NCEA Science 1.1

GZ Science Resources

Mechanics AS 90940

Achievement Criteria

Aspects of mechanics will be limited to a selection from the following:

- Distance, speed, interpretation of distance and speed time graphs, average acceleration and deceleration in the context of everyday experiences such as journeys, sport, getting going. The relationships:

  $$v = \frac{\Delta d}{\Delta t} \quad a = \frac{\Delta v}{\Delta t}.$$

- Mass, weight and the acceleration due to gravity, balanced and unbalanced forces, in the context of everyday experiences such as being stationary, moving at constant speed, accelerating. The relationship:

  $$F_{net} = ma.$$

- Force and pressure in the context of everyday experiences. The relationship:

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

- Work and power, gravitational potential energy, kinetic energy, and the conservation of mechanical energy in free fall situations in the context of everyday experiences such as sports performance, dropping things, tossing balls. The relationships:

  $$\Delta E_P = mg\Delta h \quad E_K = \frac{1}{2}mv^2 \quad W = Fd \quad P = \frac{W}{t}.$$

Definition of motion

Objects that move from one point of space to another over time are said to have motion. Examples include a tortoise slowly moving across the ground or a bullet moving fast after it has been fired from a gun. Objects that remain at the same point of space over a period of time are called stationary. Examples include a person sitting still on a chair or a parked car.

Speed

Speed is a measure of the distance travelled over the time taken. The more distance covered by an object during a given time, the faster the speed it is moving. In this unit, we use the term velocity to mean the same thing.

Constant speed occurs when the object travels the same amount of distance at each even time period. When we travel on an object moving at a constant speed, we do not feel movement for example travelling in an airplane. Only when we observe other objects moving at a different speed to us do we notice that we are moving.

Measuring Motion in Science

Quantity	**Unit**	**Symbol**	**Equipment used**
Distance	Kilometre	km	odometer
	Metre	m	Metre ruler
	millimetre	mm	Hand ruler
Time	Hour	hr	clock
	minute	min	watch
	second	s	Stop watch

Converting measurements

Quantities are often measured in different scales depending upon what is most appropriate for the original size. In Science (and Mathematics) we use common prefixes to indicate the scale used.

We sometimes want to convert scales from one to another to compare data or to place the measurements into equations.

Prefix		**Scale**
Kilo	=	1000
Centi	=	1/100th
Milli	=	1/1000th

So 1 kilometre = 1000 metres
1 metre contains 100 centimetres
1 metre contains 1000 millimetres

To convert from metres to kilometres divide by 1000
To convert from kilometres to metres multiply by 1000
Time is measured in "imperial units" 1 hour has 60 minutes and 1 minute has 60 seconds therefore 1 hour has 3600 seconds

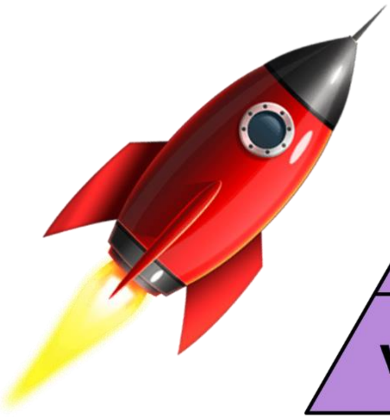
Calculating speed

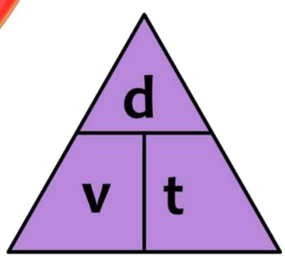
We use this formula to calculate speed by placing in the information we have about distance / time into it. We can also rearrange the formula to calculate distance or time, as long as we know the other two values. It is important to also use the units after any value in Science.

This formula will be given with all assessments (but not what the letters stand for or the units) and you will need to learn where to apply it.

$v=d/t$

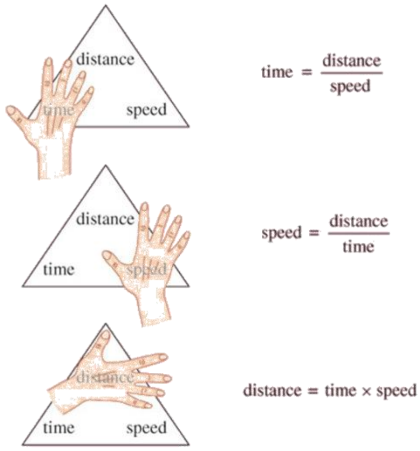
v = velocity (ms^{-1})
d = distance (m)
t = time (s)





Calculating speed using triangles

Triangles can be used to calculate speed, distance or time. The numerator is placed at the top of the triangle. Cover the part of the triangle you wish to calculate and then multiply or divide the remaining two values.



Average speed and instantaneous speed

We calculate average speed (velocity). That is, the speed that has been travelled on average over the entire distance. In a car, the odometer measures instantaneous speed. This is the speed that the car is travelling at in that particular moment.

The average speed a car may have been travelling at for a journey from Cambridge to Hamilton may have been 70km per hour but at some times they may have been travelling at 100km per hour and at other times, they may have been travelling at 45km per hour.

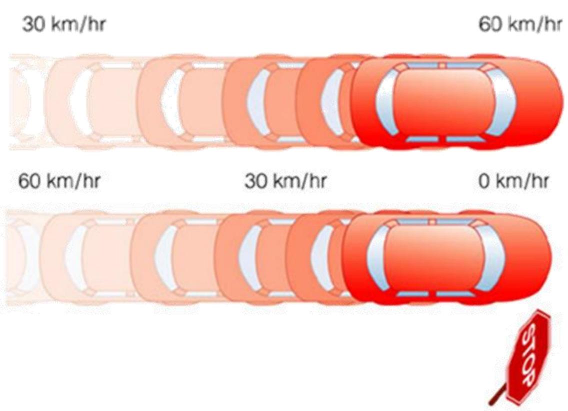
We use the symbol Δ to mean, "change in". So using the formula, we calculate the average velocity by dividing the change in distance by the change in time taken.

$$\boxed{v_{ave} = \Delta d / \Delta t}$$

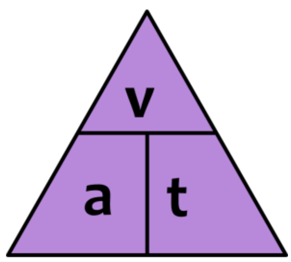
v = velocity (ms^{-1})
d = distance (m)
t = time (s)

Acceleration is a change in velocity

Objects that have a change in velocity are said to have acceleration. An increase in velocity (top example) is called acceleration and a decrease (bottom example) in velocity is normally called deceleration but are both types of acceleration.



Deceleration can also be called negative acceleration.
We notice when we are travelling on an object that is accelerating by experiencing a change in gravity or G-force.



NOTE: We only need to learn about straight-line speed, NOT velocity that also involves a direction. Acceleration in this unit will be calculated from changing speed only.

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Calculating Acceleration

The units for Acceleration depend on what velocity and time are measured in.

If time is measured in seconds (s) and velocity is measured in metres per second (ms^{-1}) then the units for acceleration will be metres per second per second (ms^{-2}).

Acceleration = $\frac{\text{change of velocity}}{\text{change in time taken}}$

$$a_{ave} = \Delta v / \Delta t$$

a = acceleration (ms^{-2})
v = velocity (ms^{-1})
t = time (s)

Acceleration or Deceleration

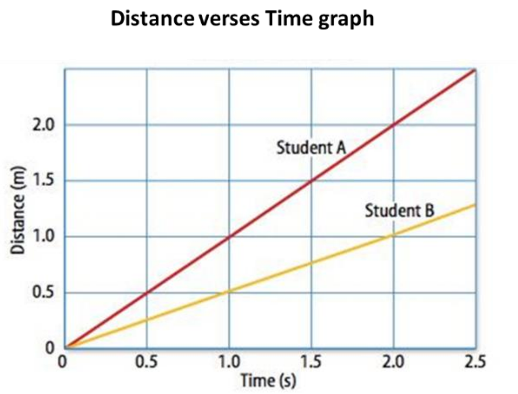
If an object is changing in speed and that change is positive, then the object is speeding up. When calculating a value we can place a + sign in front of it if we wish.

