Forces and Motion Junior Science

GZ Science Resources

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

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

- ❑ The shape of an object
- ❑ The movement of an object
- ❑ The speed of an object
- ❑ The direction of an object

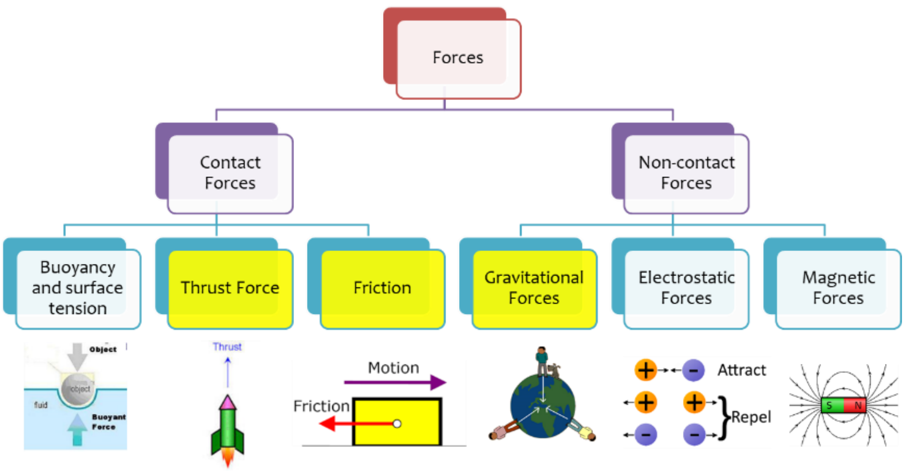
Not all forces can be seen but the effects can be measured. Forces be contact forces, where the force needs to be in contact with the object experiencing the force OR non-contact forces that will act on an object from a distance without touching it.

Units of Force, Motion and Energy in Science

Quantity	What is it measured in?	Symbol	Equipment used
Force (including weight)	Newton	N	Spring balance
Mass	kilograms	kg	scales
Velocity / speed	metres per second	ms^{-1}	Ticker timer
Acceleration (including gravitational acceleration)	metres per second per second	ms^{-2}	Ticker timer
Energy (including Work)	Joules	J	

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.



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.

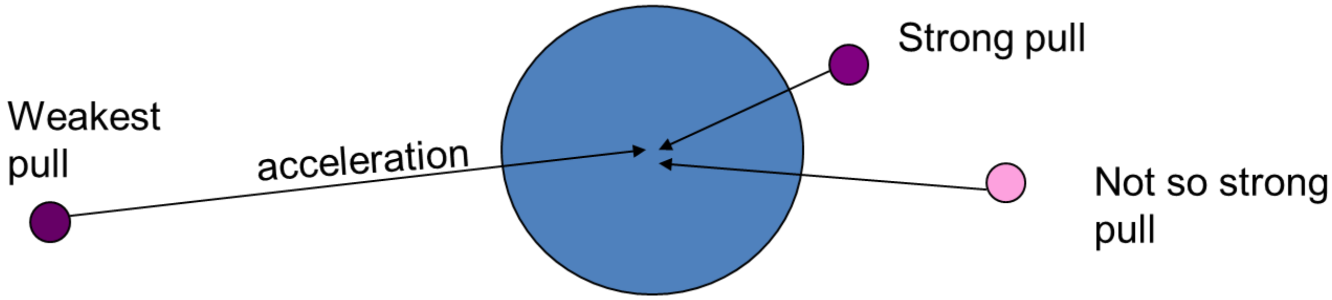
- the bigger the object; the stronger the field
- the further away from the object, the less gravitational pull

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

>accelerating

>feeling weight

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



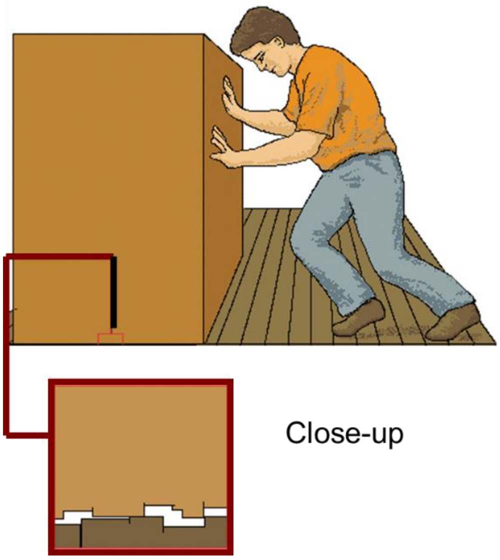
Thrust force

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.

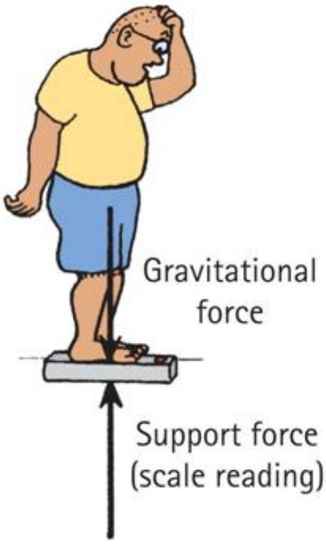
When friction occurs, and one surface moves against another, the movement causes Kinetic energy to be changed into heat energy.

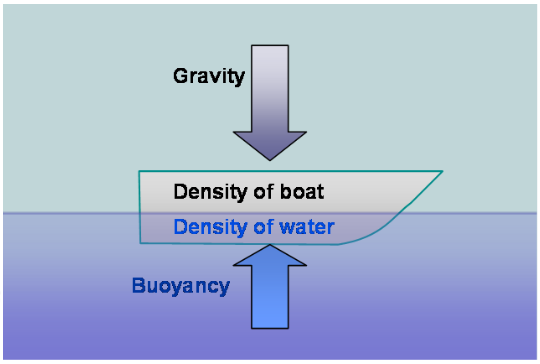
Smooth surfaces create less friction than rough surfaces. Friction that occurs between air or water and a solid body is called resistance.

