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Physics Topic P8
Forces in balance

Section 1: Key terms

Scalar	A quantity with **magnitude (size) only,** e.g. speed, distance, time, area, volume.
Vector	A quantity that has both **magnitude (size)** and **direction,** e.g. all forces, displacement, velocity, weight, momentum.
Distance	How much ground an object has covered during its motion (scalar).
Displacement	Displacement is **distance** in a given **direction** (vector).
Magnitude	The value of a force in newtons.
Friction	The force **opposing** the **relative motion** of **two solid surfaces** in **contact**.
Contact force	Force between objects that are **touching** e.g. friction, air resistance.
Non-contact force	Force that acts on things **not touching** e.g. gravitational force, magnetic force.
Balanced forces	When forces are equal and opposite each other, also known as **equilibrium**.
Newton	Unit force is measured in.
Weight	The **force of gravity** acting **on an object's mass**. Measured using a **newtonmeter**.
Centre of mass	A **point** in the **middle** of an object where **all its mass acts**.
Resultant force	The **overall force** once all the forces have been considered.
Work done	Work is done when an **object is moved through a distance**. When work is done **against friction** there is a **temperature rise**.
Newton's first law	If the forces on an object are balanced the object will either: 1. Remain still 2. Keep moving with the same velocity
Newton's third law	When **two objects interact** they exert an **equal and opposite** force on each other.
Moment (HT)	**Turning effect** of a force
Load (HT)	Weight of an object

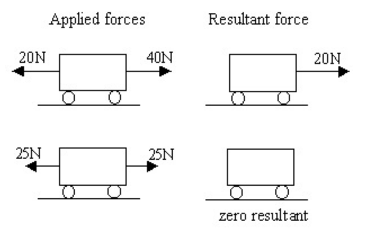
Section 2: Types of forces

Force	**Between**	**Contact or non-contact**	**Example**
Friction	Two moving surfaces	Contact	Brakes
Upthrust	An object & water	Contact	Boat
Reaction	Two stationary objects	Contact	Book on shelf
Air resistance	A moving object & air	Contact	Plane
Weight	Two masses	Non-contact	You and the earth
Tension	Two ends of an elastic material	Contact	Spring
Magnetic	Magnetic & magnetic materials	Non-contact	Magnet picking up a nail

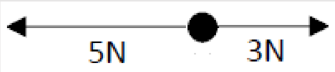
Section 3: Resultant forces

If the resultant force on an object **is zero**, then the object **stays at rest** or at the **same speed and direction.**
If the resultant force is **greater than zero**, the **speed or direction** of the object **will change**.

If two forces act on an object along the **same line**:
- the resultant force is **their sum** if the **forces act** in the **same direction.**
- the resultant force is their **difference** if the forces **act in opposite directions.**



A **free-body** force diagram of an object shows **the forces acting on it**.
Each force is shown on the diagram by a **vector** (an arrow pointing in direction of the force.)

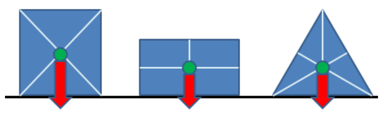


Free body force diagram (HT) showing forces in opposite directions.

Section 4: Centre of mass

Point at which mass of an object appears to be concentrated is known as its **centre of mass**. When an object is freely suspended, it comes to rest with its centre of mass **directly below the point of suspension.**

The centre of mass of a **regular shape** is at the **centre** (where the axes of symmetry meet.)

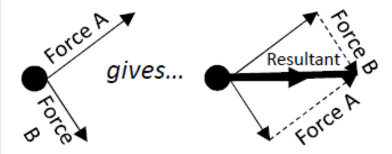


Section 5: The parallelogram of forces (HT)

The parallelogram of forces is a scale diagram of two force vectors which is used to find the **resultant of two forces** that are **not parallel** (don't act along the same line).

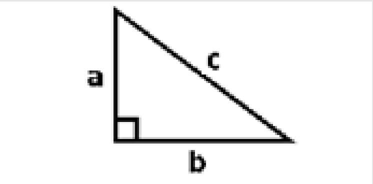
Force A and Force B are two forces that are **not parallel.**

The resultant is the **diagonal** of the parallelogram that **starts** at the **origin** of the two forces.