If an object is changing in speed and that change is negative, then the object is slowing. When calculating acceleration we need to show this with a – (negative sign) in front of the value. Alternatively if we clearly state the value is deceleration then we can leave the – sign off.

Distance-Time graphs

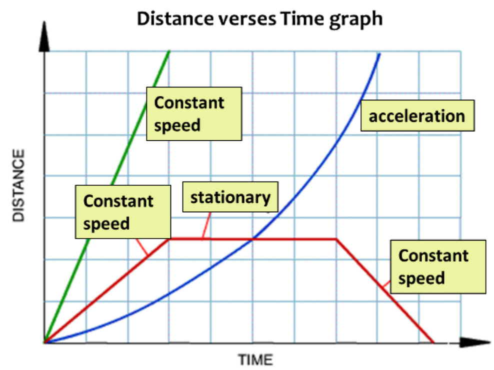
Distance (y-axis) and time (x-axis) data can be plotted on a line graph to show patterns and compare speeds.

The as the gradient of the line increases so does the average speed. The steeper line on the left shows student A has a faster speed than student B. A straight diagonal line indicates constant speed. A straight horizontal line indicates the object is stationary.



Interpreting Distance-Time graphs

A distance time graph can also show acceleration with a curved line (blue) because at each time interval the distance travelled becomes larger and larger. Changes in speed are also shown with a combination of diagonal and horizontal lines (red).

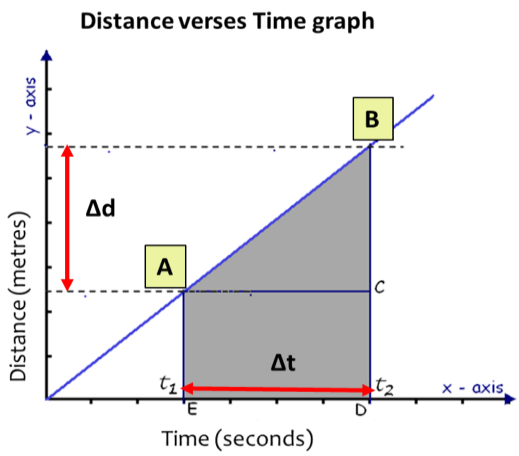


Velocity (speed) can be calculated from a Distance-time graph

A distance - time graph can be used to calculate speed (velocity). The co-ordinates of a straight line in the graph are taken (for example from A to B) by projecting back to the x and y-axis.

To calculate the value for time find the difference between t1 and t2 by subtracting the smallest value from the largest value. This will be your Δ time. Repeat to find distance on the y-axis. This will be your Δ distance. Place both values into your formula to calculate speed (velocity) v = Δd/ Δt

Make sure the part of the line you are using is straight



Speed-Time graphs

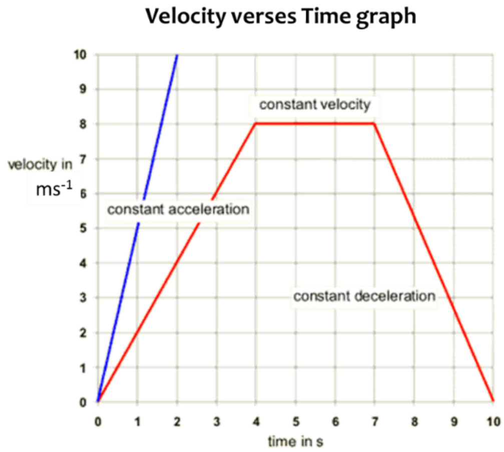
A speed - time graph can show acceleration.

The steeper the line (gradient), the faster the acceleration.

Constant velocity (no acceleration) is shown with a straight horizontal line.

A straight line sloping downwards shows deceleration.

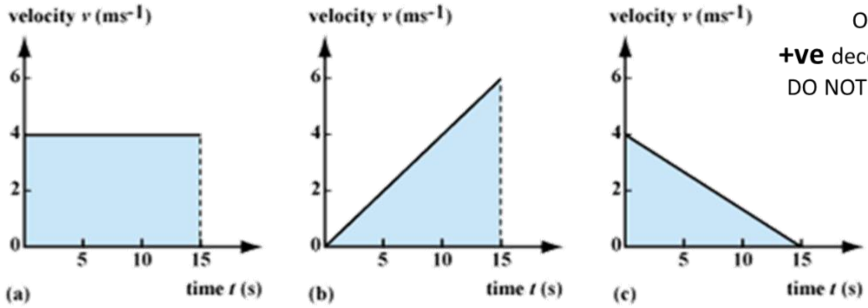
Values can be taken from the graphs and used to calculate acceleration.



The blue line shows a velocity of $10ms^{-1}$ travelled in 2 seconds.
The acceleration would therefore be:
$a = \Delta v / \Delta t \quad = \quad 10ms^{-1} / 2s \qquad a = 5ms^{-2}$

Acceleration can be calculated from a speed-time graph

Use the start and finish points of the time and the velocity to work out the total change. If the time starts from 0 use that as your start point.

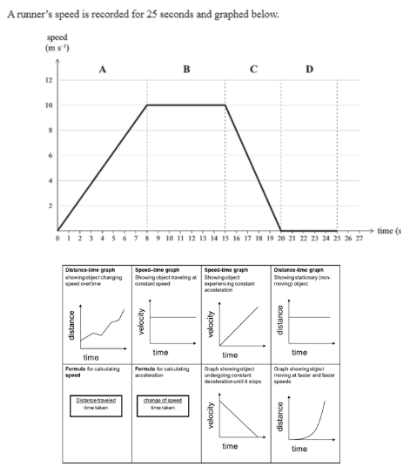


Deceleration can be written as
-ve acceleration
OR
+ve deceleration
DO NOT MIX UP

Remember: that Δ means change in. The line must be straight in order to calculate acceleration

Describing motion in Graphs

Q 1a: Describe the motion of the runner through sections A, B, C, and D.
Your answers should include descriptions AND any relevant calculations



How do we answer this question?
Section A: Accelerating at a constant rate of 1.25 m s^{-2}, from 0 m s^{-1} to 10 m s^{-1} in 8 seconds.

Check if graph is distance/time or speed/time. Link gradient of line to motion.
Back up with data or calculation

Section B: Constant speed of 10 m s^{-1} for 7 seconds.

Repeat for each section of graph

Section C: Decelerating from 10 m s^{-1} to 0 m s^{-1} at a constant rate of 2 m s^{-2} (−2 m s^{-2} if discussing acceleration) for 5 seconds.
Section D: Stationary (constant speed of 0 m s^{-1}) for 5 seconds.

Make sure EVERY section is described and linked to data

Distances travelled can be calculated from the area under a velocity-time graph

The total distance can be calculated from a velocity time graph by calculating the area under the graph. The area is divided into rectangles and triangles.

