AQA Combined Science: **Trilogy**

Year 11
Knowledge organiser booklet
Paper 2

PHYSICS

P5 Forces

P6 Waves

P7 Magnets and electromagnetism

Name:

P5 – Forces

Scalar and Vector Quantities

Scalar quantities – have **magnitude** only
e.g. temperature, mass and speed.
Vector quantities – have both **magnitude** and **direction**
e.g. velocity. displacement.

Vectors can be shown using **arrows:**
Size of arrow = magnitude of the quantity
Direction of arrow = direction of quantity

Contact and Non-Contact Forces

Force = a push or pull that acts on an object due to interaction with another object.

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

- Forces are **vectors** – shown by arrows.

Gravity

Weight = the **force** acting on an object due to gravity.

- Gravity close to Earth is due to the gravitational field.

- Weight of an object depends on the gravitational field strength at the point where the object is.

Weight can be calculated using:

weight = mass x gravitational field strength

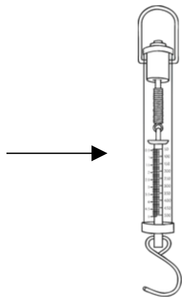
$$W = m \times g$$

W	m	g
Newtons (N)	Kilograms (kg)	Newtons per kilogram (N/kg)

- Earth's gravitational field strength = 9.8 N/kg

- Weight of an object can be considered to act at a single point = object's '**centre of mass**'
-
- Weight can be measured using a **newton meter**.

Newton meter



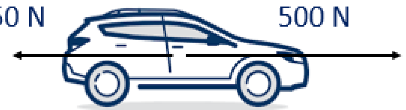
Resultant Forces

Resultant force = The sum of all forces or overall force acting on an object

Bike is being pushed forward with a force of 13N but there are resistive forces of 13N backwards.
Resultant force = 0N

What happens to the motion depends on what the bike was doing before these forces were applied:

- If the bike was stationary, it will stay stationary
- if the bike was moving, it will continue to move at a constant velocity



Car is being pushed to the left by a force of 350N. It is also pushed to the right by 500N.
Resultant force is: 500N – 350N = 150N

What happens to the motion depends on what the car was doing before these forces were applied:

- If the car was stationary, it will **accelerate** to the right
- If the car was already moving to the right, it will move faster **(accelerate)**
- If the car was moving to the left (ie reversing), it will slow down (**decelerate)**

P5 – Forces

Vector Diagrams (HT only)

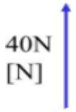
- Used to calculate resultant forces that are not acting directly opposite each other, on a straight line.

Rules ('tip to tail'):

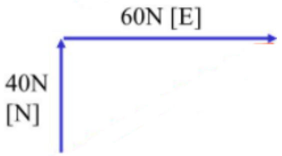
- Draw first vector to scale, in the direction stated
- Draw second vector, from the tip of the first one in the direction stated.
- Join the two lines in a triangle and measure the resulting line
- Convert length to force using your scale – this is the resultant force

Example:
Two forces act on an toy boat - 40N acting north, 60N acting East. Calculate the resultant force and state the direction.

1. Draw the first vector to scale

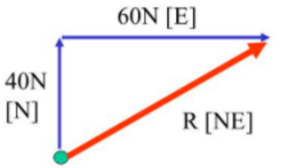


2. Draw 2nd vector from tip of the first one. Again, to scale.



3. Join the two lines. Measure the resulting line.

Resultant force = 72N NE



Work done and Energy Transfer

- When a force acts on an object and makes it move – **work is done**.
Work done = energy transferred

Work done is calculated by:

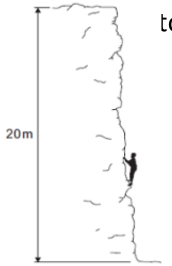
work done = force x distance

W = F x s

Joules (J) | Newtons (N) | Metres (m)

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

e.g A climber and his gear weigh 750N. Calculate the energy transferred top of the cliff



W = F s
W = 750 x 20m
W = 15000J

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

Forces and Elasticity

- When work is done on an elastic object (e.g. stretching or compressing a spring), energy is stored as elastic potential energy.

Elastic deformation:
- When force is applied, object changes shape and stretches.
- When the force is no longer applied, object returns to original shape.

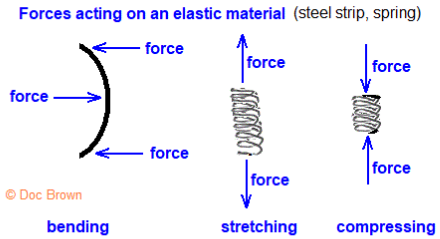
Inelastic deformation = stretched beyond limit – will not return to original shape and size.

