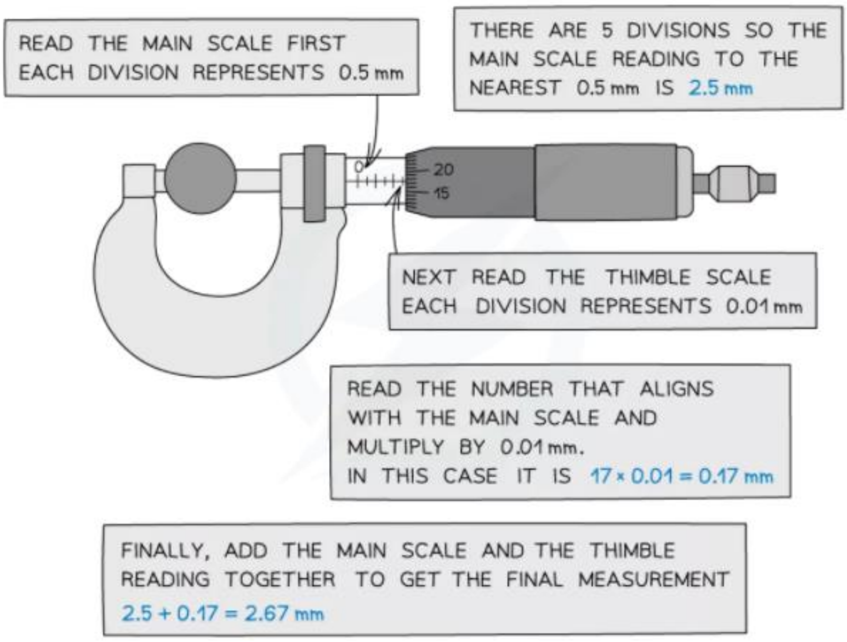
Chapter 1 General Physics

1.1 Physical quantities and measurement techniques

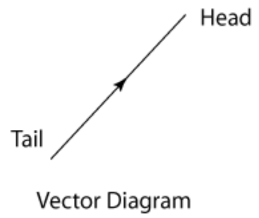
Core	Supplement
1 Describe the use of rulers and measuring cylinders to find a length or a volume	
2 Describe how to measure a variety of time intervals using clocks and digital timers	
3 Determine an average value for a small distance and for a short interval of time by measuring multiples (including the period of oscillation of a pendulum)	
	4 Understand that a scalar quantity has magnitude (size) only and that a vector quantity has magnitude and direction
	5 Know that the following quantities are scalars: distance, speed, time, mass, energy and temperature
	6 Know that the following quantities are vectors: force, weight, velocity, acceleration, momentum, electric field strength and gravitational field strength
	7 Determine, by calculation or graphically, the resultant of two vectors at right angles, limited to forces or velocities only

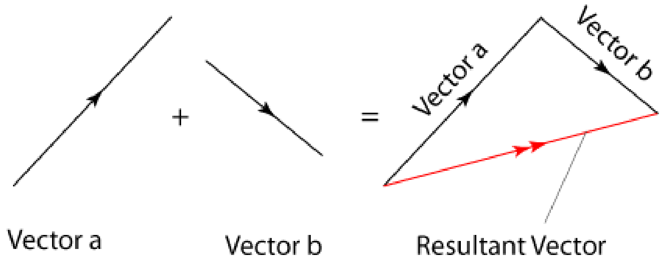
- A ruler is used to measure **length** for distances between 1 mm and 1 meter.
- The SI unit for length is in **meters**.
- To measure the volume of a regular object you will need to know the formula and several of its length. For e.g., to measure the volume of a solid box, you'll need its height x length x width.
- To measure the volume of an irregular object you put the object in a measuring cylinder with water and measure the rise in water. The rise in water is the volume of the object.
- **Time** is measured using clocks or watches.
- The SI unit for time is in **seconds**.
- You can increase the accuracy for measuring any object by taking an average value.
- For e.g., to measure the period of a pendulum, you can take the time it takes to complete ten cycles instead of one and dividing the time by ten.
- A micrometre screw gauge is a tool used for measuring small widths, thickness, or diameters
- It has a resolution of **0.01 mm**
- A micrometre is made up of two scales:
  1) main scale – this is on the sleeve (sometimes called the barrel)
  2) the thimble scale – this is a rotating scale on the thimble
- The value measured from the micrometre is read where the thimble scale aligns with the main scale.



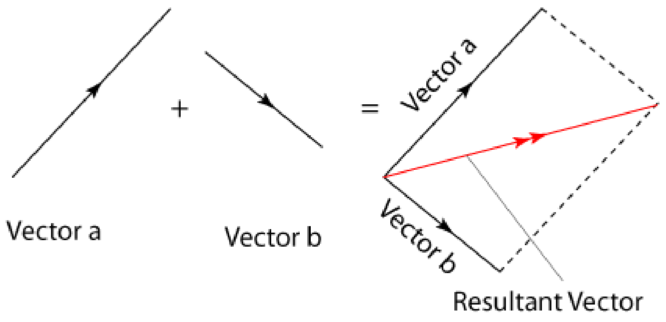
- A **scalar** quantity has <u>magnitude</u> only.
- Example of scalar quantities include distance, time, speed and mass.
- A **vector** quantity has both <u>magnitude</u> and <u>direction</u>.
- Example of vector quantities include distance, velocity, acceleration and force.
- The easiest way to tell if a quantity is scalar or vector is to know whether you can put "negative" sign in front of it.
- Example mass and time are both scalars because there is no "-" seconds or "-" kilograms.
- Velocity is a vector because you can have "-" in front of the unit as you will see later.
- Vectors can be added using triangle or parallelogram method.