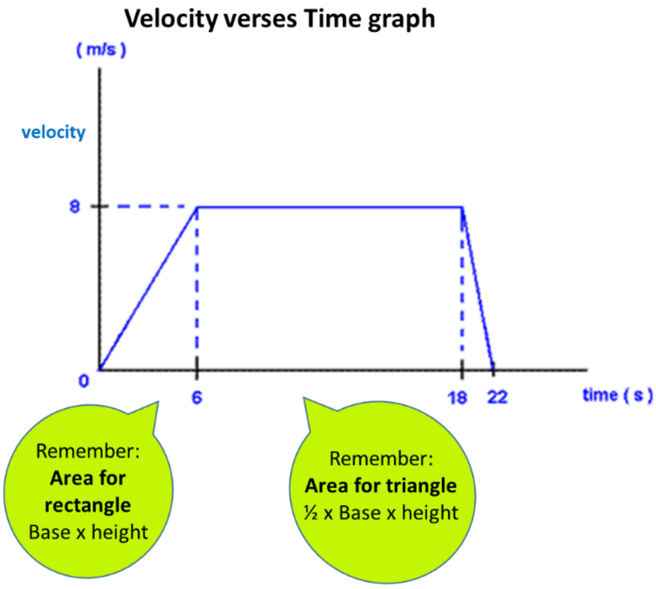
Work out the area of each triangle (1/2 height x width) and add to the area of each rectangle (height x width)

For example:

d = (½ 8 x 6) + (1/2 8 x 4) + (8 x 12)

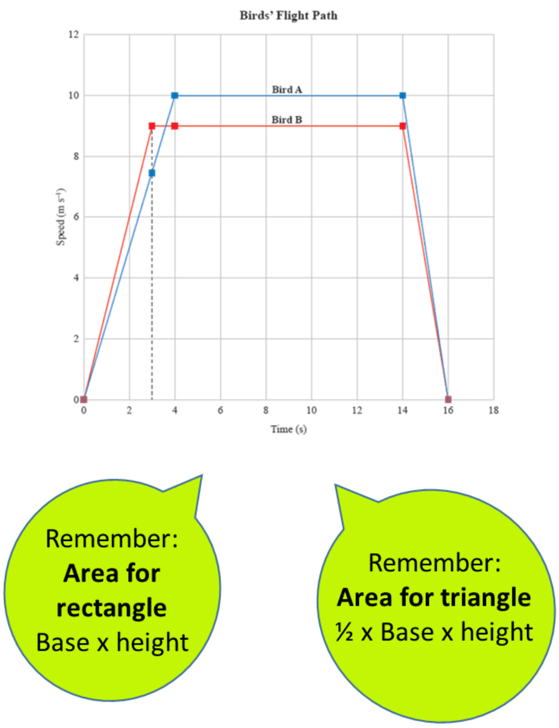
d = 24 + 16 + 96

d = 136 metres



Distance from Speed/time graph

Question 2c (ii) : In 16 s, **Bird B** travelled 121.5 m. How much further did **Bird A** travel in the same time? *Show all working.*



How do we answer this question?

Bird A travelled:

(A) 0 – 4 s:

(B) 4 – 14 s:

(C) 14 – 16 s:

Determine the size of each section

$$d = \frac{1}{2} \times 4 \times 10 = 20 \text{ m}$$

$$d = 10 \times 10 = 100 \text{ m}$$

$$d = \frac{1}{2} \times 2 \times 10 = 10 \text{ m}$$

Calculate the area of each section (show working)

Total distance = 130 m

So Bird A has flown 8.50 m further.

(130 – 121.5 = 8.50 m)

TOTAL area (as distance) and compare to other distance if required

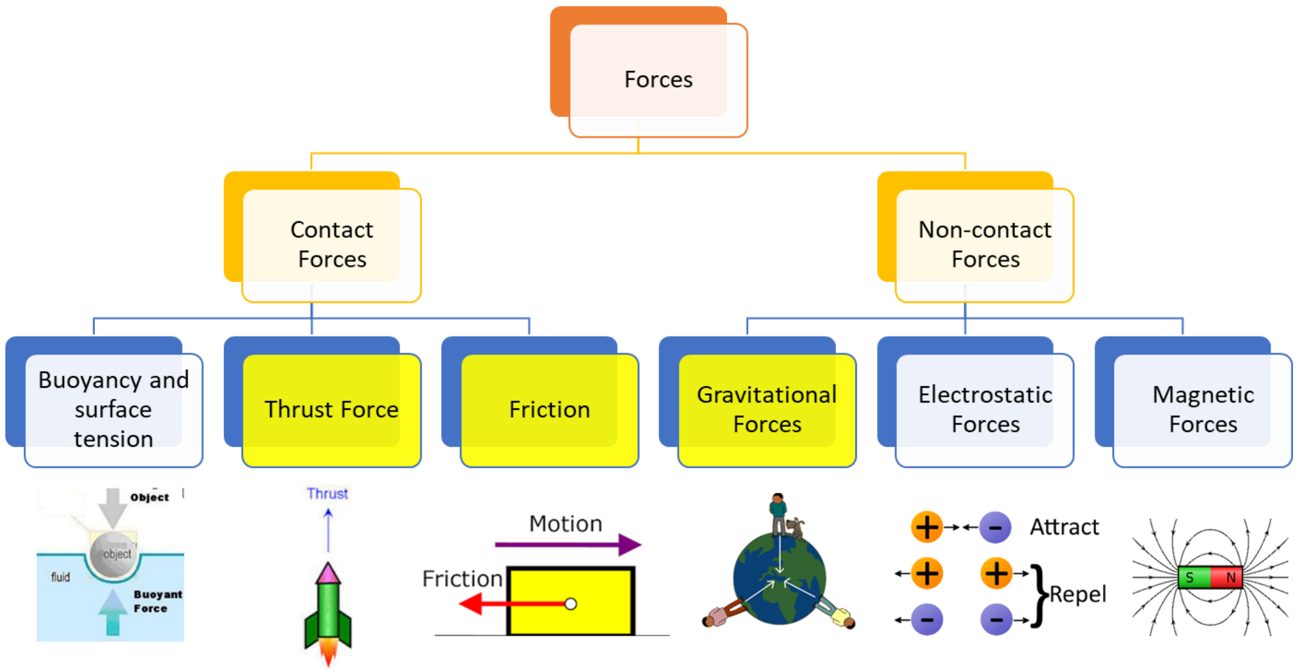
Force can cause an object to change its velocity or movement.

Forces push, pull, tug, heave, squeeze, stretch, twist or press. Forces change:

- The shape of an object
- The movement of an object
- The velocity of an object

Not all forces can be seen but the effects can be measured. Forces can either be contact forces, where the force needs to be in contact with the object experiencing the force OR non-contact forces that will act on an object from a distance without touching it.

Contact and non-contact forces



Pushes, pulls, friction and tension are contact forces. Whatever causes the force actually touches the object it acts upon. Non-contact forces such as electrostatic forces, magnetic forces and gravitational forces act without contact between the object.

Thrust force

Thrust (or applied force) requires some parts of an object (whether gas, liquid or solid) being pushed forcefully from itself (rocket fuel from a rocket, for example). Once the rocket has left, the "thrust" is no longer present. It also requires reaction (actual touching) of the thrust medium against the object.

Acceleration is the state of an object, due to a force applied. It is dependent on the force, and on the mass of an object, but is not a force itself. Friction force opposes an object that is experiencing thrust force. Thrust and friction are “paired forces” that act in opposite directions on an object

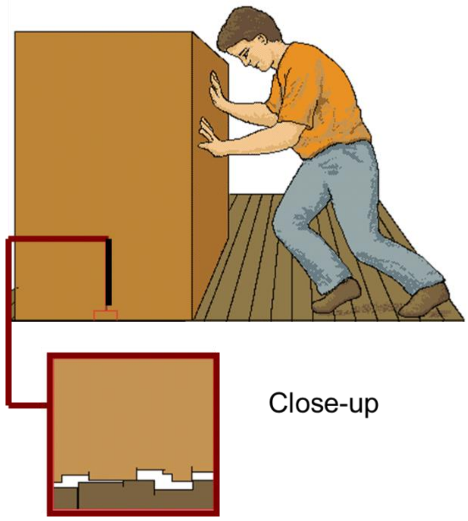
Friction often provides opposing force acting on moving bodies

Friction is a force that opposes motion. If an object has no motion then there is no friction.

When friction occurs, and one surface moves against another, the movement causes Kinetic energy to be changed into heat energy.

Smooth surfaces create less friction than rough surfaces. Friction that occurs between air or water and a solid body is called resistance.