Force = spring constant x extension

F = k x e

Newtons (N) | Newtons per metre (N/m) | Metres (m)

Two forces are needed to stretch or compress



Work done in stretching (or compressing) a spring:

elastic potential energy = 0.5 x spring constant x (extension)^2

$$E_e = \frac{1}{2} \times k \times e^2$$

P5 – Forces

Required Practical

Aim: Investigate the relationship between force and extension for a spring (or any elastic object, eg elastic band)

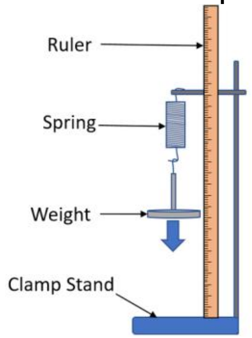
Method

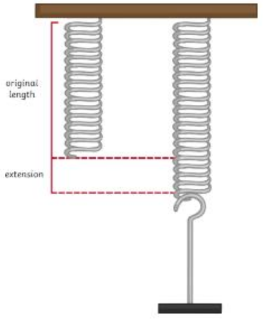
1. Hang a spring from a clamp and stand
2. Measure original length of the spring and record this.
3. Attach a 100g mass – record the new length of the spring.
4. Continue adding 100g masses recording the length each time, up to a total of 500g.
5. Work out the extension for each mass using:

final length – original length

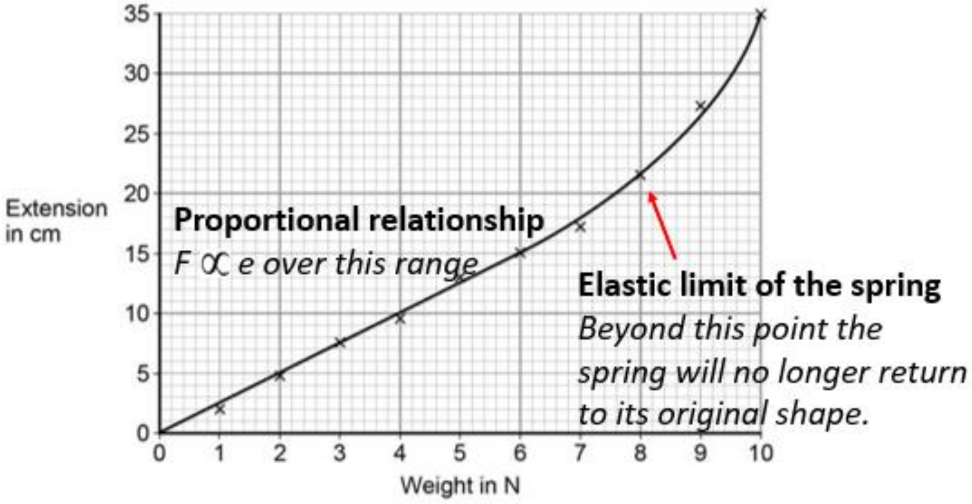
6. Repeat steps 1-5 twice and calculate a mean
7. Plot a line graph with extension (m) on the x-axis and force (N) on the y-axis.

Independent variable : mass on the spring
Dependent variable : extension of the spring
Control variables : same spring

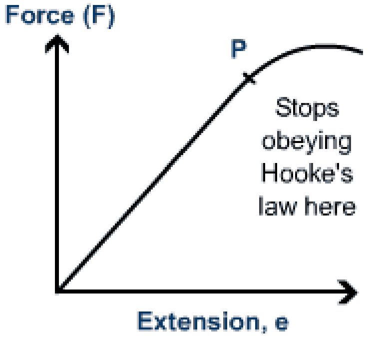




Results :



- There is a proportional relationship (shown by a straight line through the origin) at first.
- This means: **Force ∝ Extension** (F ∝ E)
- However, there comes a point when the 'elastic limit' of the spring is reached. This is also known as the **limit of proportionality**.
- If more force is applied after this, relationship is **no longer proportional**.
- After this point, the spring will not return to its original shape and size when the force is removed.



You may see the graphs with the axes switched – with extension on X and force on Y.

gradient of linear part = spring constant, k, for the spring being used.

P5 – Forces

Distance and Displacement

Distance

- How far an object moves
- Does not involve direction
- Distance = scalar quantity

Displacement

- Includes both the **distance** an object moves, measured in a straight line, from start to finish point and the **direction** of that straight line.
- Displacement = vector quantity

Speed

You should be able to recall the following typical speeds:

Activity	Typical Speed (m/s)
Walking	1.5
Running	3
Cycling	6
A car	25
A train	55
Speed of sound	330

Calculating speed:

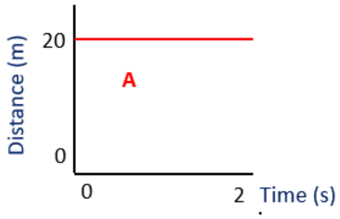
speed = distance x time

E.g. A car travels 100 metres in 3.8 seconds. What is the average speed?