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

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.





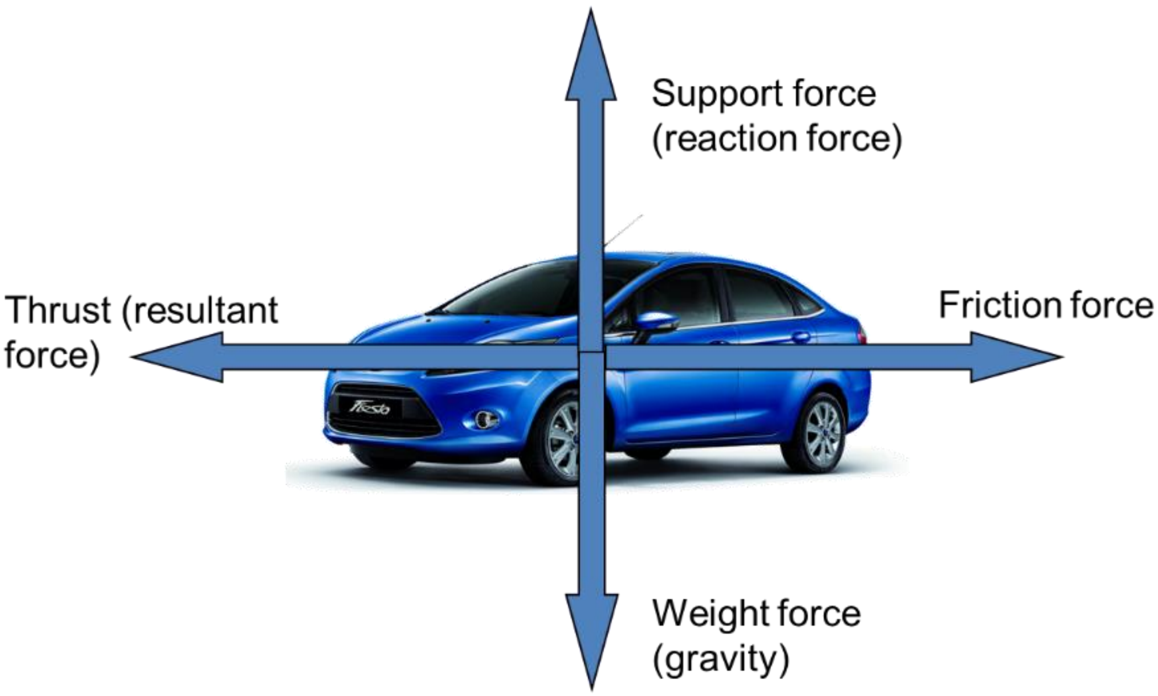
Sometimes friction is useful, at other times it is unhelpful.

Situations where Friction is useful		Situations where Friction is unhelpful	
situation	Increased by	situation	decreased by
walking	Having grip on the soles of your shoes	Friction in bearings	Oil around bearings
cycling	Wider tyres with tread	Drag on car	Aerodynamic design to reduce drag
driving	Good tread on tyres. Brake pads	Drag on snowboard	Smooth lacquered surface

Balanced forces

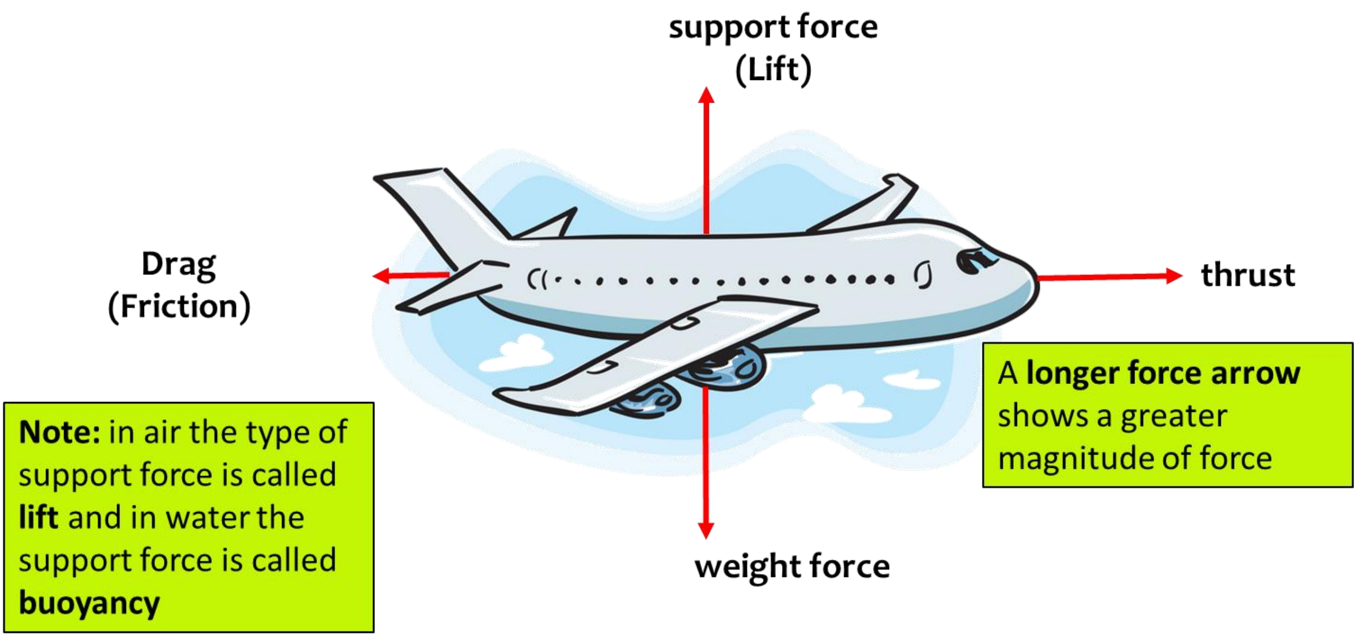
If pairs of forces acting on an object are equal and opposite, they are said to be balanced. The length of the arrow shows relative magnitude of the force. The arrows must start from the middle of the object.