If friction and thrust forces are equal and opposite then they are said to be balanced.



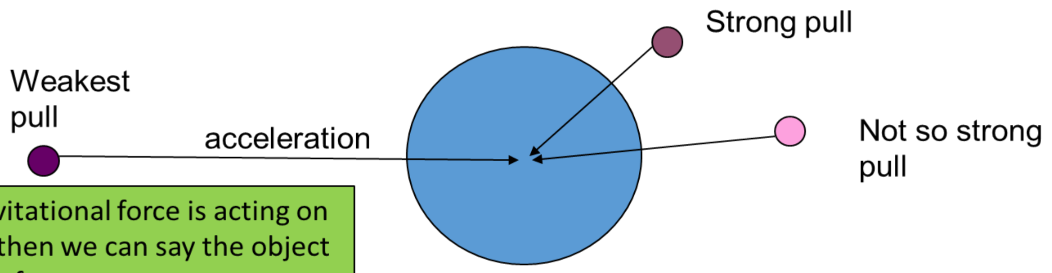
Gravity is a force, which acts between bodies even though they are not in contact

Objects create a gravitational field around them. Gravity gives objects of mass in the field a weight force. If the object is not in a gravitation field, it is "weightless"

- the bigger the object; the stronger the gravitation field it creates
- the further away from the object, the less gravitational pull on other objects

Any other object within the field is pulled to the center of the mass:

- this causes acceleration if there is no equal support force
- an object of mass will experience weight force

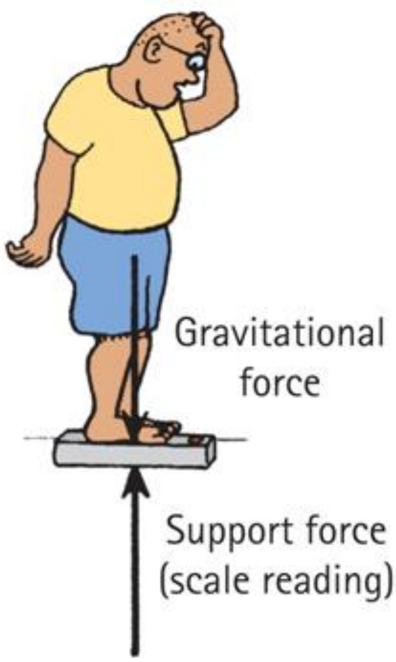


When gravitational force is acting on an object then we can say the object has weight force

Support forces

Support forces are equal and opposite to an object experiencing weight if the forces are balanced. Support force in air is called lift and in water is called buoyancy.

Buoyancy is an upward support force caused by a fluid that opposes the weight (gravitational force) of an object in the fluid, usually water. Once the object remains at a set depth then the support force and weight force are balanced.



Force is measured in Newton's

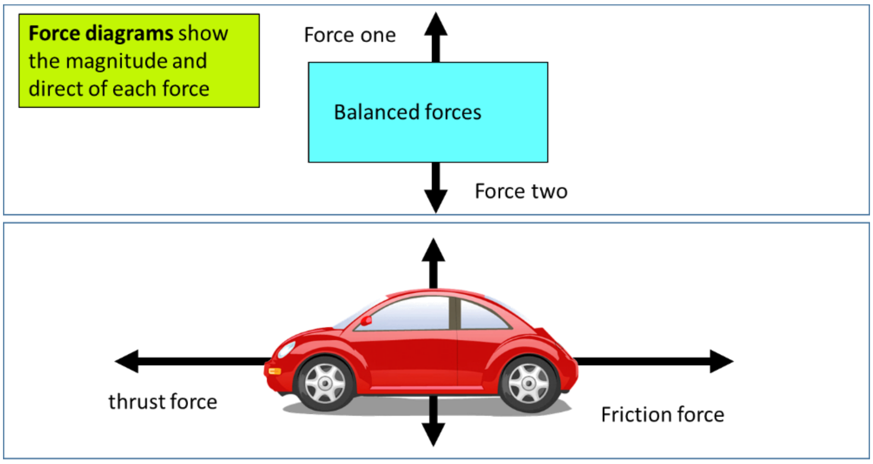
Isaac Newton was born in 1642 in England. He created laws of motion and gravity.

Isaac Newton used three laws to explain the way objects move and how force acts upon them. They are often called Newton's Laws.

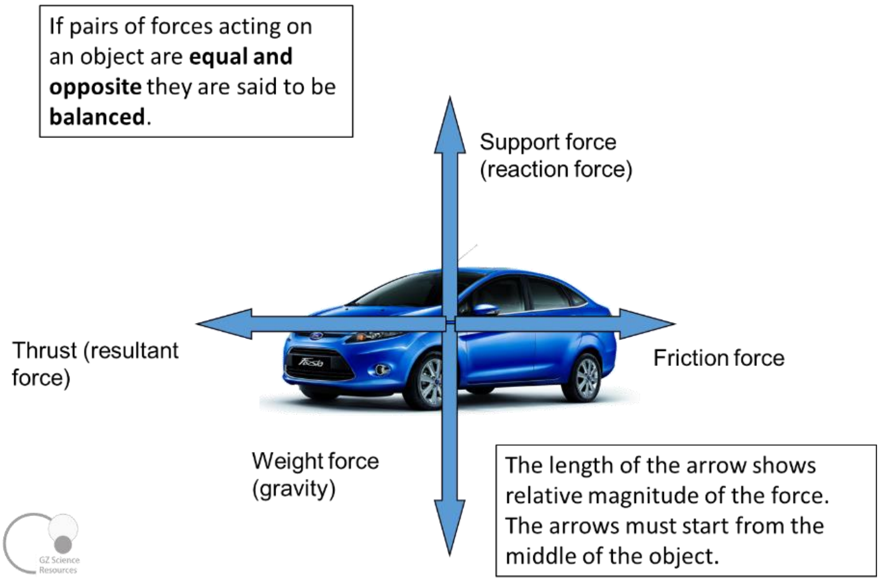
The units of force are named after this scientist and are called Newton's.

Newton's Laws - <u>First Law</u>

If the forces acting on an object are balanced, then the object will remain stationary or carry on at the same speed in the same direction.



Force diagram showing balanced forces



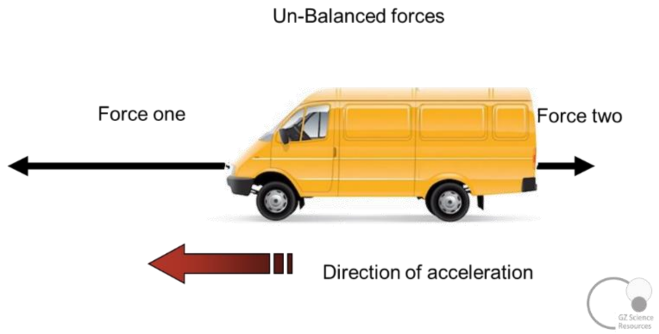
Note: when an object is stationary there are only two forces acting upon the object; support and weight force. There is no thrust or friction force

When forces are balanced, an object will either remain at rest or travel with a constant velocity

When skydivers reach terminal velocity, they are traveling at a constant speed. The forces of gravity accelerating the skydiver towards earth are matched exactly by the force of friction from the air particles pushing against the skydiver. If the person wears an aerodynamic suit or points their body downwards so there is less surface area to act against the air, which reduces friction, then the terminal velocity will be faster.