Triangular method





Parallelogram method



1.2 Motion

Core	Supplement
1 Define speed as distance travelled per unit time; recall and use the equation $v = \frac{s}{t}$	
2 Define velocity as speed in a given direction	
3 Recall and use the equation $\text{average speed} = \frac{\text{total distance travelled}}{\text{total time taken}}$	9 Define acceleration as change in velocity per unit time; recall and use the equation $a = \frac{\Delta v}{\Delta t}$
4 Sketch, plot and interpret distance–time and speed–time graphs	
5 Determine, qualitatively, from given data or the shape of a distance–time graph or speed–time graph when an object is: (a) at rest (b) moving with constant speed (c) accelerating (d) decelerating	10 Determine from given data or the shape of a speed–time graph when an object is moving with: (a) constant acceleration (b) changing acceleration
6 Calculate speed from the gradient of a straight-line section of a distance–time graph	11 Calculate acceleration from the gradient of a speed–time graph
7 Calculate the area under a speed–time graph to determine the distance travelled for motion with constant speed or constant acceleration	
	12 Know that a deceleration is a negative acceleration and use this in calculations
8 State that the acceleration of free fall g for an object near to the surface of the Earth is approximately constant and is approximately $9.8\,m/s^2$	13 Describe the motion of objects falling in a uniform gravitational field with and without air/liquid resistance (including reference to terminal velocity)

- **Distance:** The distance travelled by an object is the total **length** that is travelled by that object.
- The SI unit for distance is also in **meters**.
- **Speed:** *Rate of change* in **distance**.
- SI unit: meter per second (m/s)
- Speed is a **scalar** quantity

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

v is the speed, d is the distance travelled and t is the time taken

- **Velocity:** Is speed with a given direction!

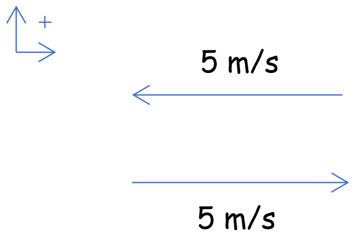
- SI unit: meter per second (m/s)
- Velocity however is a **vector** quantity

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

v is the speed; s is the displacement and t are the time taken

- Note: In velocity the positive/ negative sign indicates direction.

Example problem



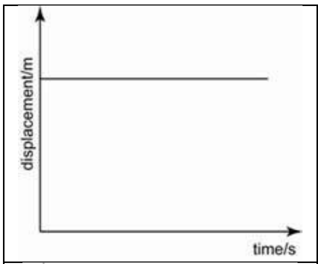
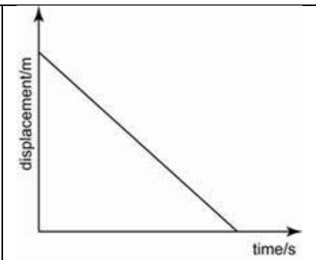
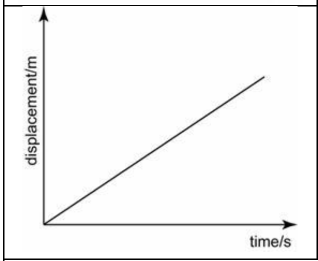
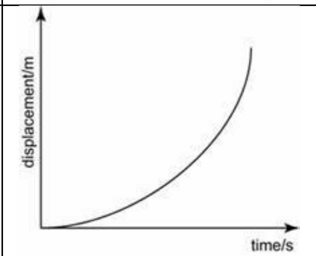
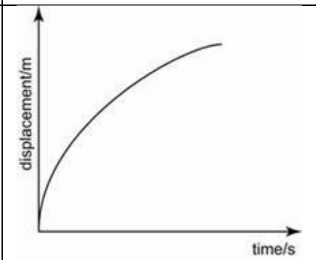
Speed of top arrow:
Velocity of top arrow:
Speed of bottom arrow:
Velocity of bottom arrow:

- **Acceleration:** Rate of change of velocity.
- The SI unit for acceleration is m/s^2
- Acceleration is a vector quantity

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

- In IGCSE you need to be able to read as well as plot displacement-time graphs and velocity-time graphs!
- For a displacement-time graph, the **gradient** represents the **velocity**.
- For a velocity-time graph, the **gradient** represents the **acceleration** while the **area** under the graph represent the **displacement**.

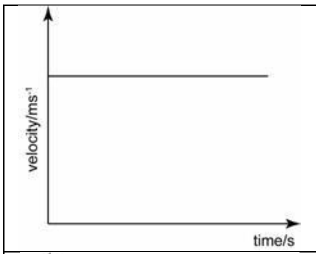
Displacement-Time graph

	Velocity is zero!		Velocity is constant and "-"
	Velocity is constant and "+"		Velocity is not constant but increasing
			Velocity is not constant but decreasing

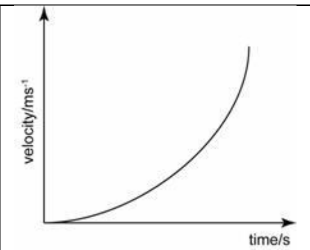
Flex your brain!

A car starts from rest and accelerates at a constant acceleration of 3m/s^2 for 10 seconds. The car then travels at a constant velocity for 5 seconds. The brakes are then applied and the car stops in 5 seconds. What is the total distance travelled by the car?