Note: when an object is stationary there are only 2 forces acting upon the object; support and weight force. There is no thrust or friction force



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)

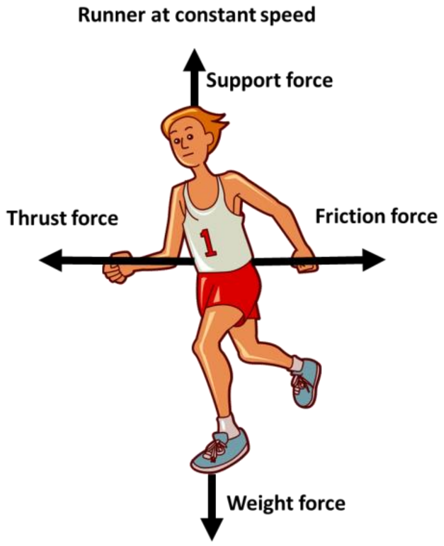


Rules of Force Diagrams

We use force diagrams to show the direction and magnitude (size) of a force.

Force diagrams have rules:

- The arrows showing a force must start (preferably) from the centre of an object, but at least touching it.
- Pairs of forces, such as support and weight, must be directly opposite each other
- Arrows must be pointing out.
- The length of an arrow indicates magnitude of a force. More force=longer arrow
- Pairs of balanced forces have equal length arrows.
- Pairs of unbalanced forces have different length arrows



Net Force

A net force is the resultant force when multiple forces interact. 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.

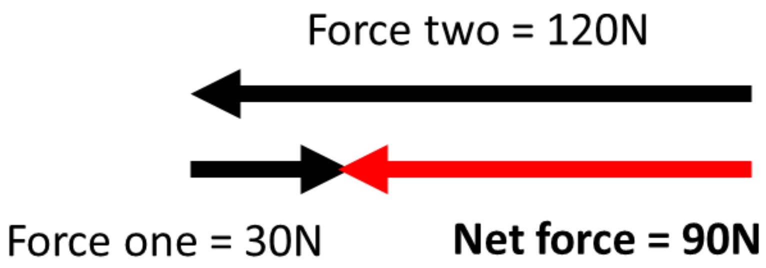
If the net force is pointing in the same direction as the direction of motion, the object accelerates. If the net force is pointing in the opposite direction to the direction of motion, the object decelerates.

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)

Note: if there are two or more forces acting in the same direction then they are added



