means more energy transferred per unit charge
  - this means energy is shared between fewer electrons
  - less electrons mean less resistance
  - less energy is wasted as heat energy by resistance heating

8 SPACE PHYSICS

8.1 SOLAR SYSTEM; STABILITY OF ORBITAL MOTIONS; SATELLITES

8.1.1 Our solar system

- Within our solar system there is:
    - a star (the Sun)
    - eight planets that orbit around the Sun
    - dwarf planets that orbit around the Sun
    - natural satellites (the moons) orbit their planets

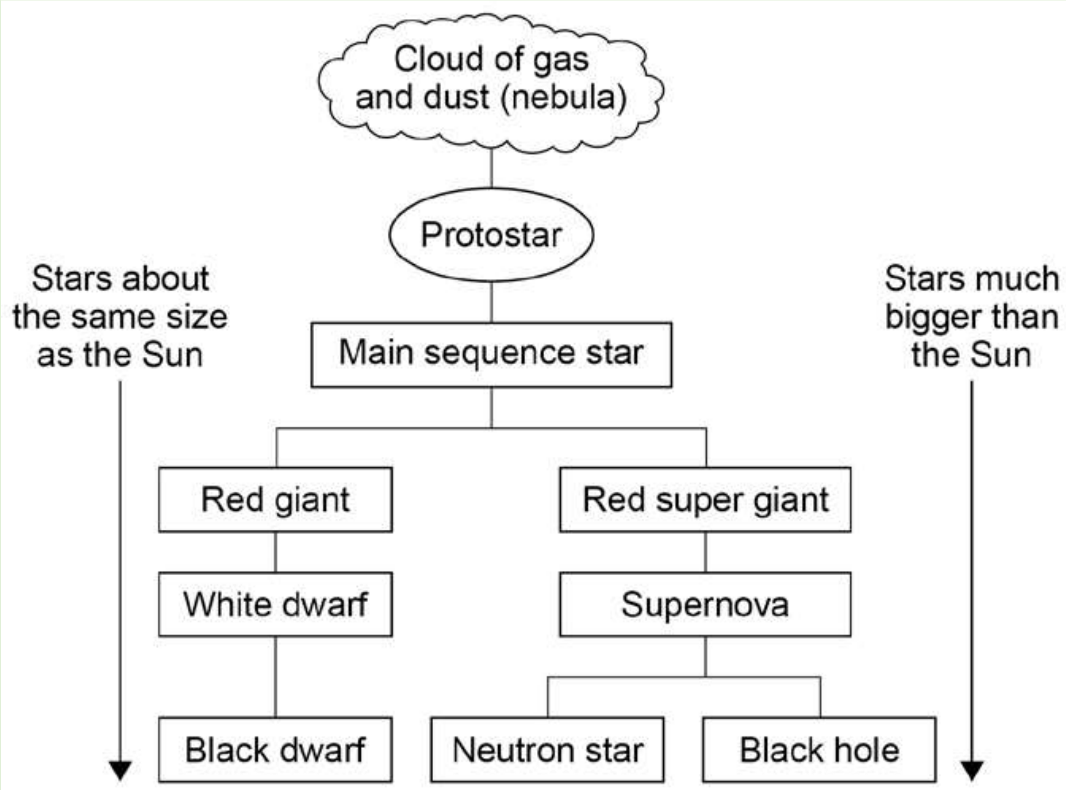
- Our solar system is a small part of the Milky Way Galaxy.

- The Sun was formed from a nebula (cloud of dust and gas) pulled together by gravitational attraction.

- Formation of a star:
    - **particles** in the nebula **merge** together **due to their gravitational attraction**
    - **nebulae merge** together to form a more concentrated protostar
    - **protostar becomes denser** and **particles collide more**
    - **collisions transfer heat energy** to the protostar
    - if the star becomes hot enough, the **nuclei of hydrogen atoms fuse** together to form **helium nuclei**
    - this **releases more energy**, which **makes the star even hotter**
    - **fusion reactions lead to an equilibrium between** the **gravitational collapse of the star** and **the expansion of a star due to fusion energy**

8.1.2 The life cycle of a star

- A star goes through a life cycle which is determined by the size of the star:



- Stars about the same size of the Sun:
    - the star **runs out of hydrogen nuclei** to fuse
    - **hydrogen fusion stops**
    - the star is now a **red giant**
    - **helium nuclei in the core fuse to form heavier elements**
    - eventually there are **no more light elements** and **fusion stops**
    - there is **no longer equilibrium** so the **star collapses in on itself** and releases **heat**
    - the star is now a **white dwarf**
    - the **star cools down** and becomes a **black dwarf**

- Stars much bigger than the sun:
    - the star **runs out of hydrogen nuclei** to fuse
    - **hydrogen fusion stops**
    - the star is now a **red super giant**
    - helium and other **light elements in the core fuse to form heavier elements**
    - eventually there are **no more light elements** and **fusion stops**
    - the **massive star** collapses in a **supernova** explosion
    - there is **enough energy to fuse small nuclei into nuclei bigger than iron nuclei**
    - **elements are scattered** around the universe

- Fusion processes in stars produce all of the naturally occurring elements.
- Elements heavier than iron are produced in a supernova, as there is not enough energy to produce iron in a red giant.