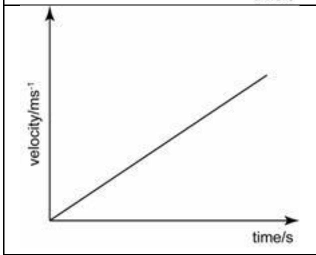
Velocity-Time graph



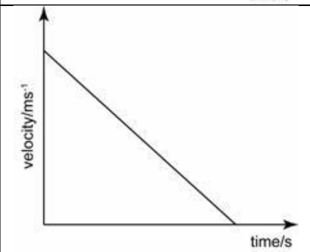
Zero acceleration!



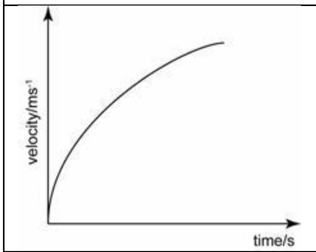
Acceleration is not constant but increasing



Constant and positive acceleration



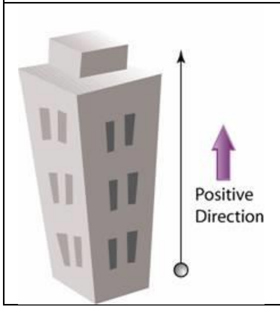
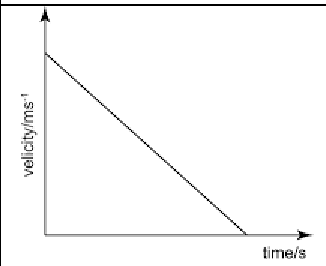
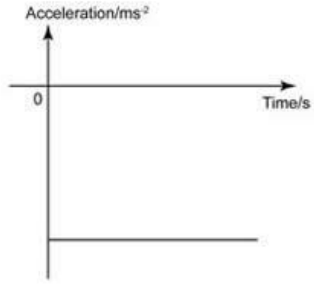
Constant but negative acceleration



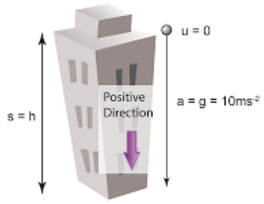
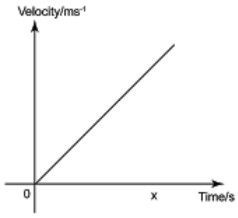
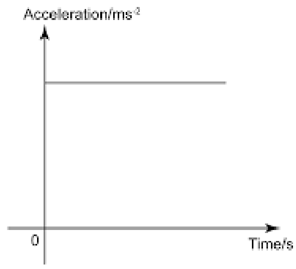
Acceleration is not constant but decreasing

- **Free falling:** Free falling is a motion under gravitational force as the only force acting on the moving object.
- The acceleration of a free-falling object is always *constant*.
- On the surface of the earth, the acceleration due to gravity, g is equal to 9.8ms^{-2}.
- In reality objects are slowed by air resistance. Once air resistance is equal to the force of gravity, the object stops accelerating. The object is said to have reached <u>terminal velocity</u>.

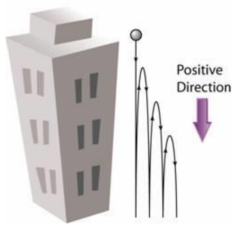
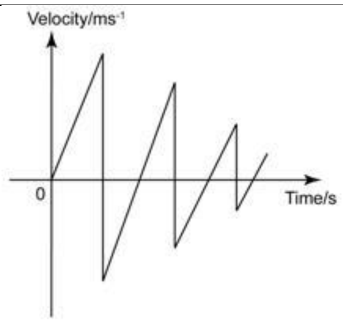
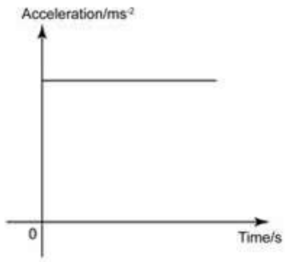
Launching Object Upward