Force, mass and acceleration

F=ma

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

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

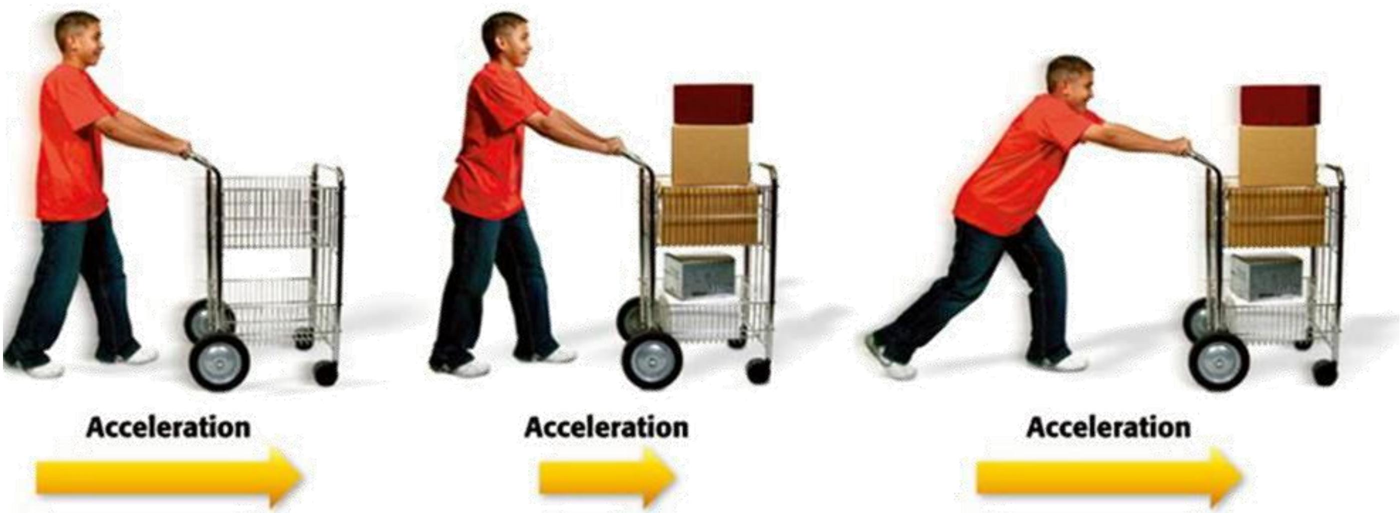
Force = Mass x Acceleration

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

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

Force = Mass x Acceleration

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

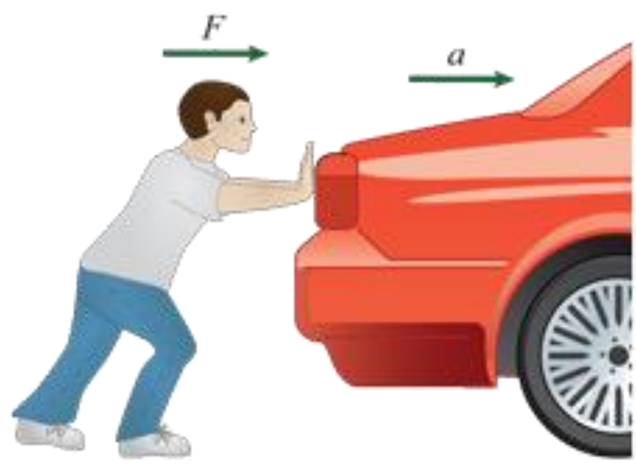


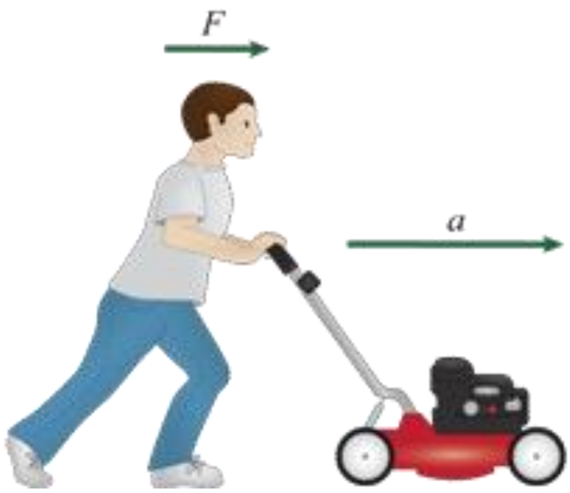
F = ma calculations

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.

Converting mass to weight

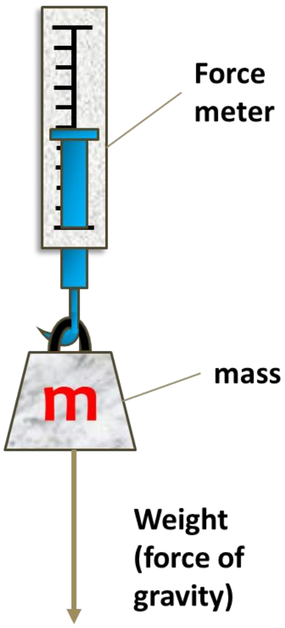
$$F_w = mg$$

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

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

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 Newtons (N)

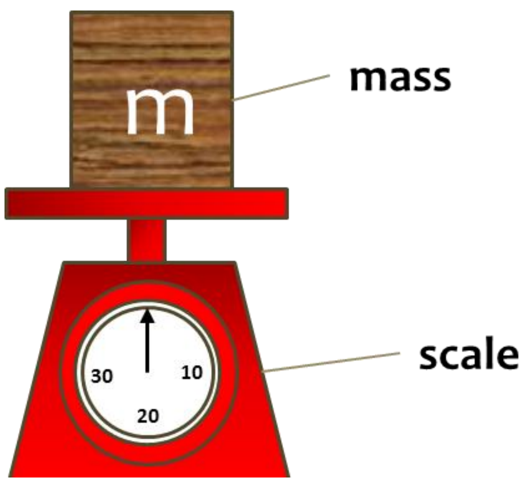
Measuring Mass and weight



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)



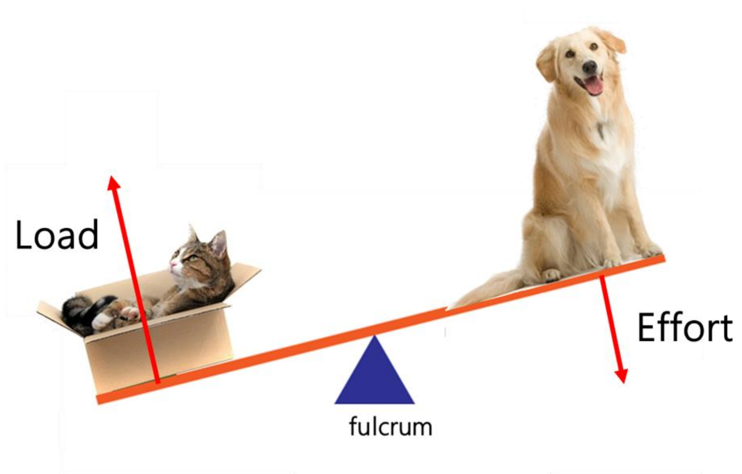
The Earth is the source of a gravitational field

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. 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.

Simple machines (Levers)



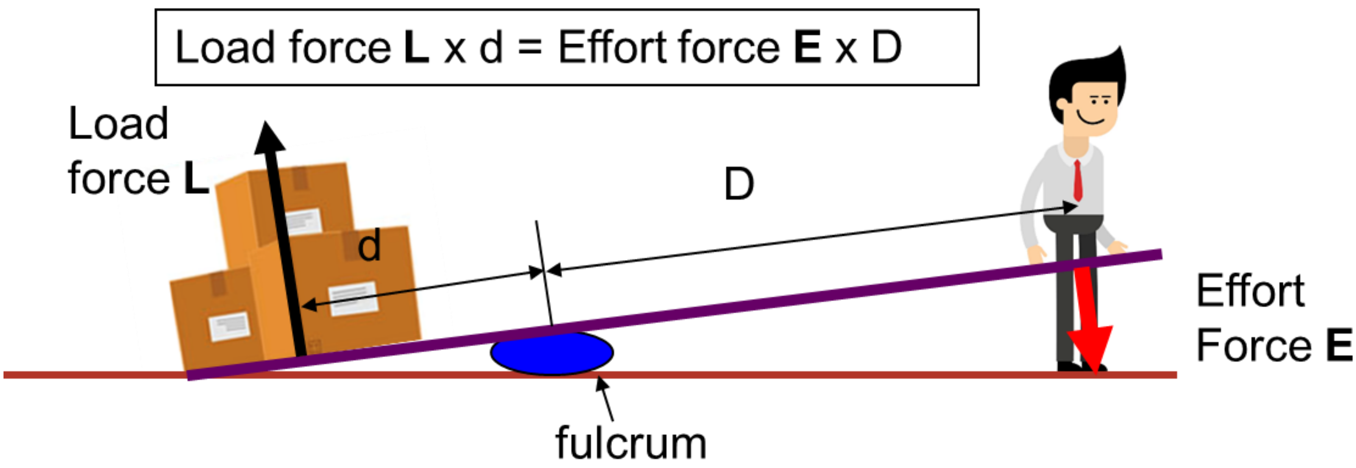
Simple machines can change the direction or size of a force by using 'mechanical advantage' to multiply force. A lever is balanced on a fulcrum, which allows it to pivot. A load is lifted by placing effort on another part of the lever. A lever involves moving a load around a pivot using effort (or a force).