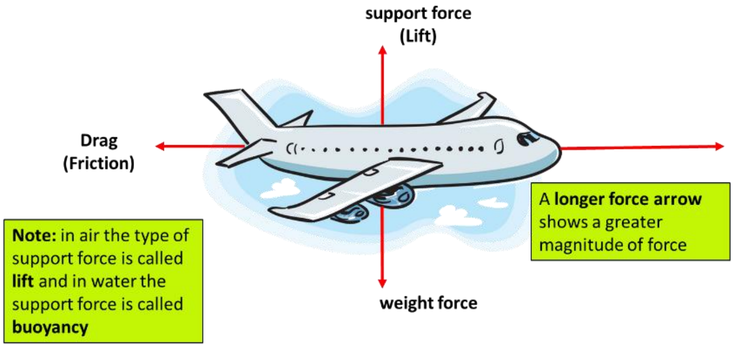
Newton's Laws - <u>Second Law</u>

If unbalanced forces act on an object, then the object will accelerate in the direction that the net force acts. More than one force can act on the object in the same direction, so these forces are added.



Unbalanced forces change motion

Balanced forces cause no change in speed or direction, since they exert equal, but opposite, push/pull effects on an object. However, Unbalanced forces can change the speed and/or direction of an object. Unbalanced forces occur when opposite forces are of a different magnitude (size)



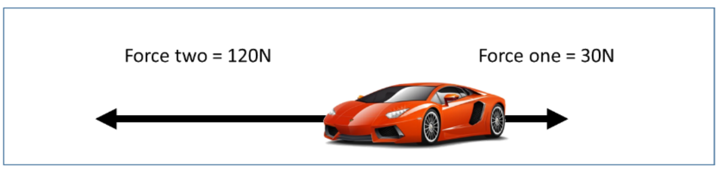
Net Force

<u>A net force is the resultant force when multiple forces interact</u>. When forces are balanced on an object, the net force is zero. If there is zero net force, the object maintains constant speed or is stationary. An object experiencing unbalanced force will have a net force greater or less than zero and will accelerate in the direction of the largest force.

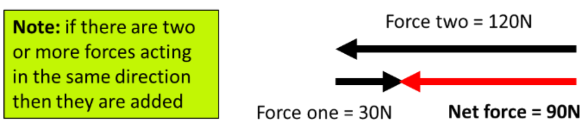
If the net force is pointing in the same direction as the direction of motion, the object accelerates. If the net force is pointing in the opposite direction to the direction of motion, the object decelerates.

Calculating Net Force

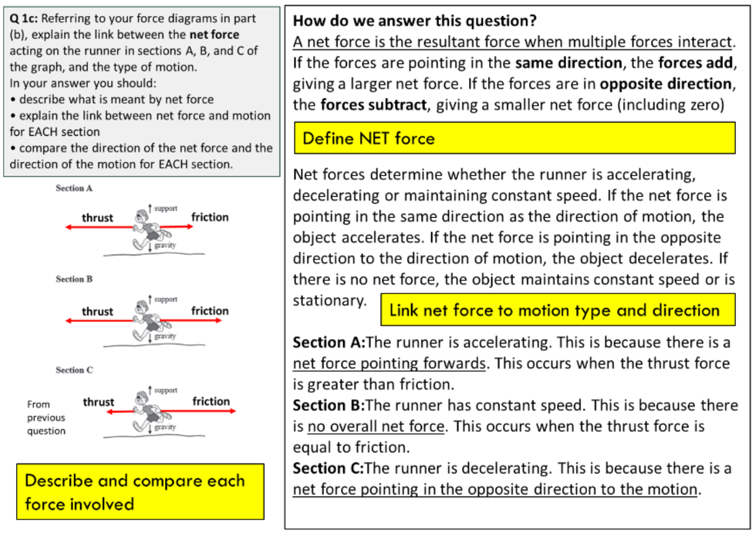
The net force can be calculated by subtracting the smaller force from the larger force. If the forces are pointing in the same direction, the forces add, giving a larger net force. If the forces are in opposite direction, the forces subtract, giving a smaller net force (including a zero net force).



Net force = 120N – 30N = 90N accelerating the object from right to left (forward)



Net Force



Q 1c: Referring to your force diagrams in part (b), explain the link between the **net force** acting on the runner in sections A, B, and C of the graph, and the type of motion.
In your answer you should:
• describe what is meant by net force
• explain the link between net force and motion for EACH section
• compare the direction of the net force and the direction of the motion for EACH section.

Describe and compare each force involved

How do we answer this question?
A net force is the resultant force when multiple forces interact. If the forces are pointing in the **same direction**, the **forces add**, giving a larger net force. If the forces are in **opposite direction**, the **forces subtract**, giving a smaller net force (including zero)

Define NET force

Net forces determine whether the runner is accelerating, decelerating or maintaining constant speed. If the net force is pointing in the same direction as the direction of motion, the object accelerates. If the net force is pointing in the opposite direction to the direction of motion, the object decelerates. If there is no net force, the object maintains constant speed or is stationary.

Link net force to motion type and direction

Section A: The runner is accelerating. This is because there is a net force pointing forwards. This occurs when the thrust force is greater than friction.
Section B: The runner has constant speed. This is because there is no overall net force. This occurs when the thrust force is equal to friction.
Section C: The runner is decelerating. This is because there is a net force pointing in the opposite direction to the motion.

Force, mass and acceleration

The Force experienced by an object can be calculated by multiplying the mass of the object by its acceleration.

Force = Mass x Acceleration

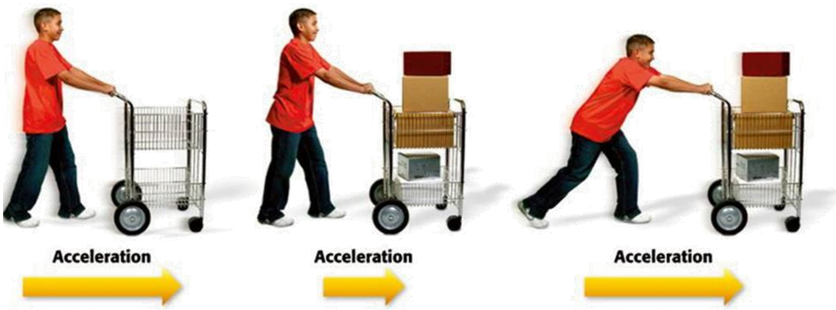
If more force is applied to an object then it will accelerate faster

$$F=ma$$

a = acceleration (ms^{-2})
F= force (N)
m = mass (kg)

Acceleration of a body depends both on its mass and on the size of the unbalanced force acting on it

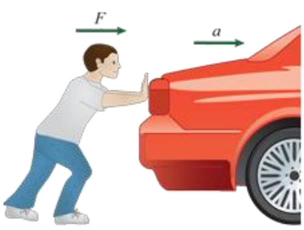
If the same amount of force is applied to two similar objects that have different mass, then then smaller object will accelerate faster.

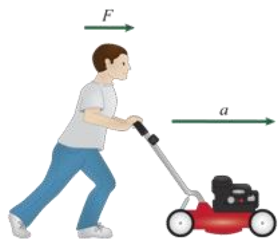


F = ma calculations

Ben is able to push both the car and the lawn mower so they accelerate at 0.5ms-2. The mass of the car is 950kg and the mass of the lawn mower is 10kg. What is the force required to accelerate the car compared to the lawn mower?

Car	lawn mower
F=ma	F=ma
F=950kg x 0.5ms-2	F=10kg x 0.5ms-2
F= 475N	F= 5N

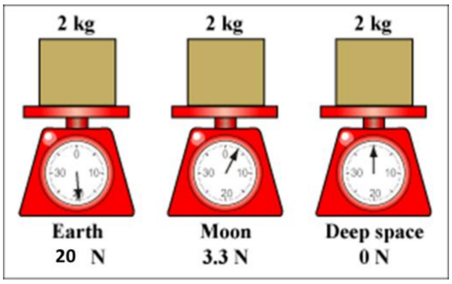




Mass and Weight

All objects have Mass. Mass refers to the amount of atoms, or substance, in an object. The formula symbol for mass is m. Mass is measured in kilograms (kg). 1kg = 1000g. The mass of the object remains the same regardless of its location.