Motion	Velocity-Time Graph	Acceleration-Time Graph
		

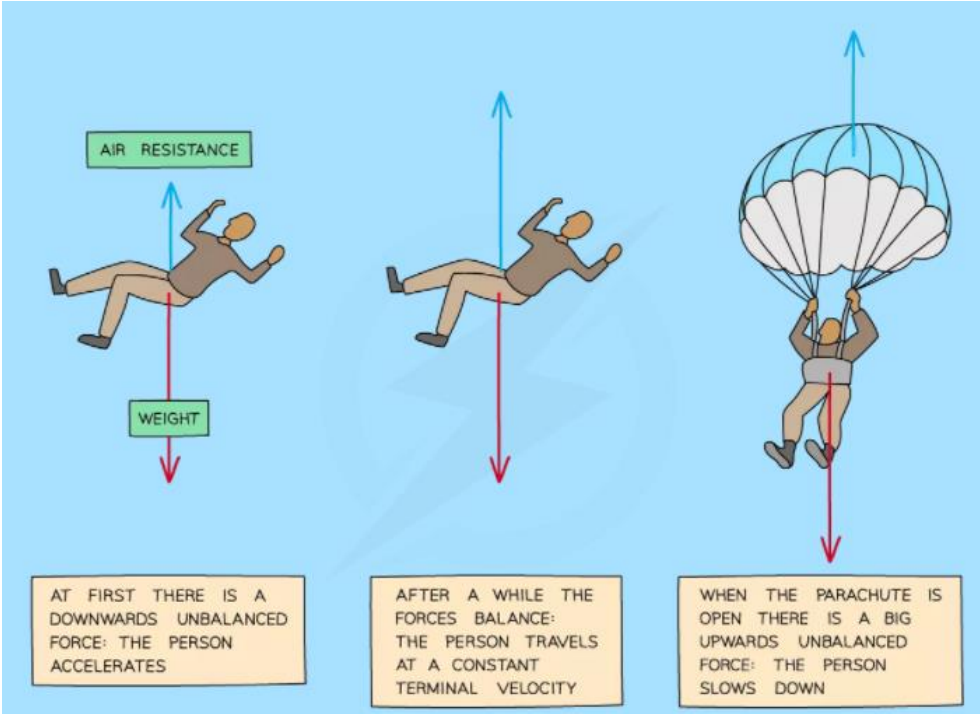
Dropping Object from a High Place

Motion	Velocity-Time Graph	Acceleration-Time Graph
		

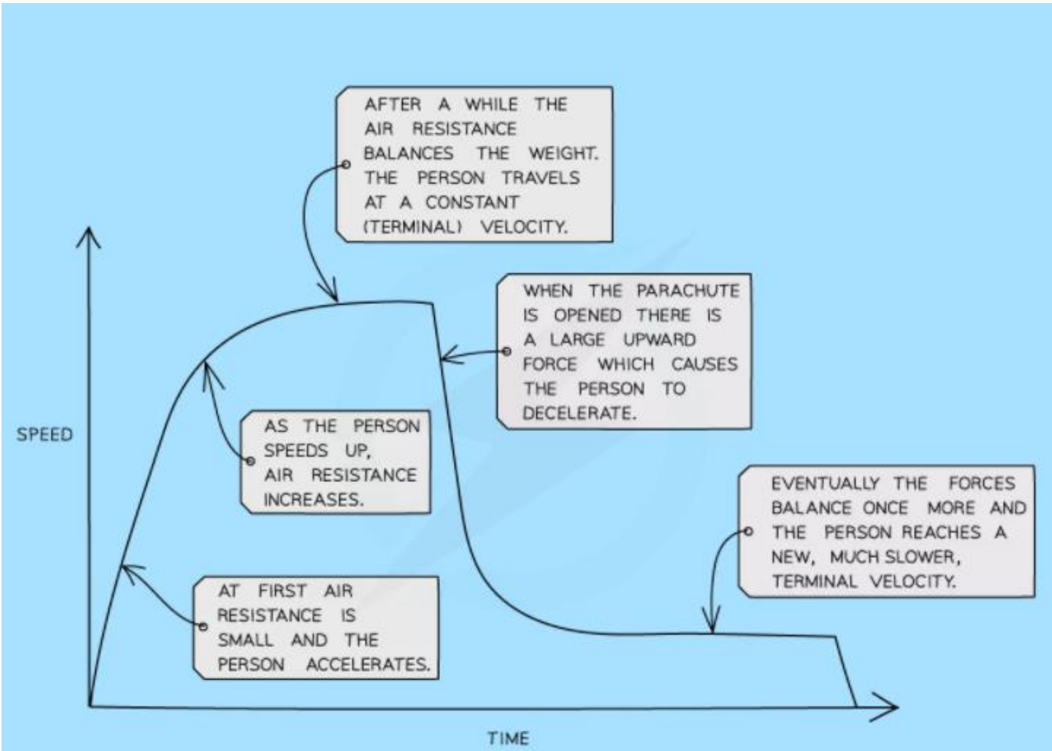
Object Falling and Bounce Back

Motion	Velocity-Time Graph	Acceleration-Time Graph
		

- Two forces act on a parachutist upon jumping out of a plane
  1) Weight
  2) Air resistance



- Plotting the motion on a speed-time graph



1.3 Mass and weight

Core	Supplement
1 State that mass is a measure of the quantity of matter in an object at rest relative to the observer	
2 State that weight is a gravitational force on an object that has mass	5 Describe, and use the concept of, weight as the effect of a gravitational field on a mass
3 Define gravitational field strength as force per unit mass; recall and use the equation $g = \frac{W}{m}$ and know that this is equivalent to the acceleration of free fall	
4 Know that weights (and masses) may be compared using a balance	

- **Mass:** Mass is defined as the amount of matter in an object.
- The SI unit is in kg
- Mass is a scalar quantity.
- **Weight:** Is the force of gravity acting on an object.
- The SI unit is in Newtons

Weight = mass x gravitational acceleration

W = mg

1.4 Density

Core	Supplement
1 Define density as mass per unit volume; recall and use the equation $\rho = \frac{m}{V}$	
2 Describe how to determine the density of a liquid, of a regularly shaped solid and of an irregularly shaped solid which sinks in a liquid (volume by displacement), including appropriate calculations	
3 Determine whether an object floats based on density data	4 Determine whether one liquid will float on another liquid based on density data given that the liquids do not mix

- **Density** is defined as mass per unit volume.
- The SI unit for density is kgm^{-3}

$$\rho = \frac{m}{v^3}$$

- You can determine the mass of an object by using a weighing scale.
- The volume for the object can be calculated out for regular shapes (cylinder, box etc.) or using a measuring cylinder for irregular shapes.
- An object will float if it is less dense then medium it is in and sink if more dense.