Examples of tools that are classified as levers include scissors, pliers, hammer claws and tongs.

Levers are a simple machine that increase force

For a tool to be classed as a lever there must be:

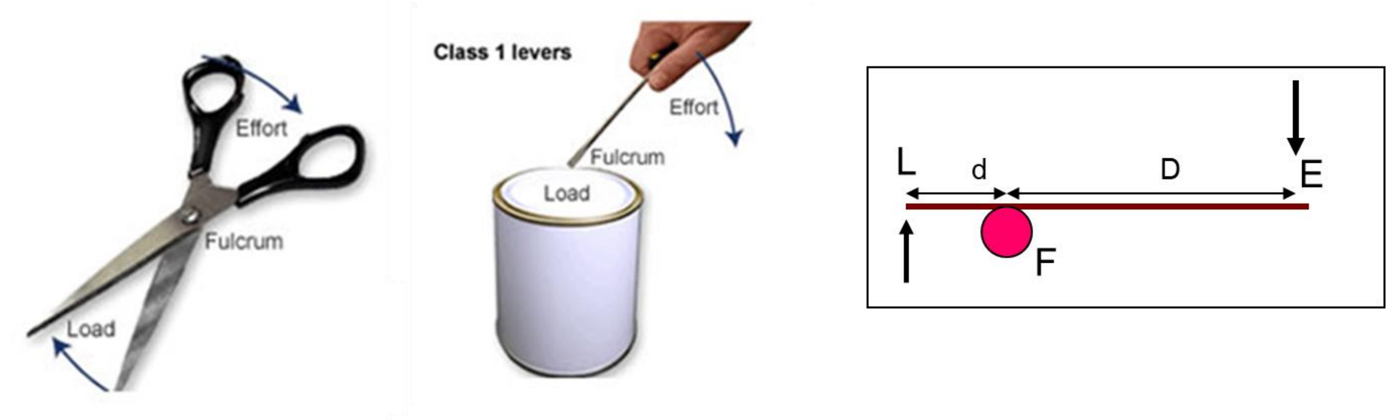
- a rigid handle
- a fulcrum (or pivot) around which the handle rotates
- a force increase – caused by the distance from the effort force to the fulcrum being larger than the load force to the fulcrum



Levers are a simple machine that increase force

Levers are classified in classes depending on the position of the effort and load in relation to the fulcrum.

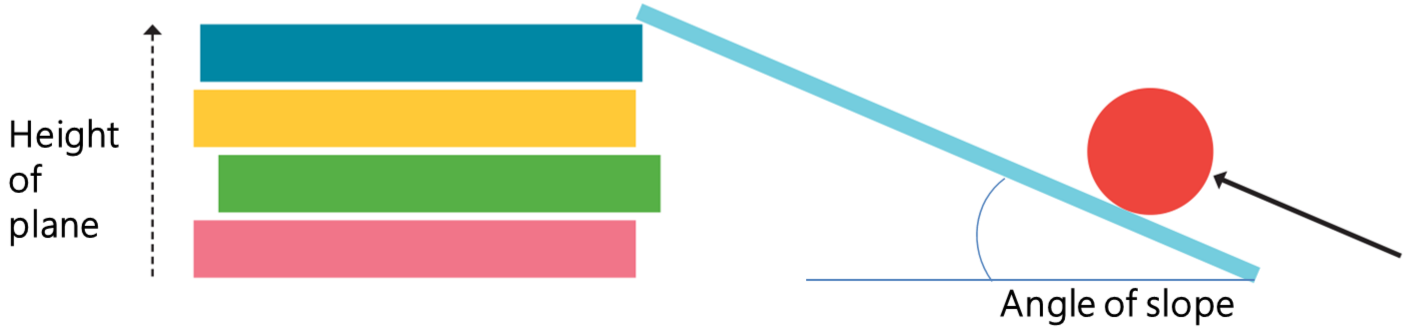
- Seesaw type Lever (Class 1): A lever where the load force acts on the opposite side of the fulcrum to the effort force. Examples include a Crowbar, Hammer and Tyre iron



Wheelbarrow type lever (class 2): A lever where the load force acts on the same side of the fulcrum as the effort force. Examples include a Wheelbarrow, a Spanner and a Ratchet/tiedown

Inclined Planes

An inclined plane is a simple machine and it can be used to reduce the effort required to move a load. If the slope has a small angle, then a person has to push or pull the object over a longer distance to reach a height, but with very little effort. If the slope is steep, with a greater angle, a person has to push or pull the object over a very short distance to reach the same height, but with more effort. Mechanical advantage is calculated by length of slope divided by height of the slope. There is a greater mechanical advantage if the slope is gentle because then less force will be needed to move an object up (or down) the slope.



The different types 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.