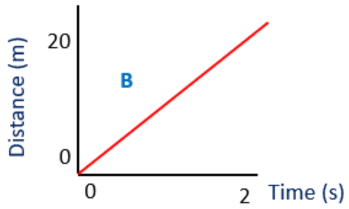
v=s/t
v = 100 m / 3.8 s
v= 26 m/s

Distance time graphs

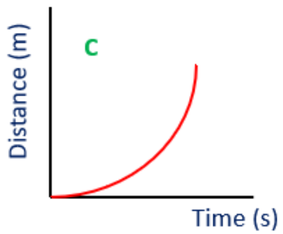
Distance time graphs show the motion of an object
The gradient tells us the speed of the object



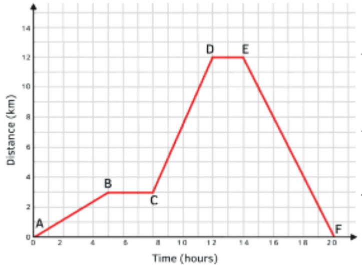
Object is stationary (distance not changing)



Object is travelling at constant speed
v = 20/2
v = 10 m/s



Object is accelerating
(HT only) Speed can be calculated by:
- Drawing a **tangent** and finding the **gradient** of the tangent



A journey generally has different speeds. Average speed can be calculated by using total distance ÷ time

Velocity and Acceleration

Velocity & acceleration = vector quantities
1. Velocity = **speed** in a given **direction**
- positive velocity = forwards (eg +5 m/s)
- negative velocity = backwards (eg -5 m/s)
2. Acceleration is a **change in velocity**
- positive acceleration = speeding up
- negative acceleration = slowing down

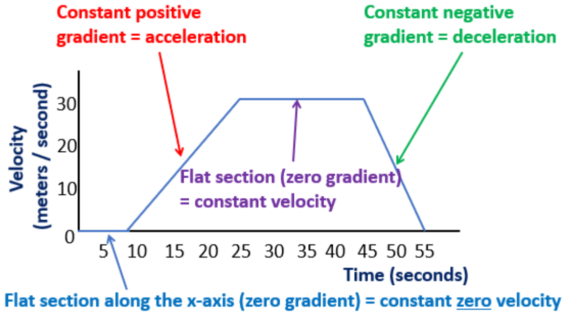
Average acceleration of an object can be calculated using:

$$\textbf{acceleration} = \frac{\textbf{final velocity – initial velocity}}{\textbf{time taken}}$$

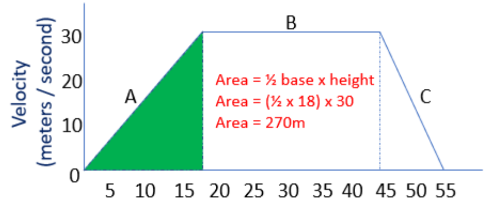
Units for acceleration are m/s^2

Velocity time graphs

Show how velocity changes during a journey
The gradient shows the acceleration



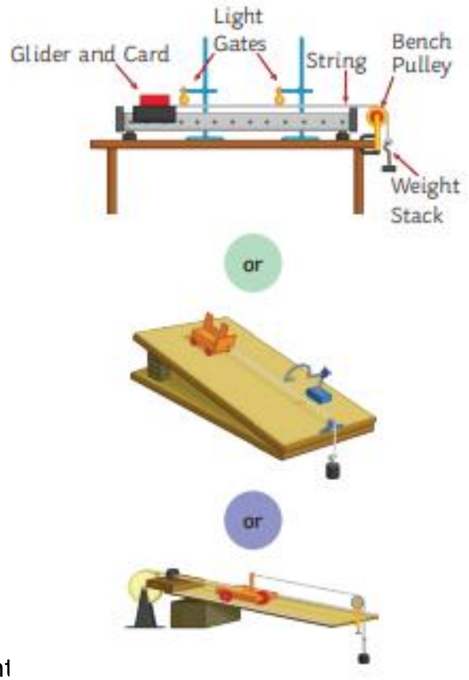
HT only - area underneath a velocity time graph is the distance travelled by an object



P5 – Forces – Required Practical - Acceleration

Aim: To investigate the effect of **varying force** on the acceleration of an object of constant mass.
You may be given any of the following apparatus set-ups to conduct these investigations:

Independent variable = force applied
Dependent variable = acceleration
Control variables = mass of toy car and surface car is on.