Resulting displacement (HT)

The resulting displacement (c) is **measured** using a **ruler** on a scale diagram or calculated using **Pythagoras.**



$$c = \sqrt{a^2 + b^2}$$

KNOWLEDGE

Physics Topic P9
Forces in action - Motion

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Section 1: Key terms

Displacement	The **distance** an object moves in a given **direction**. A **vector** quantity.
Velocity	The **speed** of an object in a **given direction**. A **vector**.
Acceleration	The **change** of an object's **velocity per second**.
Deceleration	A negative acceleration, the object is slowing down.
Gradient	Change in quantity on the y-axis divided by change in quantity on the x-axis.

Section 2: Distance-time graphs

A distance-time graph **shows** the **distance** of an object from a starting point (plotted on y-axis) **against** the **time** taken (plotted on the x-axis.)

Constant speed - **straight line** that slopes **upwards**.

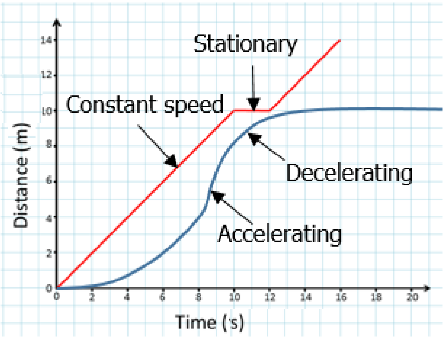
Accelerating - **curved** line getting **steeper**.

Decelerating - curved line getting **less steep**.

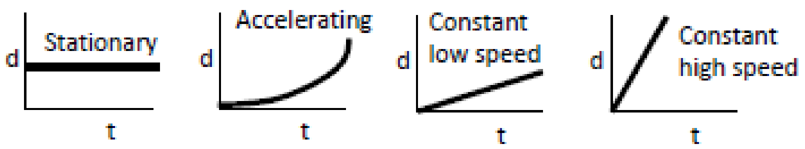
Stationary - **horizontal** line, the **gradient** is **zero**.

The **gradient** represents the object's **speed**.

The **steeper** the gradient, the **greater** the speed.



Slopes of distance-time graphs



Section 3: Velocity-time graphs

A velocity-time graph **shows** the **velocity** of an object (plotted on y-axis) **against** the **time** taken (plotted on the x-axis.) A **motion sensor** linked to a computer can be used to **measure velocity changes**.

Constant velocity (zero acceleration)- **horizontal line**

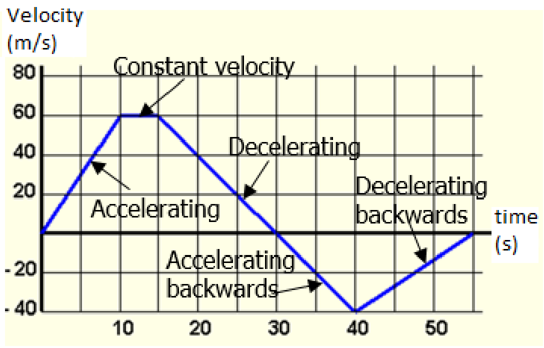
Constant acceleration - **straight line** with velocity **increasing**

Constant deceleration - **straight line** with velocity **decreasing**

Stationary - **horizontal line on x-axis** (velocity = 0)

Moving **backwards** - **below x-axis**

The **steeper** the **gradient** the **greater** the **acceleration**.

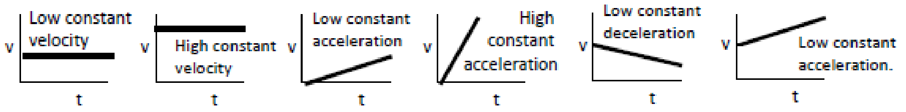


Velocity-time graph

A **positive gradient** represents **acceleration**, a negative gradient represents deceleration.

Area under the graph represents **distance** travelled (HT).

Slopes of velocity-time graphs

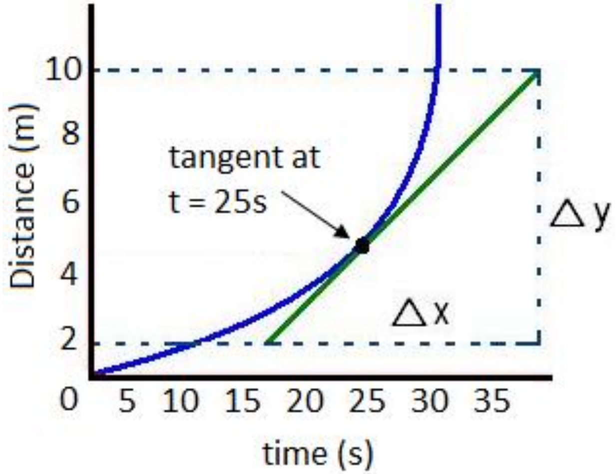


Section 4: Equations to learn

Distance = speed x time s = v x t	Distance – metres (m) Speed – meters per second (m/s) Time – seconds (s)
Acceleration = $\frac{\text{change in velocity}}{\text{time taken}}$ a = ΔV/t	Acceleration – metres per second (m/s^2) Change in velocity – meters per second (m/s) Time taken – seconds (s)

Section 5: Calculating the gradient (HT)

The distance-time graph for an object moving at **changing speed** is a **curve**. **To find the speed** at a particular instant in time, draw a **tangent** to the line **at that instant** and determine the **gradient** of the tangent.