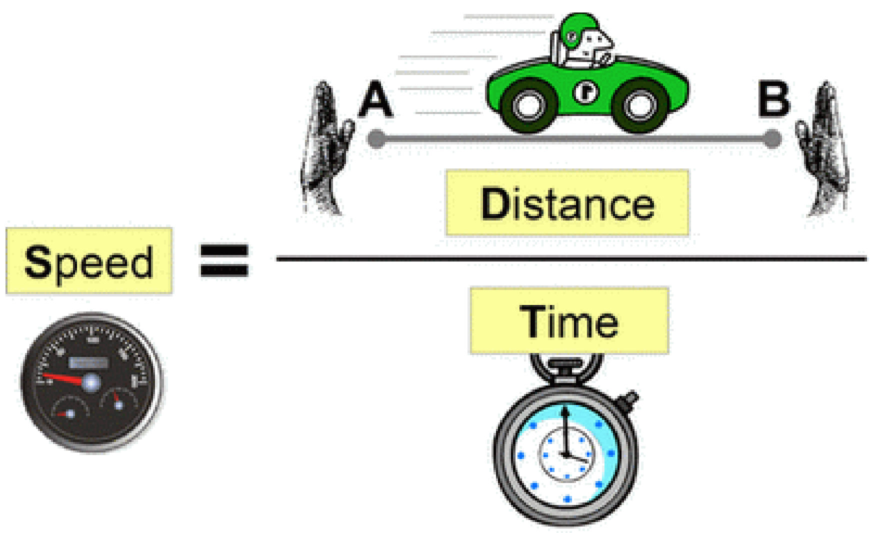
Measuring Motion in Science

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

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.



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.

$$v=d/t$$

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

This formula will be given with all assessments (but not what the letters stand for or the units)

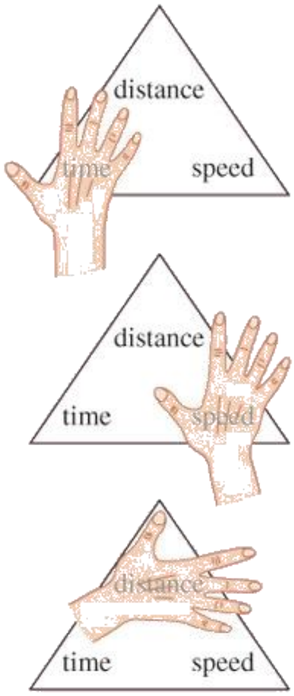
and you will need to learn where to apply it.

The relationships between distance, time and speed

Triangles can be used to calculate speed, distance or time.

Cover the part of the triangle you wish to calculate and multiply or divide the remaining two values.

The unit for speed depends upon the units for time and distance but the most common unit in the lab is metres per second (ms^{-1})



$$\text{time} = \frac{\text{distance}}{\text{speed}}$$

$$\text{speed} = \frac{\text{distance}}{\text{time}}$$

$$\text{distance} = \text{time} \times \text{speed}$$

Speed calculations

A football is kicked and during the first 2s it travels 36m. What speed is it going during this time?

v=d/t

v=36m/2s

v=18ms^{-1}

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.