8.1.3 Orbital motion, natural and artificial satellites

- Gravity provides the force that allows planets and satellites (both natural and artificial) to maintain their circular orbits.

- For circular orbits, the force of gravity can lead to changing velocity but unchanged speed:
    - the magnitude of its velocity does not change
    - the direction of its velocity continually changes as it is always perpendicular to the direction of gravity
    - it experiences an acceleration towards the centre of the circle

- For a stable orbit, the radius must change if the speed changes:
    - if speed increases
    - body moves out of its circular orbit (radius increases)

    this also means:
    - energy transferred from kinetic to gravitational potential energy store of body
    - so speed decreases

Body	Orbits around
Planet	the Sun
Moon (natural satellite)	its planet
Artificial satellite	the Earth

- Types of artificial satellite orbits:
    - **geostationary:** orbit anticlockwise at same speed as Earth's rotation (used for GPS)
    - **low polar orbits:** orbit by the poles at a lower height (used for weather monitoring, military, spying, and Earth observation)

8.2 RED-SHIFT

- Red-shift is when:
    - there is an observed increase in the wavelength of light from most distant galaxies
    - the further away the galaxies:
        - the faster they are moving
        - the bigger the observed increase in wavelength

- The observed red-shift provides evidence that the universe is expanding and supports the Big Bang Theory:
    - the Big Bang Theory suggests that the **universe began from a very small region** that was **extremely hot and dense**
    - since 1998 onwards, **observations of supernovae suggest that distant galaxies are receding ever faster**

- There is still much about the universe that is not understood, e.g. dark mass and dark energy.

WORD EQUATIONS

weight (N) **= mass** (kg) **x gravitational field strength** (N/kg)

work done (J) **= force** (N) **x distance** (m)

force (N) **= spring constant** (N/m) **x extension** (m)

moment of a force (Nm) **= force** (N) **x distance** (m)

$$\textbf{pressure}\ (\text{Pa}) = \frac{\textbf{force normal to a surface}\ (\text{N})}{\textbf{area of that surface}\ (\text{m}^2)}$$

pressure (Pa) **= height of column** (m) **x density of liquid** (kg/m^3) **x gravitational field strength** (N/kg)

$$\textbf{speed}\ (\text{m/s}) = \frac{\textbf{distance}\ (\text{m})}{\textbf{time}\ (\text{s})}$$

speed is a scalar quantity

$$\textbf{velocity}\ (\text{m/s}) = \frac{\textbf{displacement}\ (\text{m})}{\textbf{time}\ (\text{s})}$$

velocity is a vector quantity

$$\textbf{acceleration}\ (\text{m/s}^2) = \frac{\textbf{change in velocity}\ (\text{m/s})}{\textbf{time}\ (\text{s})}$$

$$\textbf{acceleration}\ (\text{m/s}^2) = \frac{\textbf{final velocity – initial velocity}\ (\text{m/s})}{\textbf{time}\ (\text{s})}$$

force (N) **= mass** (kg) **x acceleration** (m/s^2)

momentum (kg m/s) **= mass** (kg) **x velocity** (m/s)

$$\textbf{impact force}\ (\text{N}) = \frac{\textbf{change in momentum}\ (\text{kg m/s})}{\textbf{change in time}\ (\text{s})}$$

$$\textbf{period}\ (\text{s}) = \frac{\textbf{1}}{\textbf{frequency}\ (\text{Hz})}$$

wave speed (m/s) **= frequency** (Hz) **x wavelength** (m)

force (N) **= magnetic flux density** (T) **x current** (A) **x length** (m)

$$\frac{\textbf{p.d. across primary coil}\ (\text{V})}{\textbf{p.d. across secondary coil}\ (\text{V})} = \frac{\textbf{number of turns on primary coil}}{\textbf{number of turns on secondary coil}}$$

p.d. across secondary coil x current through secondary coil = p.d. across primary coil x current through primary coil

SYMBOL EQUATIONS

$W = m\,g$

$W = F\,s$

$F = k\,e$

$M = F\,d$

$p = h\,\rho\,g$

$p = \frac{F}{A}$

$v = \frac{s}{t}$

$a = \frac{\Delta v}{t}$

$a = \frac{v-u}{t}$

$F = ma$

$p = mv$

$F = \frac{\Delta p}{\Delta t}$

$T = \frac{1}{F}$

$v = f\,\lambda$

$F = B\,I\,l$

$\frac{V_p}{V_s} = \frac{N_p}{N_s}$

$V_s \times I_s = V_p \times I_p$

PHYSICS PAPER 2