Method (using toy car)

1) Place the car on a ramp. Incline the ramp until the car just does not move. This is to remove as much of the effect of friction as possible.

2) Set up a light gate at the end of the ramp

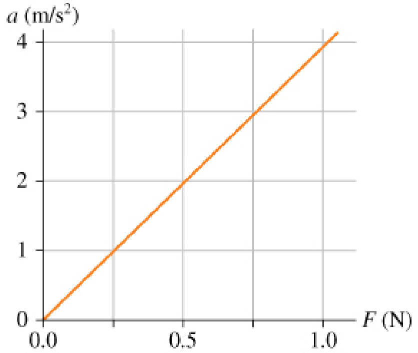
3) Place a 1N weight on the pulley attached to the toy car.

4) Allow the weight to drop and read the acceleration of the car from the light

5) Repeat the experiment several times, decreasing the weight on the pulley each time (e.g. 0.8N, 0.6N, 0.4N etc.) Place the removed mass onto the car to keep the mass of the system constant

Results

Acceleration is proportional to force applied

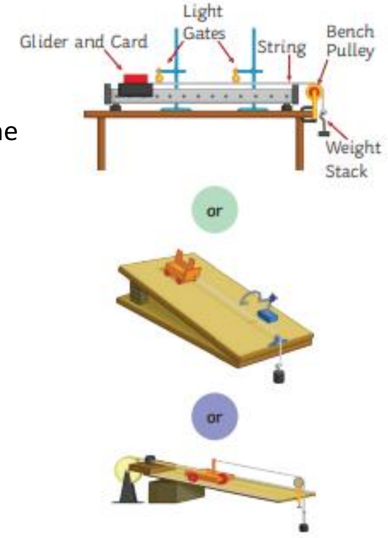


Aim: Investigate the effect of **varying mass** of an object on the acceleration produced by a constant force.
You may be given any of the following apparatus set-ups to conduct these investigations:

Independent variable = mass of glider
Dependent variable = acceleration of glider
Control variables = force applied and surface car is on

Method (using glider)

1) Place the glider on the track. Switch on the air blower and adjust until the glider just doesn't move. This is to remove as much of the friction as possible.



2. Set up a light gate at the end of the air track

3) Add a 10g mass onto the glider. Place a 1N weight on the pulley attached to the glider and let go.

4) Record the acceleration from the light gate

5) Repeat the experiment several times, increasing the mass on the glider each time (e.g. 20g, 30g, 40g etc.) whilst keeping the weight (1N) on the pulley constant.

<u>Results</u>

Acceleration is inversely proportional to mass

P5 – Forces

Stopping Distance

Stopping distance = thinking distance + braking distance

- Greater the speed of vehicle – greater the stopping distance.

Thinking Distance (reaction time)

Thinking distance = distance travelled before driver reacts and presses brakes.

Reaction times are typically 0.2s to 0.9s

Factors that affect a driver's reaction time:

- Tiredness
- Drugs
- Alcohol
- Age
- Distractions (e.g. phone/music)

Momentum (HT only)

- Defined by the equation:

momentum = mass x velocity

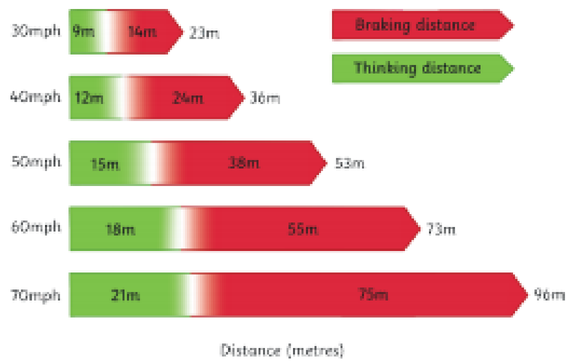
p = m x v

Units:
momentum = kilograms metre per second (kg m/s)
mass = kg
velocity = m/s

- In a closed system, total momentum before an event is equal to the total momentum after the event – this is called **conservation of momentum**.

Braking Distance

Braking distance = the distance travelled by a vehicle once with **brakes are applied** until it reaches a full stop.



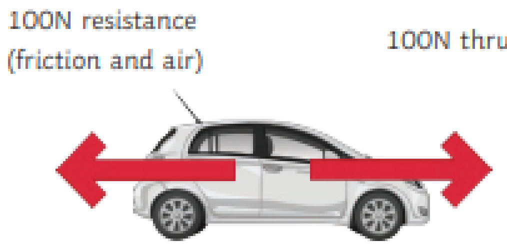
It can be affected by:
- wet/icy roads
- poor vehicle conditions (brakes/tyres)

When a force is applied to brakes, **work is done** by the friction between the car wheels and the brakes.