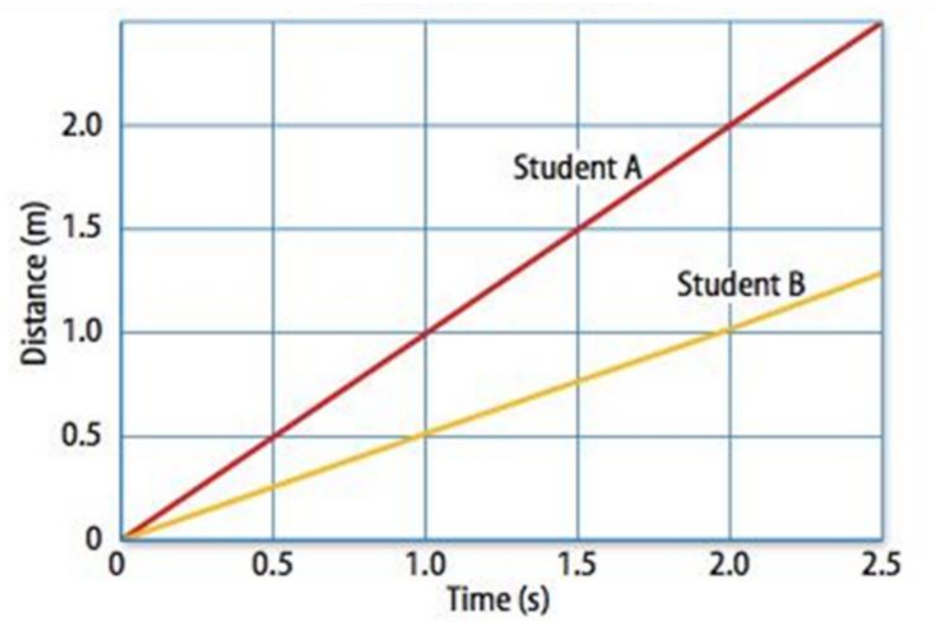
$$v_{ave} = \Delta d / \Delta t$$

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

Motion can be represented graphically - Distance vs Time

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

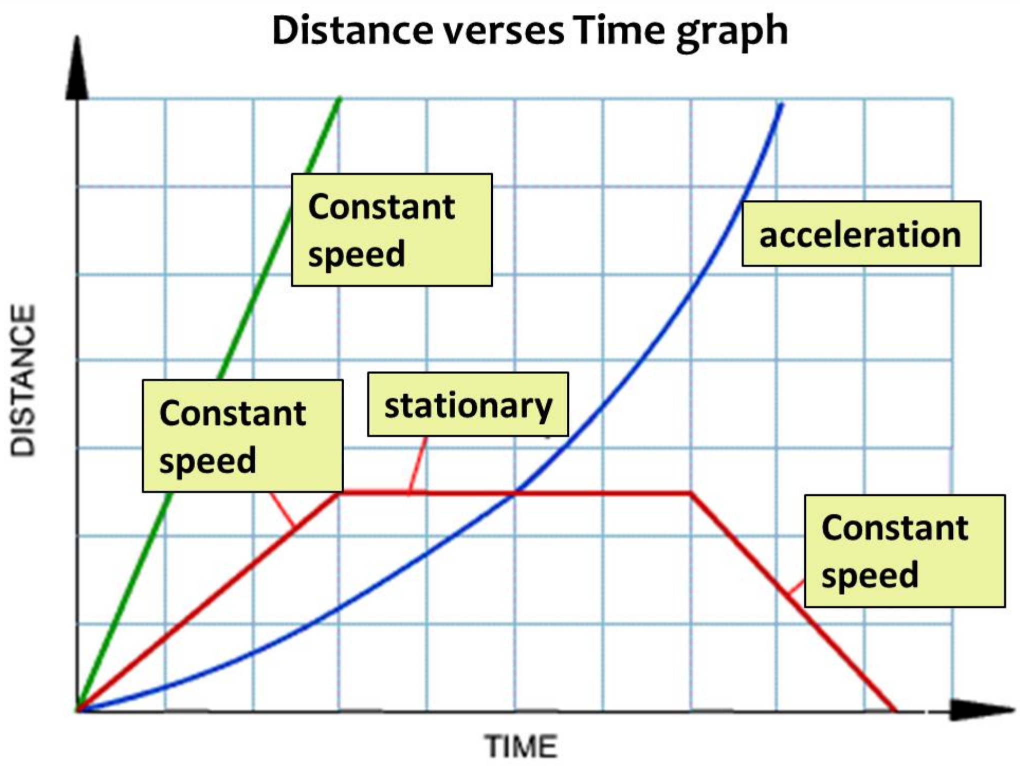
Distance verses Time graph



Interpreting Distance/time graphs

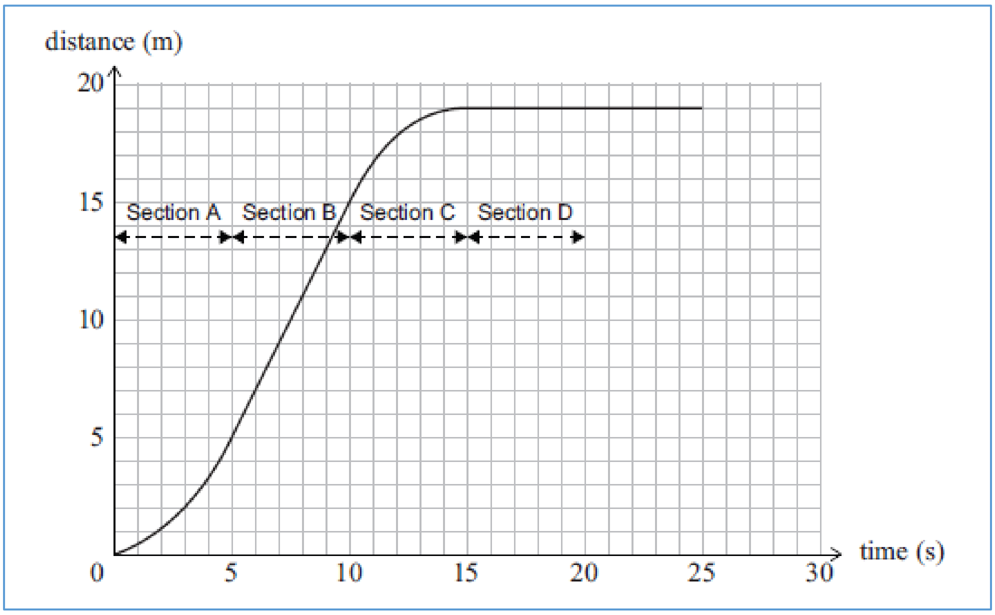
A distance time graph can also show acceleration with a curved line (blue) because at each time interval the distance travelled becomes larger and larger.

Changes in speed are also shown with a combination of diagonal and horizontal lines (red).



Distance / time graph – Describing motion

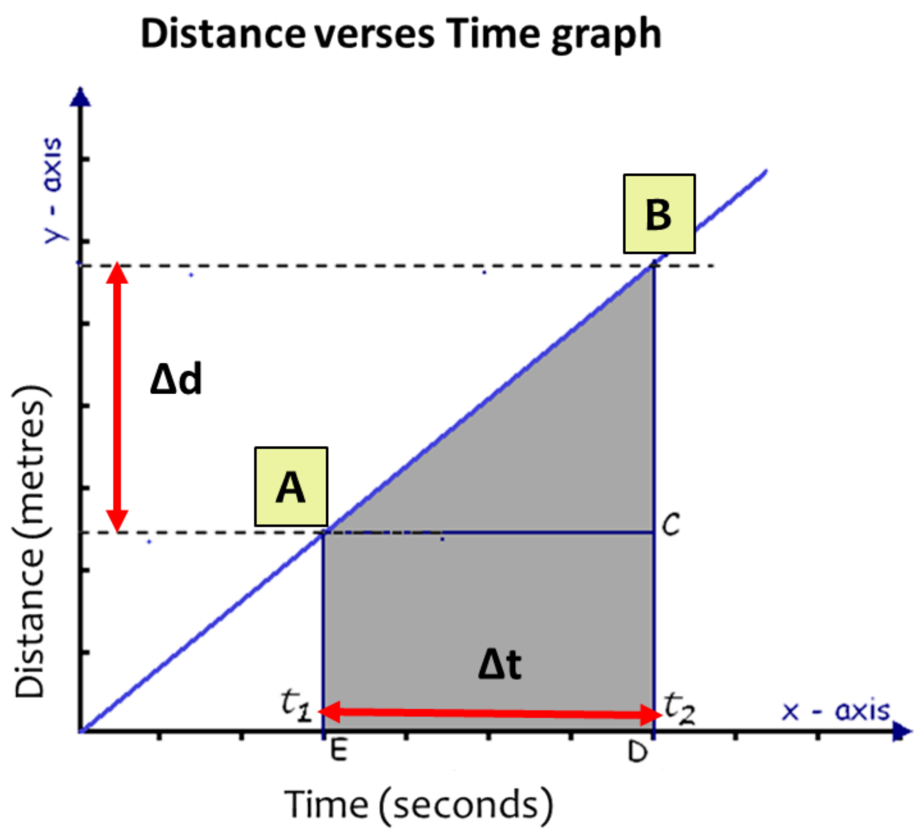
Q1: The cyclists journey was plotted on the distance / time graph below. Describe the motion of the cyclist in each of sections A,B,C and D
Section A: Increasing speed / accelerating
Section B: Constant speed
Section C: Decreasing speed, decelerating
Section D: Stopped / stationary