Calculating the gradient:

$$\text{slope} = \frac{\Delta y}{\Delta x}$$

or

$$\text{slope} = \frac{y_2 - y_1}{x_2 - x_1}$$

KNOWLEDGE

Physics Topic P10
Forces in action – Forces and motion

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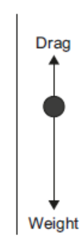
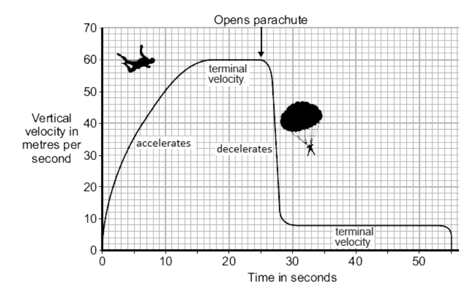
Section 1: Key terms

Displacement	The **distance** an object moves in a given **direction**. A **vector** quantity.
Velocity	The **speed** of an object in a **given direction**. A **vector**.
Acceleration	The **change** of an object's **velocity per second**.
Resultant force	The **overall force** once all the forces have been considered.
Terminal velocity	The **velocity** an object **eventually reaches** when it is falling. The **weight of the object** is then **equal** to the **frictional force** on the object.
Stopping distance	The **shortest distance** a vehicle can **safely stop** in. It depends on **thinking distance** and **braking distance**.
Momentum	A **moving object** with **mass** has momentum. Momentum is "**mass in motion**" It is a vector quantity.
Conservation of momentum (HT)	In a closed system, **total momentum before** an event **is the same** as the **total momentum after** the event.
Closed system (HT & Triple)	A **system** with **no external forces** acting on it.

Section 2: Forces and acceleration

Newton's second law of motion	The acceleration of an object is: • Directly proportional to the force • Indirectly proportional to mass	We can **investigate** the **relationship** between force and acceleration by using a trolley with constant mass, newton-meter, motion sensor and a computer.
Effect of force	The **greater the resultant force** on an object, the **greater** the objects **acceleration**. If an object is not accelerating then the resultant force on the object must be zero.	
Effect of mass	The **greater the mass** of an object, the **smaller** its **acceleration** for a given force.	
Calculation of resultant force	Resultant force = mass x acceleration f = m x a	Force – newtons (N) Mass – kilograms (kg) Acceleration = metres per second squared (m/s^2)
Inertia (HT)	the inertia of an object is its tendency to stay at rest or in uniform motion (moving at constant speed in a straight line.)	

Section 3: Weight and terminal velocity

Weight	The weight of an object is the force acting on the object **due to gravity**. Measured in newtons, N.
Mass	The **quantity** of matter in it. Measured in Kg.
Gravitational field strength.	The gravitational force on a 1kg object is called the gravitational field strength. An object acted on only by gravity accelerates at about $10m/s^2$ on the Earth.
Calculating weight	weight = mass x gravitational field strength. w = m x g Weight – newtons (N) Mass – kilograms (kg) GFS – newtons per kilogram (N/kg)
Terminal velocity Ball bearing falling though a fluid.  The ball bearing reaches its terminal velocity when the **drag is equal to the weight**.	When a parachutist jumps out of a plane, the only force acting is weight (gravity.) As the parachutist falls air resistance acts upwards. The resultant force is downwards as weight is greater than air resistance, hence the parachutist accelerates. As velocity increases, so does air resistance. **Terminal velocity** is reached **when** the **forces are balanced** (when air resistance = weight.)  When the parachute opens, the surface area increases hence there's much more air resistance. The weight (downwards force) is still the same, hence the **terminal velocity decreases** allowing the parachutist to hit the ground at a safe speed.