1.5 Forces

1.5.1 Effects of forces

Core	Supplement
1 Know that forces may produce changes in the size and shape of an object	9 Define the spring constant as force per unit extension; recall and use the equation $k = \frac{F}{x}$
2 Sketch, plot and interpret load–extension graphs for an elastic solid and describe the associated experimental procedures	10 Define and use the term 'limit of proportionality' for a load–extension graph and identify this point on the graph (an understanding of the elastic limit is **not** required)
3 Determine the resultant of two or more forces acting along the same straight line	11 Recall and use the equation $F = ma$ and know that the force and the acceleration are in the same direction
4 Know that an object either remains at rest or continues in a straight line at constant speed unless acted on by a resultant force	
5 State that a resultant force may change the velocity of an object by changing its direction of motion or its speed	12 Describe, qualitatively, motion in a circular path due to a force perpendicular to the motion as: (a) speed increases if force increases, with mass and radius constant (b) radius decreases if force increases, with mass and speed constant (c) an increased mass requires an increased force to keep speed and radius constant ($F = \frac{mv^2}{r}$ is **not** required)

- **Force:** Push or pull exerted on an object.
- Forces can change the shape and size of an object and can even change the direction and cause deceleration or acceleration of an object.
- SI unit: Newton (or $kgms^{-1}$)
- Force is a vector quantity.
- **Inertia** is a property of a body that tends to maintain its state of motion.
- **Newton's 1st Law:** In the absence of external forces, an object at rest remains at rest and an object in motion continues in motion with a constant velocity.
- **Newton's 2nd law:** States that the acceleration of an object is directly proportional to the resultant force acting on the object and inversely proportional to mass.
- So basically

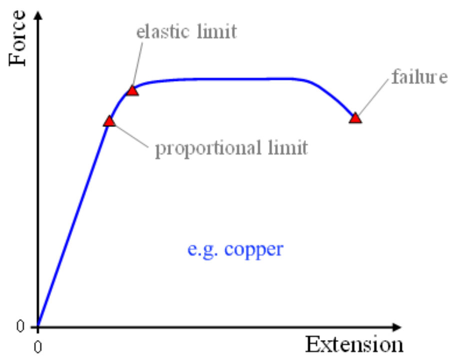
$$\text{Fnet} = \text{ma}$$

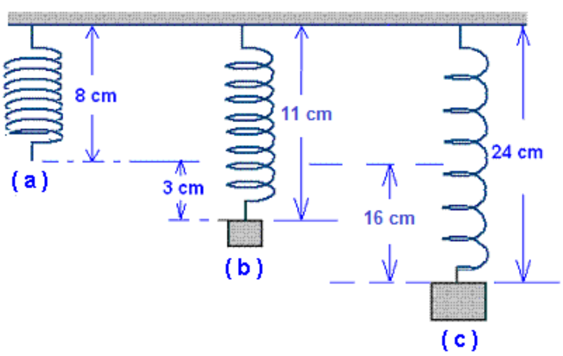
- When the forces acting on an object are not balanced, there must be a net force acting on it. This net force is known as the unbalanced force.

- Where F is the force, m is the mass and a is the acceleration. Hence, the resultant force will cause an object to accelerate.

Find the resultant force and acceleration
A box of mass 150kg is placed on a horizontal floor with a smooth surface (which means no friction). Find the acceleration of the box when 300N force is pulling it to the left and 600N is pulling it to the right. *Hint: Whenever there's more than 1 force acting on an object you'll need to find the resultant force. Draw out the problem!*

- **Hooke's Law:** Springs extend in proportion to loads, as long as they are under their proportional limit.
- **Limit of proportionality:** Point and which load and extension are no longer proportional.
- **Elastic limit:** Point at which spring will not return to its original shape even after the load is removed.





- **Circular motions:** An object at steady speed in a circular orbit is always accelerating as its direction is changing, but it gets no closer to the centre
- **Centripetal force:** is the force acting towards the centre of a circle. It is a force that is **needed** (not caused by) a circular motion, for example when you swing a ball on a string round in a circle, the tension of the string is the centripetal force. If the string is cut then the ball will travel in a straight line at a tangent to the circle at the point where the string was cut (Newton's first law)
- **Newtons 3rd law:** if object A exerts a force on object B, then object B will exert an equal but opposite force on object A or, more simply: <u>to every action there is an equal but opposite reaction</u>
- **Centrifugal force** also known as the **non-existent force** is the force acting away from the centre of a circle. This is what makes a slingshot go outwards as you spin it. The centrifugal force is the reaction to the centripetal force (Newton's third law). It has the same magnitude but opposite direction to the centripetal force ("equal but opposite").

1.5.1 Effects of forces continued

Core

6 Describe solid friction as the force between two surfaces that may impede motion and produce heating

7 Know that friction (drag) acts on an object moving through a liquid

8 Know that friction (drag) acts on an object moving through a gas (e.g. air resistance)

Supplement

1.5.2 Turning effect of forces

Core

1 Describe the moment of a force as a measure of its turning effect and give everyday examples

2 Define the moment of a force as moment = force × perpendicular distance from the pivot; recall and use this equation

3 Apply the principle of moments to situations with one force each side of the pivot, including balancing of a beam

4 State that, when there is no resultant force and no resultant moment, an object is in equilibrium

Supplement

5 Apply the principle of moments to other situations, including those with more than one force each side of the pivot

6 Describe an experiment to demonstrate that there is no resultant moment on an object in equilibrium

1.5.3 Centre of gravity

Core

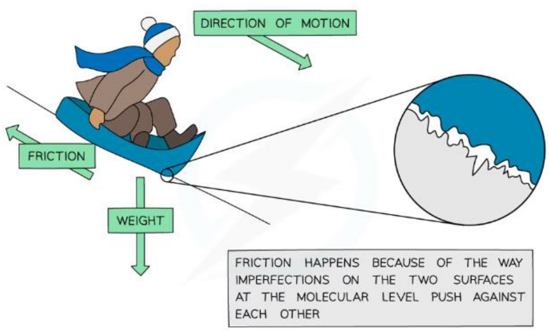
1 State what is meant by centre of gravity