Q2: Calculate the cyclists speed during section B.
v = d / t
= 10 / 5
= 2 ms^{-1}
Q3: what is the total distance covered from 5 to 15seconds?
19m – 5m
= 14m in distance covered

Gradients can be calculated from a Distance-time graph

The gradient of 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.



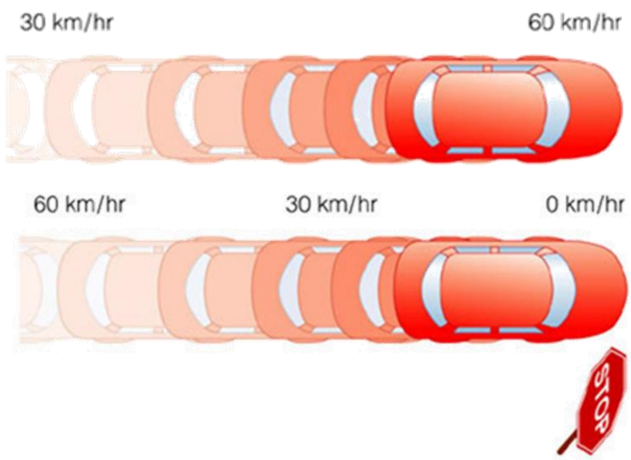
To calculate the value for time find the difference between t1 and t2 by subtracting the smallest value from the largest value. This will be your Δ time.

Repeat to find distance on the y axis. This will be your Δ distance.

Place both values into your formula to calculate speed (velocity) $v = \Delta d / \Delta t$

Acceleration is a change in velocity

Objects that have a change in velocity are said to have acceleration. An increase in velocity or a decrease in velocity (deceleration) are both types of acceleration.
A change in direction while travelling a constant speed is also acceleration. We notice when we are travelling on an object that is accelerating by experiencing a change in gravity or G-force.



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

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

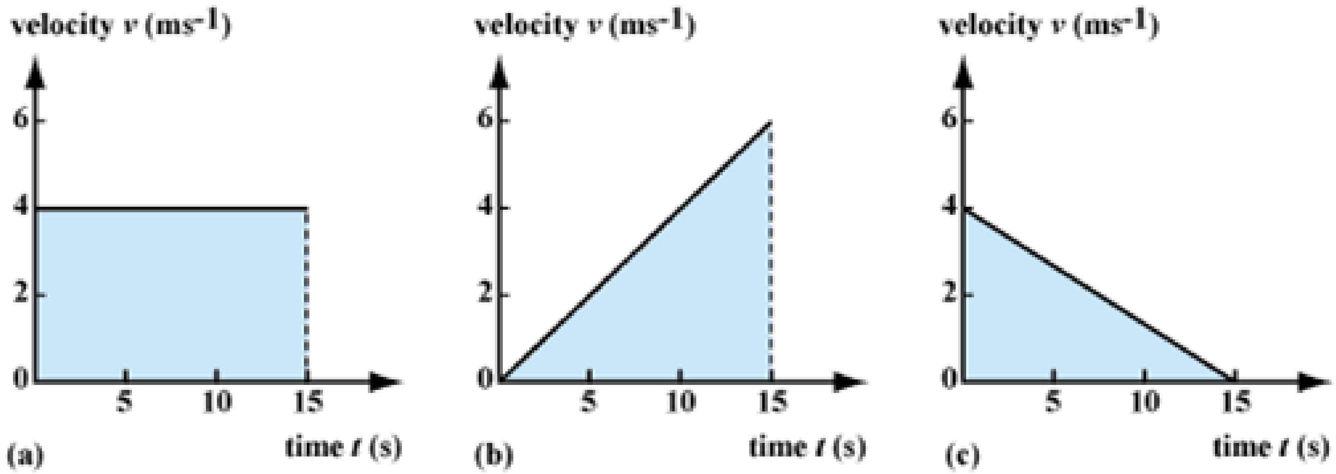
The units for Acceleration depend on what velocity and time are measured in. If time is measured in seconds (s) and velocity is measured in metres per second (ms^{-1}) then the units for acceleration will be metres per second per second (ms^{-2})

Acceleration 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 up.
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.

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.



Acceleration Calculations

The BMW 135i is a formidable sports car, accelerating from 0kmhr^{-1} to 97kmhr^{-1} in 4.6 seconds. What is the acceleration of this car in ms^{-2}?

97kmhr^{-1} /3.6 = 26.9ms^{-1}

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

a_{ave}=26.9ms^{-1}/4.6s

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

a_{ave}=5.9ms^{-2}

REMEMBER:
m/s to km/h multipy by 3.6
km/h to m/s divide by 3.6

Motion can be represented graphically – Velocity vs Time

A velocity time graph can show acceleration with a diagonal line.
Constant velocity is shown with a straight horizontal line.
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 = Δv/ t

= 10/2

a = 5ms^{-2}

Velocity verses Time graph