KNOWLEDGE

Physics Topic P10
Forces in action – Forces and motion

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Section 4: Forces and braking

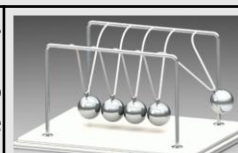
Thinking distance	The **distance** a **car travels** while the **driver reacts**.
Factors affecting thinking distance	1. Tiredness 2. Drugs 3. Alcohol 4. Distractions (e.g. mobile phones)
Braking distance	The **distance a car travels** while the car is **stopped** by the **brakes**.
Factors affecting braking distance	1. How fast you are going 2. Road conditions (weather e.g. Water or ice) 3. Conditions of tyres and brakes. 4. Type of road surface 5. Mass of vehicle
Stopping distance	The **sum** of the **thinking distance** and **braking distance**.

Section 5: Momentum (HT)

All moving objects have momentum. The greater the mass **and** velocity of an object, the greater its momentum. Momentum has size **and** direction so is a vector quantity.

Calculating Momentum	Momentum = mass x velocity p = m x v	Momentum – Kg m/s Mass - Kg Velocity – m/s

In a **closed** system, **total momentum before** an event **is the same** as the **total momentum after** the event. Momentum is conserved in a collision or an explosion as no external forces act on the objects. After a collision, the colliding objects may move off together or may move apart.



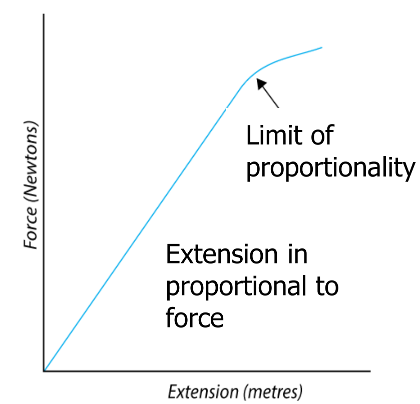
Section 6: Forces and elasticity

Elastic deformation	Occurs when a **spring is stretched** and **can** then **return** to its **original length**.
Inelastic deformation	Occurs when a **spring is stretched** and its **length** is **permanently altered**.
Limit of proportionality	The **length** a spring can be **stretched before it no longer is able to return to its original length**. Beyond the limit of proportionality, a force-extension graph is curved.
Extension	Difference between the length of an object and its original length.

Force extension graph

If you hang small weights from a spring it will stretch. If you plot a graph of the spring's extension against force applied, you get a straight line that passes through the origin. The **extension** is **directly proportional** to the **force applied.**

However if you **apply too much force**, the line begins to **curve** because you have exceeded the **line of proportionality**.



Objects and materials that behave like this are said to obey **Hooke's law**. Hooke's law states that extension is directly proportional to the force applied, provided the limit of proportionality is not exceeded.

Hooke's law	Force applied = spring constant x extension F = k x e	Force – newtons, N Spring constant N/m Extension – metres m

KNOWLEDGE — Physics Topic P12 Waves, electromagnetism & space – Wave properties — ORGANISER

Section 1: Key terms

Amplitude	The **maximum displacement** of a point on a wave away from its **undisturbed** (rest) **position**.
Wavelength	The **distance** from a point on one wave to the **equivalent point** on the **next wave**. E.g. crest to crest. Measured in **metres**.
Frequency	The **number of waves** passing a certain **point each second**. Measured in **hertz (Hz)**
Longitudinal	**Oscillations** are along **the same direction as the direction of travel** e.g. **sound** waves.
Transverse	**Oscillations are at right angles** to the **direction of travel** e.g. **water** waves, all **electromagnetic** waves.
Period	The **time needed** for **one wave** to **pass a given point**.
Compression	Stretched out region of a **longitudinal** wave where the **particles are closest together**.
Rarefaction	Region in a **longitudinal** wave where the particles are **furthest apart**. (The stretched out section.)
Oscillate	**Swing back** and **forth** in a regular rhythm.
Absorb	When the **energy** of an **EM wave** is **taken up by an object**.
Transmit	When a wave is able to **pass through** a material.
Reflect (HT)	The wave **bounces off a surface**; the **angle of incidence** is **equal** to the **angle of reflection**.
Refract (HT)	The wave **changes direction** when it enters a **medium of different density** where it has a **different speed**.
Medium	The **substance** that **carries a wave** (or disturbance) from one location to another.
Vacuum	A **space** entirely **devoid of matter**.