Weight is the downward force due to gravity that an object experiences due to its mass. The weight of an object depends on its location and the gravity pulling down on it. The weight of an object can change depending on where it is located. Astronauts weigh less on the moon because the force of gravity is less, but their mass is the same in both locations. The formula symbol for weight is F_w (weight force). Weight is measured in Newton's (N)



Converting between Mass and weight

To calculate the weight (or the downward force due to gravity) you need to multiply the objects mass by the acceleration due to gravity.

On Earth, due to the size and mass of the planet, we experience a gravitational pull of $10ms^{-2}$

This means if we were to freefall to Earth, every second we would accelerate 10m more per second – 1 second fall 10m, the next second fall 20m, the next second fall 30m etc.

Converting mass to weight

$$F_w = mg$$

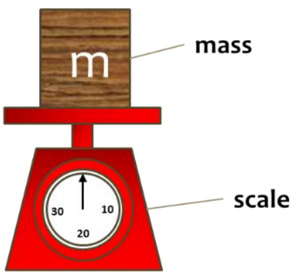
g = acceleration due to gravity = ($10ms^{-2}$)
Fw= Weight force (N)
m = mass (kg)

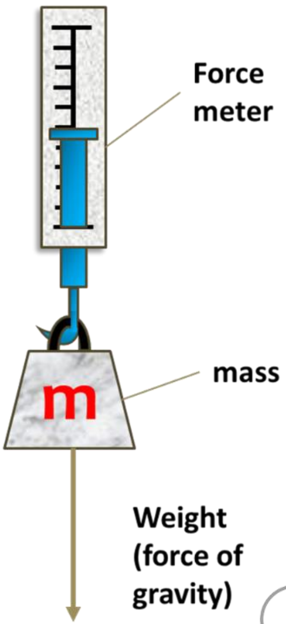
This is still the **F = ma** formula

Measuring Mass and weight

Weight can be measured with a spring balance, where the mass can vertically hang and the weight can be read off the force meter. The scale will be in Newtons (N).
A 2kg mass would read as (2 x $10ms^{-2}$) **20N**

Mass can be measured with scales, where the mass can sit on top and the mass can be read off the meter. The scale will be in kilograms kg (or grams)



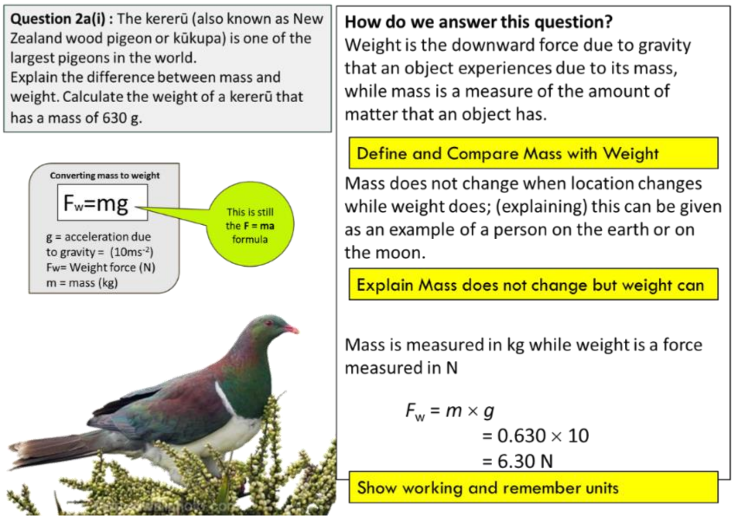


The Earth is the source of a gravitational field

The mass of the Earth creates an acceleration of 10 ms^{-2} for objects falling towards it. Regardless of the size of the object, they all fall with the same acceleration - only the shape, which causes changes in air resistance, causes some objects to experience more opposing force and accelerate slower.

To calculate our weight, which is a force on an object in a gravitational field, we multiply our mass by the gravitational acceleration of Earth ($10ms^{-2}$)

Mass and Weight

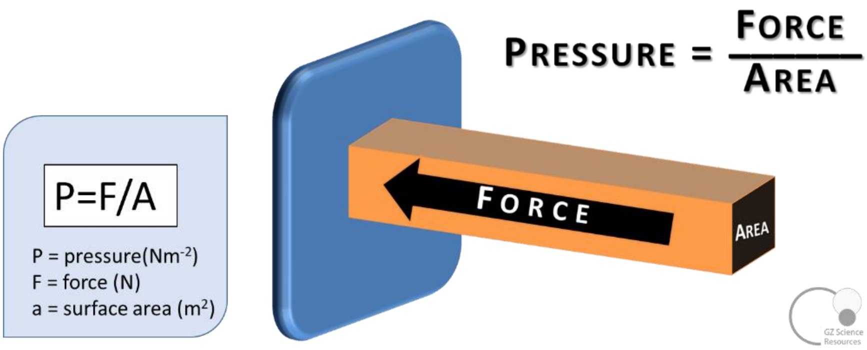


Units of Force, Motion and Energy in Science

Quantity	Unit	Symbol	Equipment used
Force (weight)	Newton	N	Spring balance
Mass	Kilogram	kg	scales
Motion	Kilometres per hour (velocity)	khr^{-1}	odometer
	Metres per second (velocity)	ms^{-1}	Ticker timer
	Metres per second per second (acceleration)	ms^{-2}	Ticker timer
Energy (work)	Joule	J	
Power	Watt	W	

Pressure

Pressure is a measure of force applied to a particular surface area. A *Pascal* is a pressure of one newton per square metre (Nm^{-2}) or using the units of Pascals (Pa). Pressure is increased by increasing the force in the same surface area or reducing the surface area the force is applied to.



Force is dependent on pressure and surface area it is exerted on

In many questions mass has to be converted into weight first.

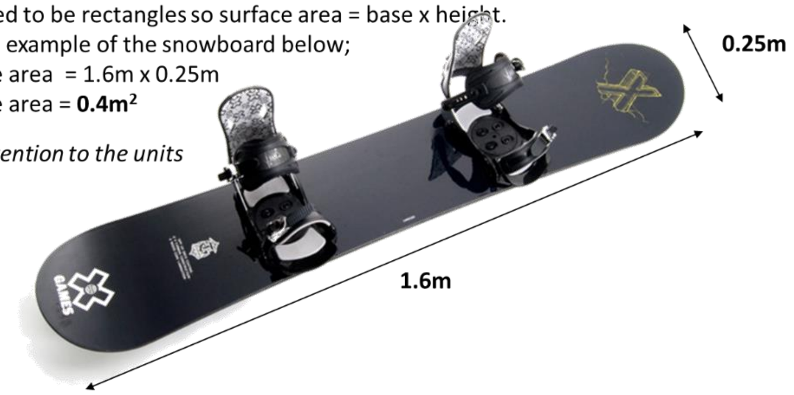
Remember $F_w = mg$ where $g = 10ms^{-2}$

Area (surface) is expressed as m^2. If the surface area is given in cm^2 then this value must be divided by 10,000 to convert to m^2

Calculating Surface Area

Surface Area is given in m^2. Sometimes this area must be calculated first. Objects are assumed to be rectangles so surface area = base x height.
For the example of the snowboard below;
Surface area = 1.6m x 0.25m
Surface area = **0.4m²**

Pay attention to the units



Pressure in real life situations

Often the effects of pressure can be seen with observation. For example, by how much an object presses into the surface it is sitting on. This could be skis into snow, tyres into mud or chair legs into carpet. The more the pressure the deeper the imprints into the surface.

When comparing the pressure created by two different people of different masses sitting on the same object then the formula P= F/A must be used, discussing each variable. Similarly, if two different people of different masses are on objects with different surface area, such as skis compared to a snowboard, the 'heaviest' person may not always create the most pressure if the surface area is large.

Remember to multiply surface area if 2 feet or 4 legs

Pressure

Q 2: The father notices that his daughter on her skis has sunk further into the snow than he has on his snowboard. The father and snowboard have a combined mass of 80 kg. The daughter and the skis have a combined mass of 58 kg. Explain why the daughter on her skis sinks further into the snow than her father on his snowboard.
In your answer you should:
- calculate the pressure exerted by the daughter and her skis on the snow
- compare the pressure exerted by the daughter and father (from part (a)) on the snow
- explain the difference in pressure in terms of force AND area
- explain how pressure relates to how far the person will sink in the snow.