2 Describe an experiment to determine the position of the centre of gravity of an irregularly shaped plane lamina

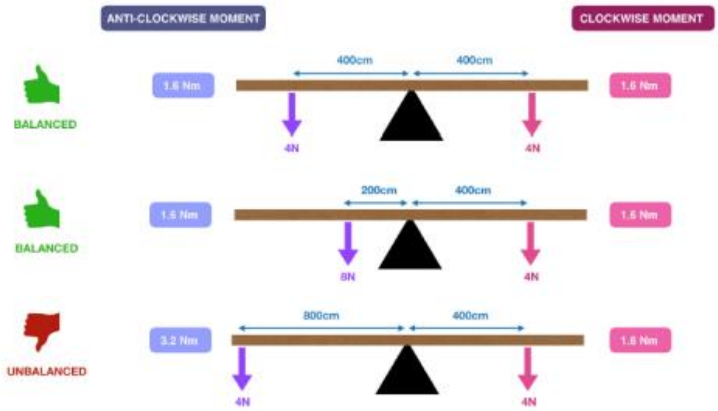
3 Describe, qualitatively, the effect of the position of the centre of gravity on the stability of simple objects

Supplement

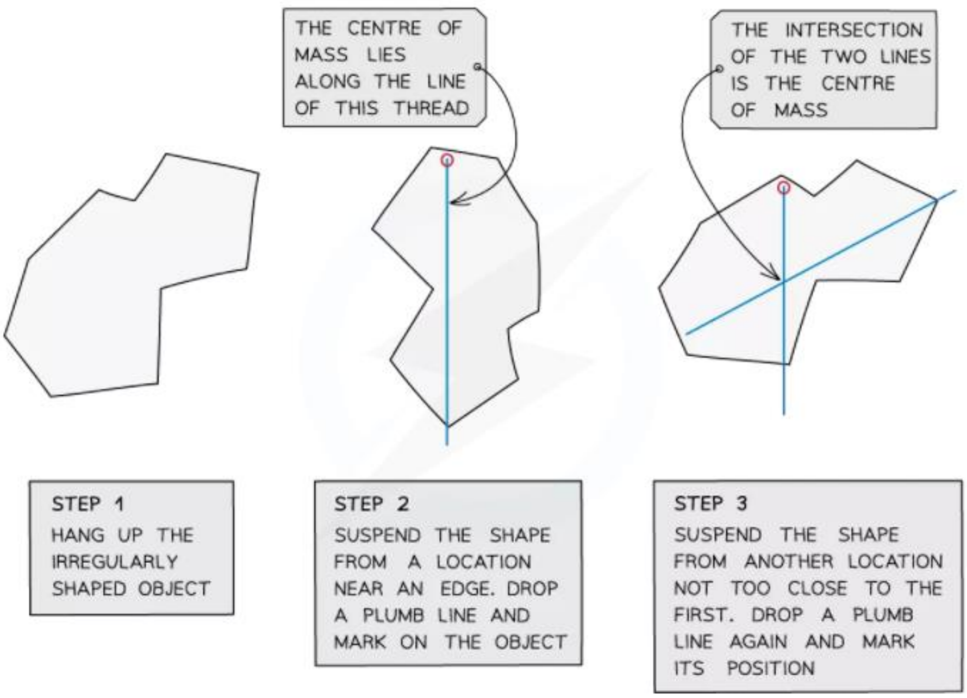
- **Friction** is a <u>force</u> that acts in a direction that is opposite to the direction of motion.
- It can occur between two surfaces that are in contact with one another or even when an object moves through fluids (e.g., air resistance)
- Friction can cause an object to slow down and produce heat.



- **Turning effect:** Moments of a force are measured in Newton meters, can either be clockwise or anticlockwise.
- **Equilibrium** is achieved when the **clockwise moment = anticlockwise moments** and when the **sum of all forces are equal to zero**.



- **Centre of mass** is an imaginary point in a body (object) where the total mass of the body can be thought to be concentrated.
- For stability the centre of mass must be over the centre of pressure.
- For a symmetrical object of uniform density (such as a square) the centre of mass is located at the point of symmetry.
- When an object is suspended from a point, the object will always settle so that its centre of mass comes to reset below the pivoting point.
- This can be used to find the centre of mass of an irregular shape:



1.6 Momentum

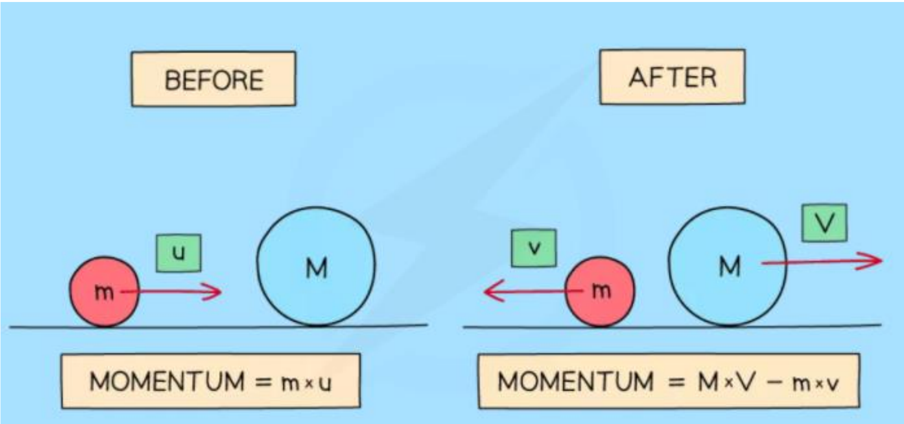
Core	Supplement
	1 Define momentum as mass × velocity; recall and use the equation $p = mv$ 2 Define impulse as force × time for which force acts; recall and use the equation impulse $= F\Delta t = \Delta(mv)$ 3 Apply the principle of the conservation of momentum to solve simple problems in one dimension 4 Define resultant force as the change in momentum per unit time; recall and use the equation $F = \frac{\Delta p}{\Delta t}$

- Momentum is defined by the equation:

Momentum = mass x velocity

p = m x v

- The units of momentum are kg/ ms^{-1}
- Momentum is a vector quantity
- The conservation of momentum states that in the **absence of external forces (such as friction), the total momentum of a system remains the same**.
- I.e., mom before = mom after



- **Impulse** is the change in momentum

Impulse = mv – mu

OR

F x t = mv – mu

1.7 Energy, work and power

1.7.1 Energy

Core	Supplement
1 State that energy may be stored as kinetic, gravitational potential, chemical, elastic (strain), nuclear, electrostatic and internal (thermal)	
2 Describe how energy is transferred between stores during events and processes, including examples of transfer by forces (mechanical work done), electrical currents (electrical work done), heating, and by electromagnetic, sound and other waves	
	4 Recall and use the equation for kinetic energy $E_k = \frac{1}{2}mv^2$
	5 Recall and use the equation for the change in gravitational potential energy $\Delta E_p = mg\Delta h$
3 Know the principle of the conservation of energy and apply this principle to simple examples including the interpretation of simple flow diagrams	6 Know the principle of the conservation of energy and apply this principle to complex examples involving multiple stages, including the interpretation of Sankey diagrams

Potential energy

- **Gravitational potential energy**: The energy stored in an object as the result of its height.
- SI units: Nm or Joule
- Quantity: Scalar

$$W = mg \times h$$

where h is the relative height of the object.

- **Elastic potential energy:** The energy stored in elastic materials when you stretch or compress the spring.
- SI units: Nm or Joule
- Quantity: Scalar

$$W = \frac{1}{2}Fx$$

- Where x is the length of the compressed or elongated spring.

Kinetic energy

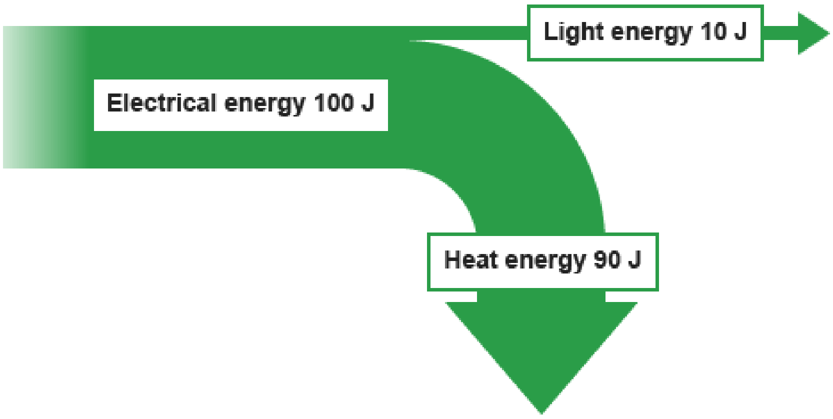
- **Kinetic energy:** The energy of a moving object.

- SI units: Nm or Joule
- Quantity: Scalar

$$W = \frac{1}{2}mv^2$$

Where v is the speed of the object

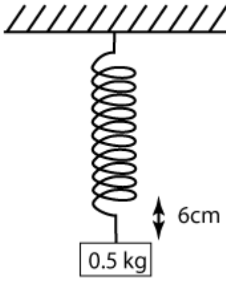
- The law of conservation of energy states that **energy cannot be created or destroyed, it can only change from one form to another**.
- Sankey diagrams summarize all energy transfers taking place in a process.
- For example, in a 100 Joules electric incandescent lamp, only 10 Joules of its electricity gets converted into useful light while the remaining 90 Joules is wasted as heat.
- The Sankey diagram can hence be drawn as:



- Try the following questions:

Ah Kau climbs 35 steps of a staircase. Each step is 10cm in height. If Ah Kau weighs 45kg, find the work done by him to reach the top of the 35 steps.

Determine the kinetic energy of a 2000kg bus that is moving at a speed of 35m/s.



Find the energy stored in the spring.

The Sankey diagram above shows the efficiency of a solar panel

What is the input power to the panel?