Work done – reduces the **kinetic energy store** and energy is transferred to **the thermal store of the brakes**, increasing their temperature.
Increased speed = increased force required to stop the vehicle
Very large decelerations can lead to brakes overheating and/or loss of control of the car.

Newton's First Law

If resultant force acting on object is zero:
- Stationary object will remain stationary
- Moving object will continue at a steady speed and in the same direction.



(HT only) Inertia = tendency of an object to continue in a state of rest of uniform motion (same speed and direction)

Newton's Second Law

Acceleration of an object is proportional to resultant force acting on it and inversely proportional to the mass of the object

Resultant force = mass x acceleration

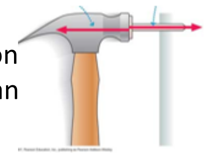
F = m x a

(HT only) Inertial mass = how difficult it is to change an object's velocity. Defined as ratio of force over acceleration.

Newton's Third Law

When two objects interact, forces acting on each other are always equal and opposite.

e.g. a hammer hitting a nail
The hammer exerts a force on the nail, and the nail exerts an equal and opposite force on the hammer.



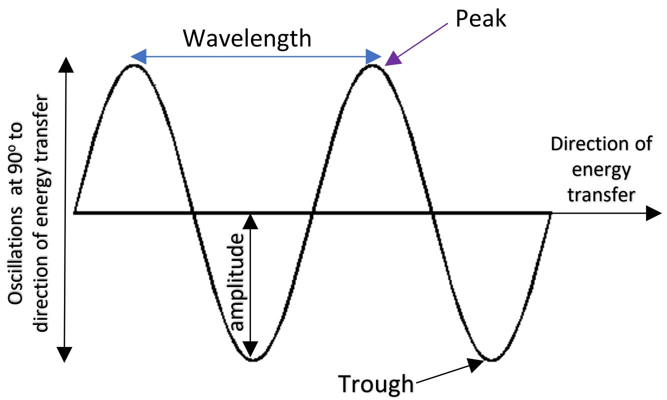
P6 – Waves

Transverse Waves

- Oscillations (vibrations) **perpendicular** to direction of energy transfer.

Examples:

- Electromagnetic waves
- Ripples on water.

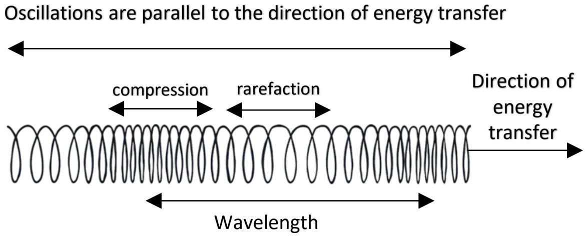


Longitudinal Waves

- Oscillations (vibrations) are **parallel** to direction of energy transfer.

Examples:

- Sound waves



Sound waves have areas of compression and rarefaction.
Compression = particles pushed closer together
Rarefaction = particles are further apart

Properties of Waves

Amplitude – maximum displacement from undisturbed position.

Wavelength – distance from a point on one wave to the equivalent point on the next wave.

Frequency – number of waves passing a point each second.
Frequency is measured in Hertz (Hz)
1Hz = 1 wave per second.

Wave speed – the speed at which energy is transferred through a medium.

You need to memorise

$$v = f \times \lambda$$

wave speed (m/s) — frequency (Hz) — wavelength (m)

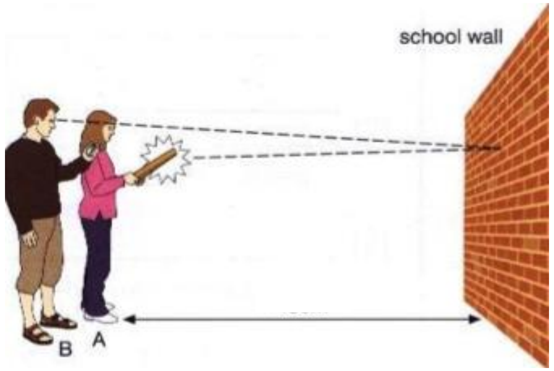
Measuring speed of sound waves in air

- Stand 50m from a large flat wall.
- One person claps/bangs bricks
- Measure time taken to hear the echo.
- Calculate speed of sound using:

Speed = distance x time

- Remember distance is double (in this case, 100m) as it travels to the wall and back.
- Take several measurements and calculate the mean to reduce error.

This is unlikely to produce an accurate value for sound in air (330 m/s) as the reaction time of the person operating the stopwatch is likely to be a significant proportion of the time measurement.