$F_{weight/gravity} = mg = 80 \times 10 = 800$ N

Area = $b \times h = 0.25 \times 1.6 = 0.4$ m²

$P = F / A = 800 / 0.4 = 2\,000$ Pa (Nm⁻²)

P=F/A

P = pressure(Nm⁻²)
F = force (N)
a = area (m²)

How do we answer this question?
Sinking depends on pressure – the greater the pressure, the further the person sinks.
P = F/A

Explain sinking/traction is due to pressure

A 'lighter' person will have less weight force than a 'heavier' person. However, if the 'lighter' person's force is spread over a smaller surface area, it can produce a higher pressure than the 'heavier' person.

Link pressure to both weight force and surface area

In this example, the skis have much less surface area than the snowboard, so the daughter sinks further than her father, even though she is 'lighter'.

Link pressure to example with comparison

$P_{dad} = 800/0.4 = 2\,000$ Pa
$F_{daughter} = 58 \times 10 = 580$ N $A_{daughter} = 2 \times 0.08 \times 1.75 = 0.28$ m²
$P_{daughter} = F / A = 580 / 0.28 = 2071$ Pa
$P_{daughter} > P_{dad}$ so daughter sinks further into the snow.

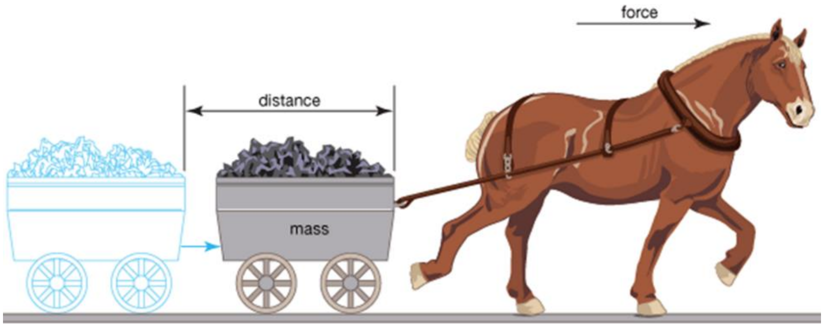
Use calculations to back up statement

Work

When a force is applied to an object of mass and moves it over a distance then work has been done. If an object does not move, no matter how much force is applied, then no work has been done.

Work is proportional to the force applied (weight force) and the distance travelled so *Work = Force × distance*. Work is needed to transfer energy. *Work is measured in joules.*

To do 1 joule of work you need 1 joule of energy.



Calculating Work

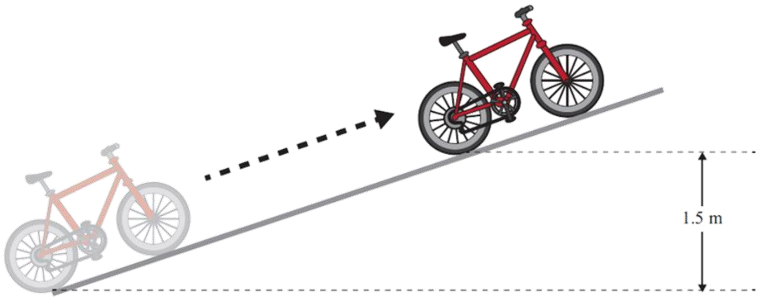
Force in a work calculation, is often refers to Weight force *(F_w)*

Remember weight is the downward force due to gravity that an object experiences due to its mass.

If mass is given then weight will need to be calculated first by $F_w = m \times g$ *with g given as $10 ms^{-2}$*

$$W=Fd$$

W = work done (J)
F = force (N)
d = distance (m)



If the force is due to weight force then the distance moved if travelling up a ramp will be the **vertical distance**. In the situation above the distance is 1.5m NOT the length of the ramp.

Power

Power is a measure of work done over time. Power is measured in units called watts (W). A watt is one joule per second. Power is also the rate at which energy is transformed, (such as electrical energy in a bulb to light and heat energy - which is the same thing as the rate at which work is done.

- A 100 Watt light bulb is able to do a large amount of work (energy) in a period of time.
- A 40 Watt bulb will do less work (energy) in the same amount of time.

100 watts means 100 J s^{-1}

$$P=W/t$$

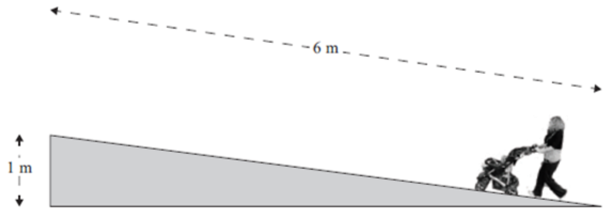
W = work done (J)
P = power (W)
t = time (s)

Ramps and Power

A ramp is a sloping surface that masses can be lifted to a height. Generally speaking, it will take a longer time to lift a mass up a ramp than lifting directly up to the same height. The ramp is a 'simple machine'.

If the same amount of work is done, for example a box of the same mass is either lifted directly upwards compared to a box wheeled up a ramp to the same height BUT lifting straight upwards takes less time – then more power is used to lift the box straight up.

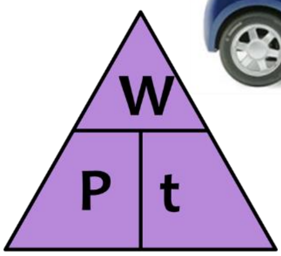
Ramps make moving masses 'easier' as allows the same amount of work to be done with a smaller force over a greater distance. In addition, ramps require less power to be used for the same weight (force) if it takes longer to reach the same height.



Calculating Power

Calculating power is normally completed in three steps:

1. Calculate the weight (force) of the object with units $F_w = m \times g$
2. Calculate the work done by the object with units $W = F \times d$
3. Calculate the power required to lift the object with units $P = W / t$



A car is pushed with a force of 20N and travels 5 metres.
The work done is W= f x d w = 20 x 5 = 100 joules
The power used to push the car is p = W/t p = 100/25 = 4 Watts

Work and Power

Q3c: A forklift lifts the box 4 metres straight up so it can be placed on a shelf. It takes 5 seconds to lift the box at a constant rate.
Calculate the work done to lift the box to the height of 4 m, and then calculate the power needed by the forklift to lift it to this height. .

How do we answer this question?
F = 25 000 N
$W = Fd$ = 25 000 × 4 = 100 000 J
$P = W / t$ = 100 000 / 5 = 20 000 W

Show working and use correct units

Why does pushing an object up a ramp seem easier than lifting it straight upwards?

How do we answer this question?
The same work is required overall but going up the ramp, the push force required is only against a component of the gravity force of the bike. However, a vertical lift would require a push equal to gravity force. Therefore the force required to lift the bike straight up is greater than the force required to push it up the ramp. The distance pushing straight upwards is shorter compared to the ramp though.

Compare both Force and Distance of both

The energy gained by the bike is the same in both cases, but the time taken to go up the ramp is greater than lifting it vertically. As $P = W / t$, a greater time would mean **less power is required**.

Link power to time taken

W=Fd
W = work done (J)
f = force (N)
d = distance (m)

P=W/t
W = work done (J)
P = power (W)
t = time (s)

Energy can exist as potential or kinetic energy

Energy can be classified into two types; kinetic energy (E_k) and potential energy (E_p)

Kinetic energy is seen when particles, waves or objects move. We will be focusing on mechanical kinetic movement, the movement of objects.