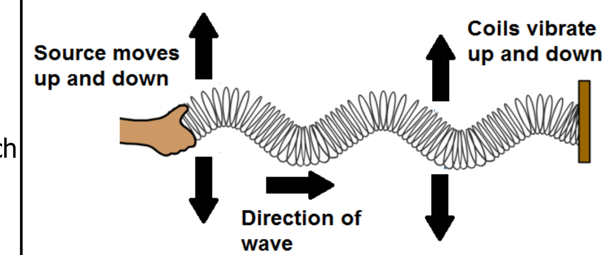
Section 2: The nature of waves

Waves **transfer energy** not matter. Waves can be used to transfer energy and information. **Mechanical waves** travel through a medium, for example light waves and radio waves, they can be **transverse** or **longitudinal**. **Electromagnetic waves** can travel through a vacuum and are **transverse**.

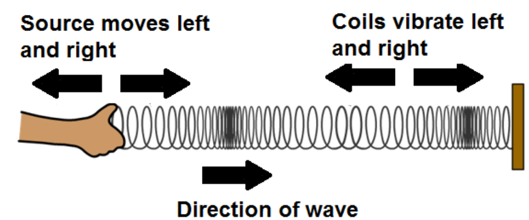
Transverse waves	Longitudinal waves
All electromagnetic waves (visible light, IR, Ultraviolet etc.) S waves. Ripples on the surface of water.	Sound waves. P waves.

Section 2: The nature of waves (continued)

Transverse waves have **oscillations** that are **perpendicular** to the direction in which the waves transfer energy.

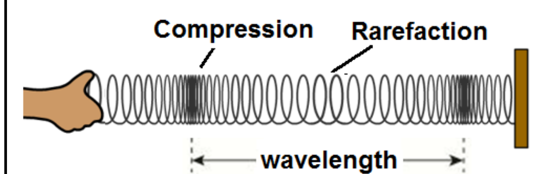


Longitudinal waves have **oscillations** that are **parallel** to the direction in which the waves transfer energy.

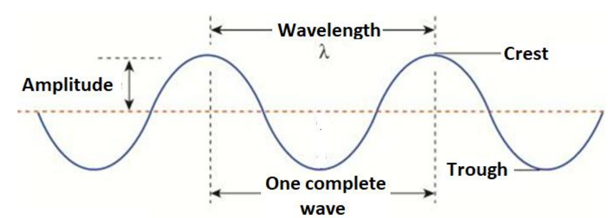


Section 3: The properties of waves

Longitudinal waves are made up of **compressions** and **rarefactions**. The **wavelength** is the **distance** from the **middle** of **one compression** to the **middle** of the **next compression**.



Distance from one crest to the next crest is the **wavelength**. The **amplitude** is the height of the wave crest.



KNOWLEDGE — Physics Topic P12 Waves, electromagnetism & space – Wave properties — ORGANISER

Section 3: The properties of waves (continued)

Period of a wave	$\text{period of a wave} = \dfrac{1}{\text{frequency}}$	
Calculating wave **speed**	Wave speed = frequency x wavelength $V = f\lambda$	Wave speed - m/s Frequency – hertz, Hz Wavelength – metres, m

Section 4: Investigating waves

Measuring the Speed of Sound

- **Measure** the **distance** to a **building.**
- **Fire a starting pistol** and **start a timer.**
- **Stop the timer** when the **echo** is heard.
- **Half** your value for **time.**
- Work out the **speed** using **distance divided by time**.

Measuring the Speed of ripples in a water tank

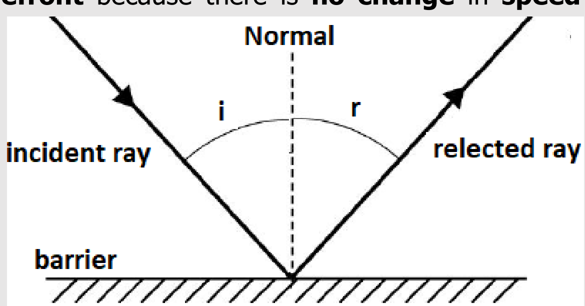
- Use a **ruler** to create **plane waves**.
- **Measure time** taken for a **wave** to travel from one end of tank to the other.
- **Measure distance** travelled.
- Work out the **speed** using **distance divided by time**.

Section 5: Reflection and refraction (HT)

The behaviour of waves can be investigated with water waves in a ripple tank. Waves travelling towards a barrier of a boundary are called **incident** waves.

Reflection

Takes place at the barrier in a tank. The **Reflected wavefront** moves away from barrier at **same angle** to the barrier as the **incident wavefront** because there is **no change** in **speed** or **wavelength**.