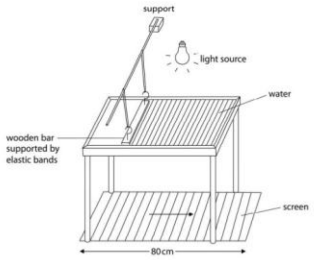


P6 – Waves – Required Practical – investigating wave in a solid and a ripple tank

Measuring waves in a liquid

Equipment

- Ripple tank
- Measuring ruler
- Stop watch



Method

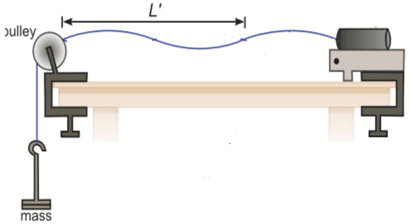
1. Set up the equipment as shown and turn on the motor to produce low frequency waves so that they are able to be counted.
2. Adjust the lamp until pattern is seen clearly on white screen underneath
3. Use a ruler to measure the length of a number of waves (e.g 10) and divide the length by the number of waves to give wavelength. This improves the accuracy of the measurement.
4. Record the waves using a camera or mobile phone. Count the number of waves passing a point in 10 seconds using a stopwatch and slowing the recording down.
5. Divide the number of waves counted by the time to give frequency.
6. Use v = f x λ to calculate the wave speed. Repeat for different frequencies of the motor.

Exp	Length of 10 waves (cm)	Wavelength of 1 wave (cm)	Number of waves in 10 s	Frequency (Hz)	Speed (cm/s)
1	65	0.65	121	12.1	7.9
2	50	0.5	155	15.5	7.9
3	42	0.42	187	18.7	7.9

Measuring waves in a solid

Equipment

- string, vibration generator, hanging mass set and pulley



Method

1. Set up the equipment as shown.
2. Turn on the vibration generator
3. Adjust the length of the string until a standing wave is achieved
4. The frequency can be read from the vibration generator
5. Measure as many complete waves as possible using a ruler
6. Divide the length by the number of waves to give wavelength
7. Calculate speed using v = f x λ

Conclusion:

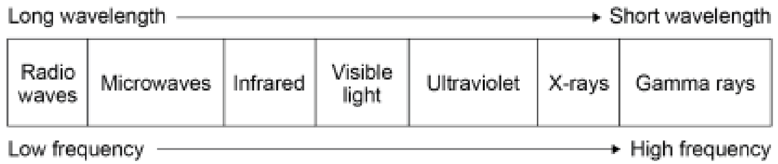
In both experiments, when you increase the frequency, the wavelength decreases – the speed remains the same in the same medium

P6 – Waves

The Electromagnetic Spectrum

- All **transverse waves**
- Transfer energy from the source of waves to an absorber.
- All travel at the same **velocity** through a vacuum or air – **speed of light**.
- Speed of light = 300,000,000 m/s

You must remember all the electromagnetic waves in order!



Wave	Use	Other information
Radio waves	Television and radio	Easily transmitted through the air. Harmless if absorbed by the body.
Microwaves	Satellite communications and cooking food	Can be harmful when internal body cells become heated by over exposure.
Infrared	Electrical heaters, cooking food and infrared cameras	Can cause burns to skin
Visible light	Fibre optic communications	Only EM wave detectable by human eye.
Ultraviolet	Energy efficient lamps, sun tanning	Causes skin tanning and can lead to burns or **skin cancer**.
X-rays	Medical imaging and airport security scanners.	Very little energy is absorbed by body tissues. Passes through the body.
Gamma rays	Sterilising medical equipment or food and treatment for some cancers.	They can lead to gene mutation and cancer.

Ray diagrams

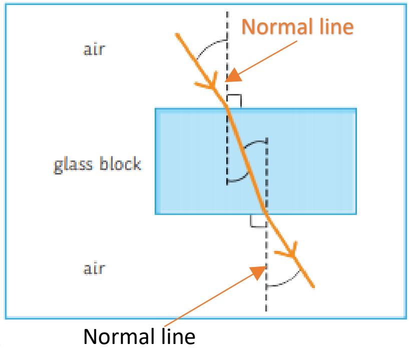
- You need to construct **ray diagrams** to show how a wave is **refracted** at the boundary of a different medium.

Less dense → More dense (e.g. air to glass)

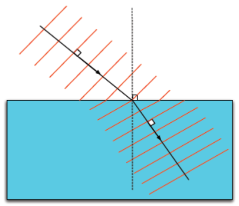
- Ray **slows down** and bends **towards the normal** line.