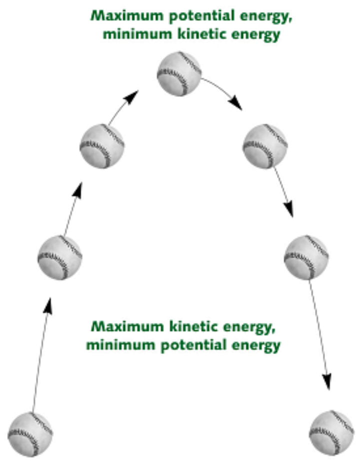
Mechanical kinetic Energy

Movement energy. This can be seen when matter changes its position in space

All forms of stored energy are called potential energy – this cannot be seen until it is transformed (changed) into active energy. We will be focusing on gravitational potential energy, the stored energy objects gain when moved to a height.

Gravitational potential Energy

This is the energy contained by an object which pulls it back to Earth. The further up from the ground, the more it contains.



Conservation of Energy

The law of conservation of energy says that energy is neither created nor destroyed. When we use energy, it does not disappear. It transforms from one form of energy into another. Conservation of energy is not “saving energy”.

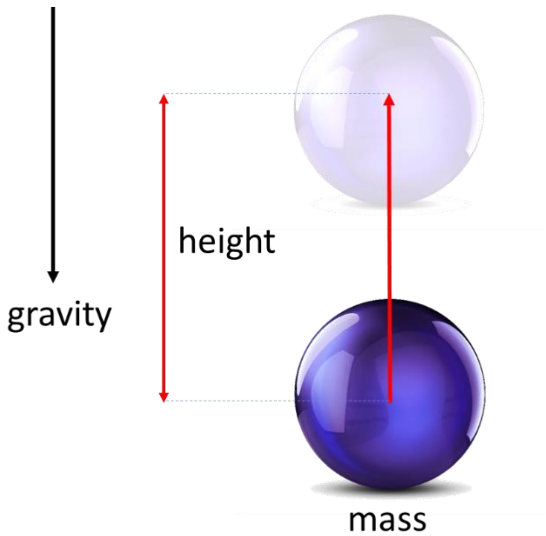
Kinetic and potential energy often exchange one form of energy for another. When we lift an object, it is given gravitational potential energy. Work is done on the object to raise it against the gravitational field of the Earth. The change in potential energy is always equal to the change in kinetic energy. (Assuming there are no other energy losses). When an object falls back down the gravitational potential energy it had transforms back into kinetic energy.

Potential energy

Potential energy is dependent on the mass of an object, the height it is at and the force of gravity upon it.

Objects with mass have stored potential energy (E_p) when they are raised above the centre of gravity.

Objects with more mass will gain more gravitational potential energy than objects of smaller mass when they are both raised to the same height.



Calculating Potential energy

Remembering $F_w = m \times g$ that if weight is given rather than mass, then this can be directly multiplied with height (in metres) to calculate gravitational potential energy. In many situations, calculating the energy gained can also be done using $W = F \times d$ if the distance is vertical (straight up and down) due to work due to work being done when a force is applied to an object of mass and moves it over a distance.

$$E_p = mg\Delta h$$

E_p = potential energy (J)
g = acceleration by gravity (ms^{-2})
m = mass (kg)
h = height (m)

Kinetic energy

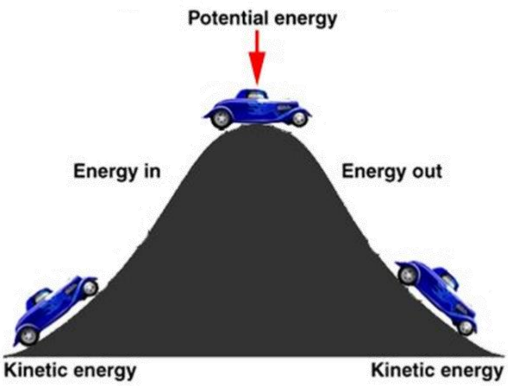
An object has kinetic energy when it is moving. Kinetic energy that an object contains depends upon both its mass and the velocity that it is moving. An object that has the same mass as another but is travelling at a greater velocity will contain far more kinetic energy. An object with more mass will possess greater kinetic energy than an object with less mass that is traveling at the same velocity.

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

E_k = Kinetic energy (J)
m = mass (kg)
v = velocity (ms^{-1})

Conservation of Energy - Example

For a car driving to the top of a hill, the kinetic energy is transformed into gravitational potential energy. Work is being done by the engine on the car because energy is being transformed from one form into another. When the car gets to the top of the hill it can coast down the other side of the hill because now the Earth's gravitational field is doing work on the car to convert potential energy back into kinetic energy. At the bottom of the hill, the car has maximum velocity and maximum kinetic energy but zero potential energy. All of the potential energy has been converted into kinetic energy in the process of the Earth's gravitational field doing work on the car.



Loss of Energy during transformation

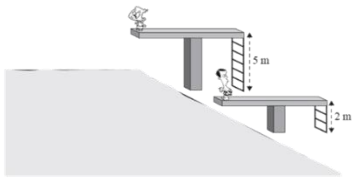
In reality, 100% of gravitational potential energy is not transformed into kinetic energy at each transformation. For example, a child swinging will gradually slow down and not swing up to the same height each time.

Whenever an object is moving, there will be friction, with water, air particles or another surface. This will cause some of the energy at each transformation to change into heat energy. This reduces the total amount available for transformation. In some cases, energy can also be changed into light and sound energy and unavailable for transformation. Without a further input of energy, an object will eventually come to rest.

Mention BOTH surfaces that act against each other to transform kinetic energy into heat and sound energy due to friction

Conservation of Energy

Question 1d: Ian jumps into the pool from the 5 m platform.
Calculate Ian's speed as he is about to hit the water (assuming conservation of energy).
In your answer you should:
- name the types of energy Ian has before he jumps, AND as he is about to hit the water
- calculate Ian's speed as he is about to hit the water.



$E_k = ½mv^2$

E_k = Kinetic energy (J)
m = mass (kg)
v = velocity (ms^{-1})

$E_p = mgh$

E_p = potential energy (J)
g = acceleration by gravity (ms^{-2})
m = mass (kg)
h = height (m)

How do we answer this question?
Ian had gained gravitational potential energy at the top of the diving board and this was converted into kinetic energy.
We assume that all gravitational potential energy will equal the kinetic energy.

If question states assuming conservation of energy then Ek = Ep

$$E_k = E_p$$
$$\frac{1}{2}mv^2 = mgh$$
$$v^2 = 2gh$$
$$v = \sqrt{2gh}$$
$$v = \sqrt{2 \times 10 \times 5}$$
$$v = 10 \text{ m s}^{-1}$$

Substitute one type of energy for the other then rearrange equation to find value.

"Missing" Energy

Question: A crane was lifting wood. The cable broke, and 150 kg of wood fell 12 m to the ground below. The wood had 15 000 J of kinetic energy just before it landed on the ground below. This was different from the amount of energy the wood had when it was hanging from the crane.
Explain why there is a difference in the energy the wood had when it was hanging from the crane compared to just before it hit the ground.
In your answer you should:
- name the type of energy the wood had when it was hanging from the crane
- calculate how much energy the wood had when it was hanging from the crane
- calculate the difference between the kinetic energy of the wood just before hitting the ground and the energy the wood had when it was hanging from the crane
- justify the difference in energy of the wood when it was hanging from the crane and then just before it hit the ground.

How do we answer this question?
At the top, the wood has a certain amount of gravitational potential energy and no kinetic energy. Just before the wood hits the ground, the gravitational potential energy has been converted into kinetic energy.

Link type of energy to position

Some kinetic energy is lost as heat energy due to the frictional force of air resistance. (and also sound energy) so not all of the gravitational energy was remaining to convert into 100% kinetic energy

Explain that the "missing energy" was due to friction converting a portion into heat energy

$E_P = mgh = 150 \times 10 \times 12 = 18\,000$ J
Difference between E_P and E_K: $= 18\,000 - 15\,000$
$= 3\,000$ J

Use equation to demonstrate explanation