1.7.2 Work

Core

1 Understand that mechanical or electrical work done is equal to the energy transferred

2 Recall and use the equation for mechanical working

$W = Fd = \Delta E$

Supplement

1.7.3 Energy resources

Core

1 Describe how useful energy may be obtained, or electrical power generated, from:

- (a) chemical energy stored in fossil fuels
- (b) chemical energy stored in biofuels
- (c) water, including the energy stored in waves, in tides, and in water behind hydroelectric dams
- (d) geothermal resources
- (e) nuclear fuel
- (f) light from the Sun to generate electrical power (solar cells)
- (g) infrared and other electromagnetic waves from the Sun to heat water (solar panels) and be the source of wind energy

including references to a boiler, turbine and generator where they are used

2 Describe advantages and disadvantages of each method in terms of renewability, availability, reliability, scale and environmental impact

3 Understand, qualitatively, the concept of efficiency of energy transfer

Supplement

4 Know that radiation from the Sun is the main source of energy for all our energy resources except geothermal, nuclear and tidal

5 Know that energy is released by nuclear fusion in the Sun

6 Know that research is being carried out to investigate how energy released by nuclear fusion can be used to produce electrical energy on a large scale

7 Define efficiency as:

(a)

$$(\%)\text{ efficiency} = \frac{\text{(useful energy output)}}{\text{(total energy input)}} (\times 100\%)$$

(b)

$$(\%)\text{ efficiency} = \frac{\text{(useful power output)}}{\text{(total power input)}} (\times 100\%)$$

recall and use these equations

- **Work is** done by a constant force to move an object a certain <u>distance</u>
- SI unit: Joule
- Quantity: Scalar

$$W = F \times s$$

Where F is the force and s is the distance travelled.

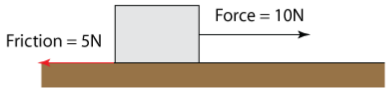


Diagram above shows a 10 N force is pulling a metal. The friction between the block and the floor is 5N. If the distance travelled by the metal block is 2m, find

a) the work done by the pulling force

b) the work done by the frictional force

- **Energy:** Is the capacity to do work.
- SI units: Joules
- Quantity: Scalar
- **Energy sources** can come from renewable or non-renewable sources.
- **Renewable** source of energy is inexhaustible, for e.g. solar, hydroelectric, wind, etc. e.g. hydro dams, tidal power scheme, wave energy, geothermal resources, nuclear fission, solar cells, solar panels.
- **Non-renewable** source of energy: is exhaustible for example fossil fuels. Eg, fossil fuel.
- **The conservation of energy principle** states that energy cannot be created or destroyed by can change from one form to another.

- **Efficiency:** The percentage of usable energy.
- SI units: dimensionless or %
- Quantity: dimensionless

$$\eta = \frac{Output}{Input} \times 100\%$$

1.7.4 Power

Core	Supplement
1 Define power as work done per unit time and also as energy transferred per unit time; recall and use the equations (a) $P = \frac{W}{t}$ (b) $P = \frac{\Delta E}{t}$	

- **Power:** Is the rate at which work is done.
- SI units: Watt or J/s
- Quantity: Scalar

$$P = \frac{W}{t}$$

- Where W is the energy or work done.

1.8 Pressure

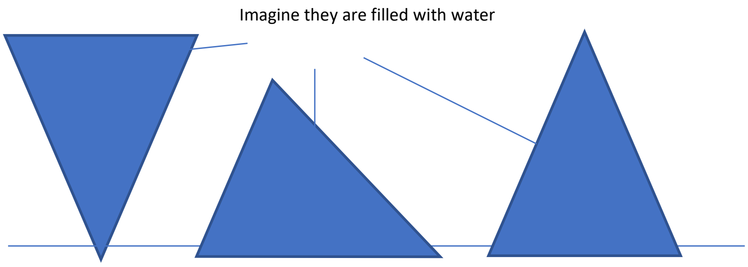
Core	Supplement
1 Define pressure as force per unit area; recall and use the equation $p = \frac{F}{A}$	
2 Describe how pressure varies with force and area in the context of everyday examples	
3 Describe, qualitatively, how the pressure beneath the surface of a liquid changes with depth and density of the liquid	4 Recall and use the equation for the change in pressure beneath the surface of a liquid $\Delta p = \rho g \Delta h$

- **Pressure,** P is the **force,** F exerted per unit **area,** A

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

- The SI unit for force is Newtons.
- The SI unit for area is m^2.
- The SI unit for pressure is then Newton/m^2 or Pascal.

Which of the following orientation do you think exerts the biggest force on the surface? *Hint: think about the area*

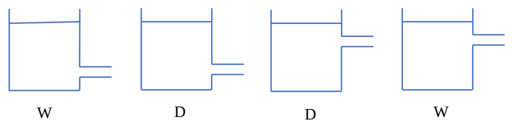


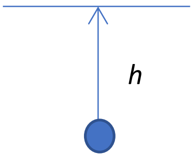
- The pressure exerted by liquids (or gas) can be found by using

$$P = h\rho g$$

- Fluids exert pressure on the fluids below due the *weight* of the fluid. The pressure acts in all directions.
- The three factors affecting fluid pressure
  -depth of the fluid
  -density of the fluid
  -gravitational acceleration (9.8 m/s^2 if you are from earth)
- The deeper the fluid, the higher its pressure.
- For instance the pressure at the bottom of the sea is much higher than at the surface making necessary special equipment in order to explore its depths like a submarine.

Which of the following do you think will "shoot" the farthest? *Hint: Density of D < Density of W. Think logically…….*





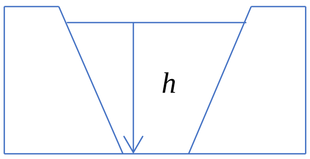
What is the pressure exerted by the water on the bubble assuming *h* is

a) 1m?

b) 5m?

c) 10m?

Hint: Density of water is 1000 kgm^{-3}



Calculate the depth of the water if the maximum pressure at the base of the dam is 750 kPa.