More dense → Less dense (e.g. glass to air)

- Ray **speeds up** and bends **away from the normal** line.



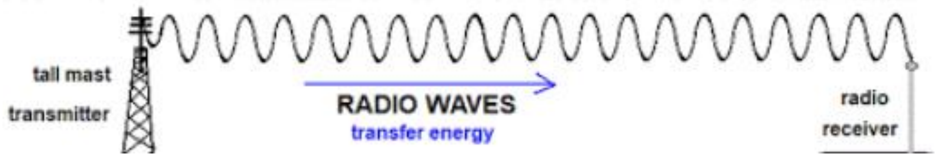
The ray bends because different parts of the wavefront cross the boundary at slightly different times –



If wave hits medium at an angle of 90^o then the ray will slow down but will not be refracted.

Radio waves (HT only)

- Radio waves can be produced by **oscillations** in **electrical circuits**.
- Those radio waves can travel for long distances to receivers.
  - When absorbed by the receiver, the radio wave creates an **alternating current** with same **frequency** as the wave itself.
  - This is how TV and radio are broadcast.



P6 – Waves – Required Practical – Infrared radiation

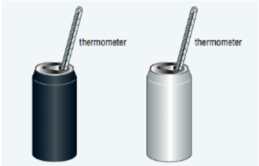
Aim
Investigate how the amount of infrared radiation **emitted** (given out) by a surface depends on the nature of that surface.

In this investigation you are finding out which type of surface emits the most infrared radiation:
- **Dark and matt**
- **Dark and shiny**
- **Light and matt**
- **Light and shiny**

Method
1. Place **Leslie cube** on a heat proof mat.
2. Once the kettle has boiled, fill the Leslie cube with water.
3. Hold the infrared thermometer 5cm from the first surface
4. Record the temperature
5. Repeat the experiment three times on each surface and calculate mean for each surface.

Independent variable: surface
Dependent variable: temperature of the air (infrared radiation emitted)
Control variables: Temperature of the water inside, the distance between the cube surface ad the infrared thermometer

In this investigation you are finding out which type of surface absorbs the most infrared radiation:



Method
1. Fill a black and a silver can with water from the tap.
2. Take the temperature of the water in each can
3. Place the infrared thermometer 5cm from the cans
4. Leave for at least 10 minutes
5. Record the temperature of the water in each can and calculate the rise in temperature

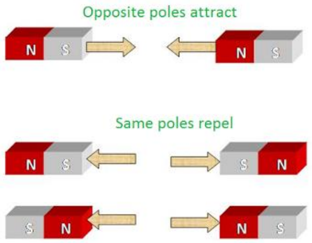
Independent variable: surface of the can
Dependent variable: Temperature increase of the water (infrared radiation absorbed)
Control variables: Temperature of the water inside, the distance between the cube surface ad the infrared thermometer

Conclusion
Black matt surfaces absorb and emit the most infrared radiation.
White/silver and shiny surfaces are poor emitters and poor absorbers of infrared radiation

P7 – Magnetism and Electromagnetism

Magnets

- Have two poles - **north** and **south**.



- **Like poles** will **repel** each other (e.g. N-N or S-S)
- **Opposite poles** will **attract** (e.g. N-S)

- Magnetism is a **non-contact** force – magnets do not need to be touching for effect to be observed.

Magnetic materials: only **iron/steel, cobalt** and **nickel** are magnetic.

Types of magnets

Permanent magnet

- Produces its own magnetic field.

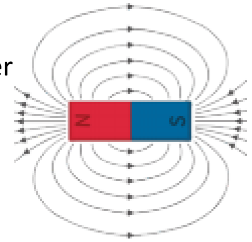
- Magnetism cannot be turned on or off.

Induced magnet

- Induced magnet = a material which becomes magnetic when placed in a magnetic field.
  - Induced magnets only attract other materials and lose magnetism when removed from the magnetic field.

Magnetic Fields

Magnetic field = the area surrounding a magnet where the force will act on another magnet or magnetic material.



- Magnet field is strongest at the **poles** where the field lines are **closest together**.

- Field lines always go away from **magnetic north** and towards **magnetic south**.

Earth's Magnetic Field

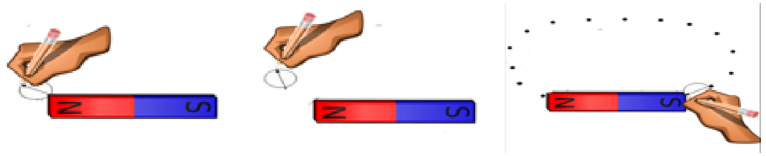
- Earth produces a magnetic field.
- Magnetic compasses use this to help navigation.
- The core of the Earth is made of **iron** (magnetic).