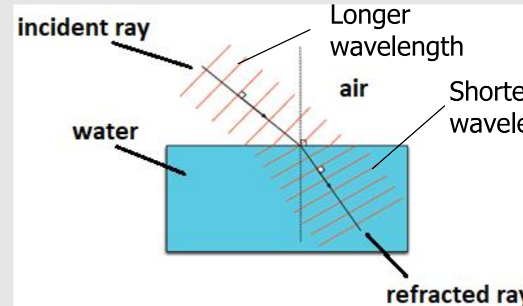


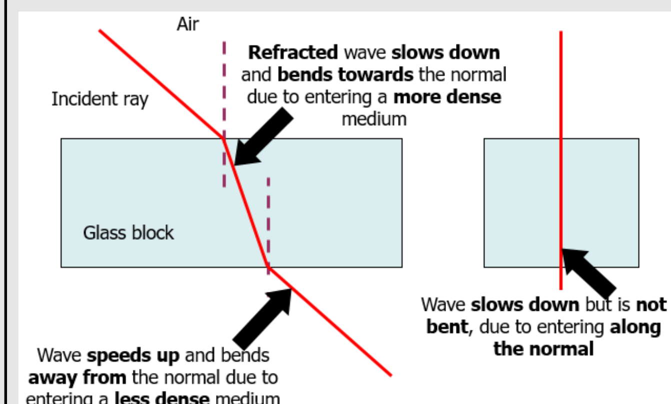
Angle of incidence (i) = angle of reflection (r)

Section 5: Reflection and refraction continued (HT)

Refraction

Waves **change speed** and **wavelength** when they **cross** a **boundary** between **different substances**. This can be seen in a ripple tank at the boundary between deep and shallow water. Unless the waves meet the boundary at right angles, the **change in speed causes** a **change in direction**. This effect is called **refraction**.





Waves and substances (HT)

When waves meet a boundary with a different substance they may be:

- Totally or partially **reflected**
- **Transmitted** through the substance
- **Absorbed** by the substance.

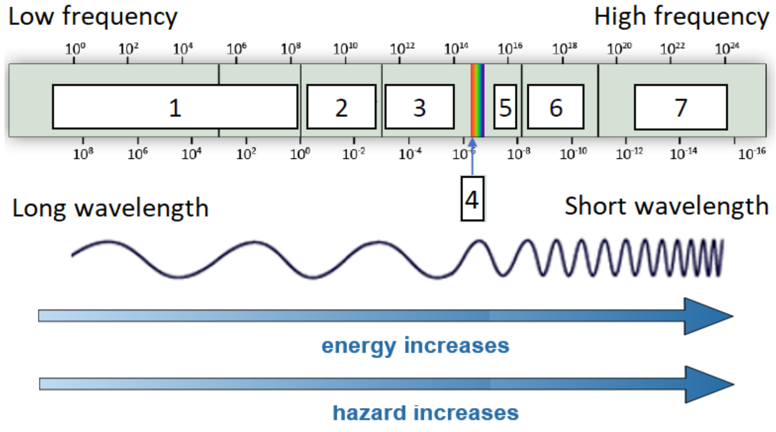
KNOWLEDGE — Physics Topic P13 Waves, electromagnetism & space – Electromagnetic waves — ORGANISER

Section 1: Key terms

Electromagnetic Spectrum	The collective name for **all types of EM radiation**. They are all **transverse waves** that travel at **300,000,000 m/s** (speed of light).
Wavelength	The distance from one wave crest to the next.
Frequency	The **number of wave crests** passing a fixed point every second.
Carrier wave (HT)	Waves used to carry information. They do this by varying their amplitude.
Ionising radiation	**High energy radiation** which can **remove electrons** leaving **ions**. If this happens **in DNA** it can cause a **mutation** that could lead to **cancer**.
Radiation dose	A **measure of** the **risk of harm** resulting **from exposure** of the body **to ionising radiation**. Measured in **Sieverts**.

Section 2: The electromagnetic spectrum

The waves in the electromagnetic spectrum are grouped together according to their wavelength and frequency. They are **transverse** waves **that transfer energy** (not matter) from a source to an absorber. The **human eye** can only **detect visible light**.