Plotting Magnetic Field Lines

A magnetic compass can be used to plot and draw the magnetic field lines around a magnet.

You need to be able to describe this method!

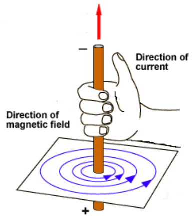
1. Place the bar magnetic in centre of paper.
2. Place a plotting compass at one end of the magnet.
3. Put a pencil dot at the place the compass arrow is pointing to
4. Move the compass to line up the tail of the compass needle to the dot you just made.
5. Repeat until you reach the other end of the magnet



6. Join the dots using a line – this is the magnetic field line. Mark on the direction the arrow pointed – it should run N→S

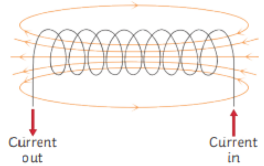
Electromagnetism

- When a current passes through a wire, a **magnetic field** is produced
- The direction of the field can be found by the right hand thumb rule
- curl the fingers of the right hand around the wire and point the thumb in the direction of the current (+ to -)
- The direction of the circular field is shown by the fingers



- Strength of magnet can be increased by increasing the current
- When the current is switched off, the magnetic field is lost

Coiling the wire will form a **solenoid**.



To increase strength of magnetic field around a solenoid you can:

- Add an **iron core**
- **Increase number of turns** in coil
- **Increase the current** passing through wire

Electromagnets

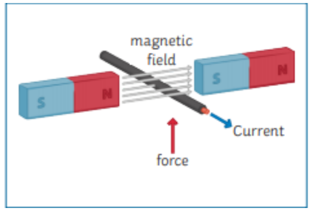
- Electromagnet is a solenoid with an iron core.
- Are **induced magnets** (can be turned on and off)

Uses = electric motors, loudspeakers, electric bells, scrapyards.

P7 – Magnetism and Electromagnetism

The Motor Effect (HT only)

- When a wire carry a **current** is placed in a magnetic field, the two magnetic fields interact and a **force** is exerted on the wire. .
- This is called **motor effect.**



- The force produced by the motor effect can be calculated using:

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

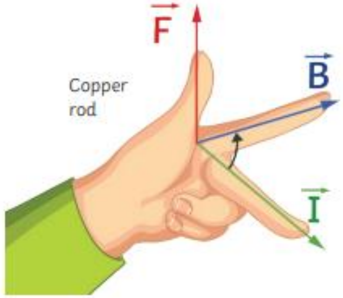
F = B x I x l

For example:
A current of 8A is flowing through a wire that is 75cm long. The magnetic field acting at a right angle on the wire is 0.5T.
Calculate the force.

Remember: the equation uses length in m. The question has given you the length in cm so you need to convert it before you answer.
F = 0.5 x 8 x 0.75
F = 3N

- If current flowing through wire is **parallel** to magnetic field, **no force** is produced.

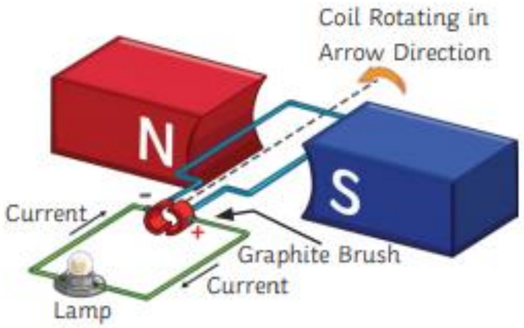
Fleming's left-hand rule.
- You may be asked a diagram and asked to indicate direction of force.
- You can use Fleming's left-hand rule to do this (picture)



Remember (**F B I**):
- Use your **left hand!**
- The angle between index and middle should be **right angle**.
- Thumb = direction of **force**
- First finger = direction of **magnetic field**
- Second finger = direction of **current** through wire.

Electric Motors (HT only)

- When wire carrying current is **coiled**, the motor effect causes wire to **rotate**.
- This is how an **electric motor** works.

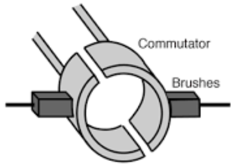


- Current flows force produced acts in **opposite directions** causing coil to **rotate** overall.

- When coil reaches a **vertical position,** force is parallel so would be zero – stops rotating.

- A gap in the **split ring commutator** in the motor cuts the current temporarily.

- Momentum ensures the coil carries on mo



- The commutator reconnects and **changes the direction of the current** to maintain a **constant rotation** in one direction overall.
- Increase speed of rotation by increasing the:
- current
- strength of magnet
- number of turns on the coil