1.	Radio	5.	Ultraviolet
2.	Microwaves	6.	X-rays
3.	Infrared	7.	Gamma
4.	Visible		

Section 3: Uses and Risks of EM Radiation

EM Wave	Use	Why it's suitable (HT)	Risks
Radio	**Television** and **radio**	**Reflected** by **ionosphere** so can broadcast over **long distances**. Is a **carrier** wave.	
Microwaves	**Satellite communications, cooking food**	Able to **pass through the atmosphere** to **satellites**. Has a **heating** effect. Is a **carrier** wave.	Internal heating of the body (cooked from the inside.)
Infrared	**Electrical heaters, cooking food, infrared cameras**	Has a **heating** effect. **Emitted by objects** so can be **detected**.	Skin burns
Visible Light	**Fibre optic communications**	Able to **pass along a cable** by **total internal reflection.**	Blindness from bright light.
Ultraviolet	**Energy efficient lamps, sun tanning, checking bank notes.**	**Increases** amount of **melanin** (brown pigment) in **skin**.	**Premature skin ageing**, increase **risk of skin cancer**
X-Rays	**Medical imaging and treatments**	**Absorbed by bone** but **transmitted through soft tissue.**	**Ionizing** – can cause **mutation of genes** and **cancer**
Gamma	**Medical imaging and treatments**	Able to **pass out of body** and be **detected by gamma cameras.** Can **kill cancerous cells.**	**Ionizing** – can cause **mutation of genes** and **cancer**

Section 4: Production of electromagnetic waves

Radio (HT)	**Radio waves** are produced by **oscillations** in **electrical circuits.** When radio waves are absorbed they may create an alternating current with the same frequency as the radio wave itself, so radio waves can themselves make electrons vibrate in an electrical circuit.
Gamma	**Gamma rays** are produced from the **decay** of an **unstable nucleus**.

Section 5: Equations to learn

Calculation	Equation	Symbol equation	Units
Wave speed	Wave speed = frequency x wavelength	$v = f\lambda$	Wave speed - metres per second (m/s) Frequency - hertz (Hz) Wavelength - metres (m)

KNOWLEDGE

Physics Topic P15 Waves, electromagnetism & space – Electromagnetism

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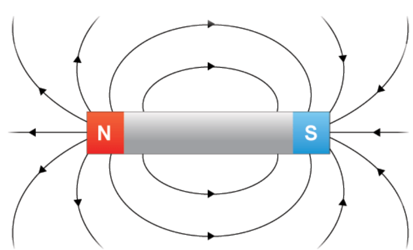
Section 1: Electromagnetism Key Terms

Pole	The **places** on a magnet where the **magnetic forces** are **strongest**.
Magnetic Field	The **area** around a magnet where a **force acts** on another magnet or magnetic material.
Repel	Occurs when two **like poles** are brought close together. The magnets **push apart**.
Attract	Occurs when two **opposite poles** are brought close together. The magnets **move together**.
Permanent magnet	A magnet that produces its **own magnetic field**.
Induced magnet	A magnetic material that **becomes a magnet** when it is placed in a **magnetic field**. When **removed** from the **field** it **quickly loses its magnetism**.
Magnetic material	There are four magnetic materials: **iron**, **steel**, **cobalt** and **nickel**.
Compass	Compasses contain small bar magnets which **points** to the **north pole** of the **Earth's magnetic field**.
Solenoid	A solenoid is a long **coil of wire** that produces a controlled magnetic field.
Electromagnet	A **solenoid containing an iron core** which increases its strength.
Motor effect (HT)	The **force produced** between a **conductor** carrying a current **within a magnetic field** and **the magnet producing the field**.
Magnetic flux density (HT)	A measure of the strength of a magnetic field.

Section 2: Magnetic fields

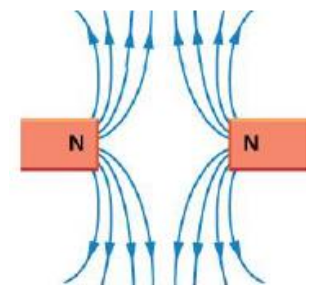
The **magnetic field lines** of a bar magnet curve around from the **north** pole of the bar magnet to the **south pole**.
The **field lines** always go from **north** to **south** and **never touch**.



Section 2: Magnetic fields (continued)

Like poles repel.

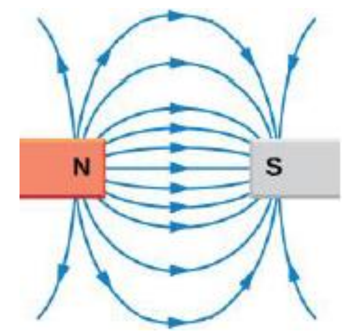
When **two north poles** (or two south poles) are placed together, they will **repel** each other.



Unlike poles attract.

When a **north pole** and a **south pole** are placed together, they will **attract**.

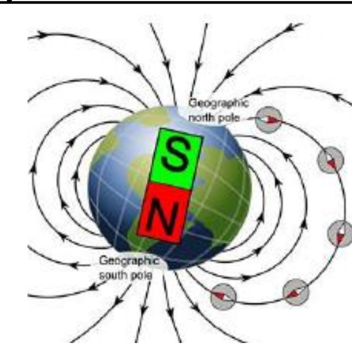
Attraction and repulsion between two magnetic poles are examples of **non-contact forces**.



Induced magnetism is **magnetism** created in an **unmagnetised magnetic material** when the material is **placed in a magnetic field**.

Steel is used **instead** of **iron** to make **permanent magnets** because steel **does not lose** its **magnetism easily** but **iron does**.

The **Earth** behaves as if there is a **bar magnet** inside it. The geographic north pole is a **magnetic south pole**. A **compass** will point towards **geographical north** and is the **north-seeking pole**.
We know it is the **core** of the Earth that is magnetic(not the whole thing) because a compass at the **north pole** points below your feet.



KNOWLEDGE

Physics Topic P15 Waves, electromagnetism & space – Electromagnetism

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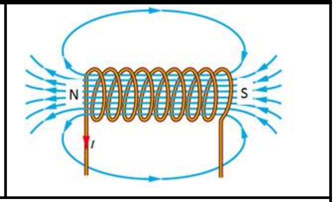
Section 3: Magnetic fields of electric currents

We can increase the strength of the magnetic field by putting a **magnetic** (e.g. iron) **core** in the **solenoid** (long coil of wire.) The magnetic field in a **solenoid** is concentrated **inside the coil in a uniform direction**, otherwise it acts in the same way as a bar magnet.



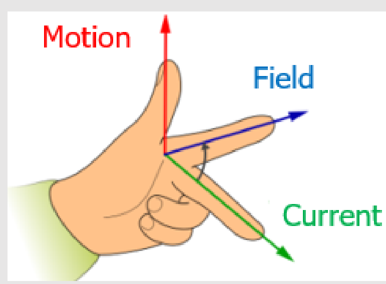
Increasing current	**Increasing current** makes the **magnetic field stronger**. **Reversing** the **direction** of the current **reverses the magnetic field lines**.
Electromagnet	An electromagnet is a **solenoid** that has an **iron core.** It consists of an **insulated wire** wrapped around an iron bar.
Increasing the force of a solenoid	• Add an **iron core** • Increase the **number of coils** of wire • Increase the **current** • Move the magnetic material **closer** to the solenoid.

Section 4: The motor effect (HT)

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 othe**r. This can be used to create a motor.

Fleming's left hand rule

- Fleming's left hand rule shows the various **directions of actions** in an **electric motor.**
- Thumb – direction of the **magnetic force**
- First finger – direction of the **magnetic field**
- Second finger – direction of the **current** in the wire.



Flux density

Magnetic flux density is a **measure** of the **strength** of a **magnetic field**. It is the number of lines of magnetic flux in a given area.

F=B x I x L

Force = magnetic flux density x current x length

Force - newtons, N
Magnetic flux density – tesla,T
Current – amps, A
Length – metres, m

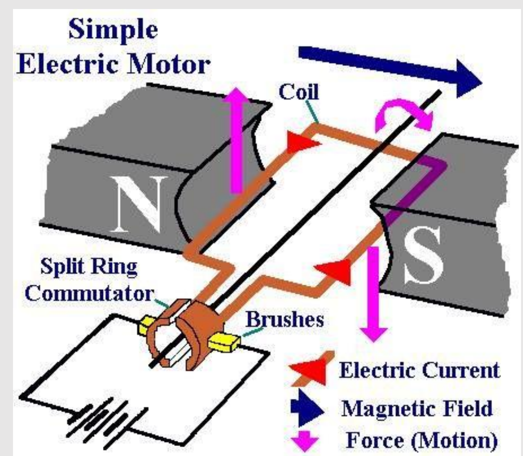
Section 5: An electric motor (HT)

Electric motor

An electric motor is a device that makes use of the **motor effect**.

The following statements explain how the electric motor creates a **turning force**:

- The power supply applies a **potential difference** across the coil
- A **current flows** through the coil
- A **magnetic field** is created around the coil
- The magnetic field **interacts** with the **magnetic field** of the **permanent magnets**
- This creates a force that makes the **coil spin**.



Increasing size of the turning force by:	• Increasing the **current** • Increasing **strength** of **magnetic field** • Increase the **number of turns** on the **coil** of wire • Adding an **iron core** inside the **coil.**
Reverse direction of force by:	• Reverse **poles** of **magnet** • Reverse **current**