90940 Demonstrate understanding of aspects of mechanics

Equations. These will be supplied. You must be able to choose the correct one when solving problems. You will need to know what each letter in the equation stands for, and what units the final answer must be in.

Equation	What it means	Units
$v = \frac{\Delta d}{\Delta t}$	speed is the distance travelled divided by the time taken. Δ means "the change in"	ms^{-1} (metres per second) or kmh^{-1} (kilometres per hour)
$a = \frac{\Delta v}{\Delta t}$	acceleration of an object is its change in speed divided by the time it took for the speed to change	ms^{-2} (metres per second squared)
$F_{net} = ma$	force = the mass of an object x its acceleration. Net means "sum of" or "total".	N (newton)
$P = \frac{F}{A}$	pressure = force divided by area	Nm^{-2} or Pa (pascals)
$\Delta E_P = mg\Delta h$	potential energy of an object = the mass x the acceleration due to gravity x change in height	J (joules) or kJ (kilojoules)
$E_K = \frac{1}{2}mv^2$	kinetic energy = ½ x mass x $(\text{speed})^2$ Note: just square the speed, v.	J (joules) or kJ (kilojoules)
$W = Fd$	work = force x distance moved force is in N and d is in m	J (joules) or Nm^{-1} (newtons per metre).
$P = \frac{W}{t}$	power = work divided by time remember W equals the energy changed	W (watts) or Js^{-1} (joules per second)

A little note about acceleration & deceleration

Avoid "speeding up" and "slowing down". Talk about accelerating and decelerating.

Consider this example:

Mike travels **90m** while decelerating at **0.2 m s^{-2}.**

This could also be written as "Mike travels **90m** while accelerating at **- 0.2 m s^{-2}**".

BUT **do not write** "Mike travels **90m** while **de**celerating at **- 0.2 m s^{-2}**"; use decelerating or a minus sign but NOT both in the same answer.

Basic Stuff

Distance (d). Measured in centimetres (cm), metres (m) or kilometres km).
Remember that 100 cm = 1 m and 1000 m = 1 km.
Speed is the distance travelled ÷ time taken. Because the speed during a journey often changes we can calculate the **average speed** for the whole journey. The speed you see on your speedometer is the **instantaneous speed**.

Average speed = *distance ÷ time*	$V_{average} = \frac{d}{t}$

The units of average speed depend on the units of distance and time in the calculation
Eg the units could be ms^{-1} which means metres per second (also written as m/s) or $km\ h^{-1}$ (kilometres per hour), also written as km/h.

Example – A car travels from Wanganui to Palmerston North (distance of 80 km) in 2 hours.

V_{av} = distance / time = 80/2 = **40 km h^{-1}**
which means the car travelled at an average speed of 40 kilometres each hour.

If the average speed was 10 km h^{-1}, how long would it take to get from Wanganui to Palmerston North?

Rearrange the equation first time = d/ V_{av} = 80km/10 kmh^{-1} = **8 h**

If a car travelled at 50 km h^{-1} for 2.5 h, how far did it travel?
rearranging the equation to give distance = V_{av} x time

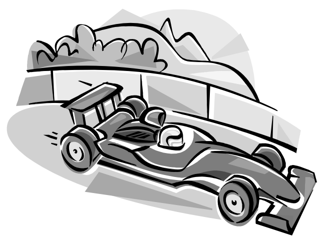
= 50 km h^{-1} x 2.5 h
= 125 km

Always show your method of calculation!

Acceleration.

If an object changes its speed, we say it has accelerated. To calculate the acceleration of an object we need to know:

- How much the speed changed
- How long it took for the speed to change

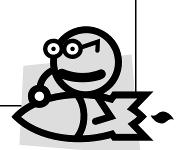


Equation to use $$a = \frac{\text{change in speed}}{\text{change in time}}$$

Unit of acceleration is **ms^{-2}** metres per second squared.

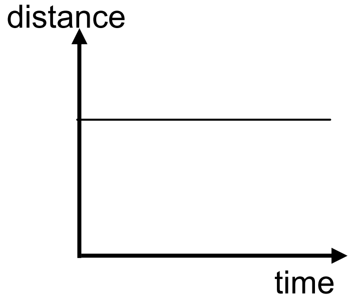
The acceleration tells us how much the speed is changing with each second of time. If the **speed is constant** (not changing) then there is **no acceleration**.

Example In 1954, Dr Strapp strapped himself onto a rocket sled and went from 0 to 16000 m s^{-1} in 5 seconds!! His acceleration was 16000 / 5 = **3200 ms^{-2}**
Each second of the journey, his speed increased by 3200 metres per second!!
Apparently his eyeballs fused to his eyelids!

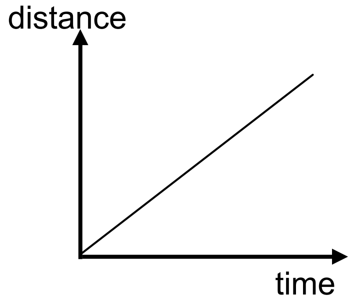


Distance-time graphs

stationary



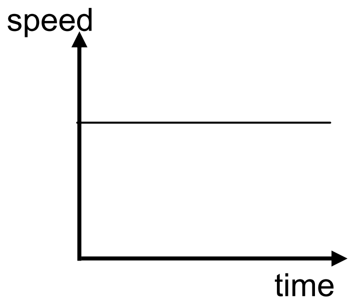
moving with constant speed



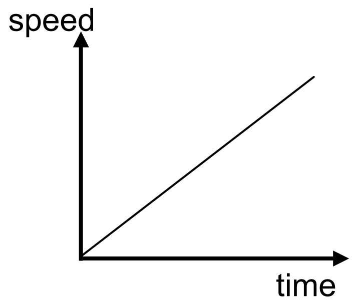
The steeper the slope of the graph, the greater the speed. The gradient of a distance time graph represents the speed the object travels.

Speed-time graphs

constant speed



constant acceleration

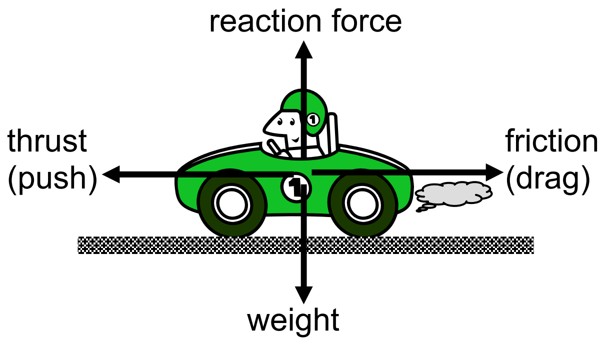


The steeper the slope of the graph, the greater the acceleration it represents. The gradient of a speed-time graph represents acceleration. The area under a speed-time graph represents the distance travelled.

Mass
The amount of stuff (matter) that is in something. Unit is the **kilogram (kg)**

Force
Examples are: Thrust, push, pull, friction, weight and reaction (reaction force)

Example



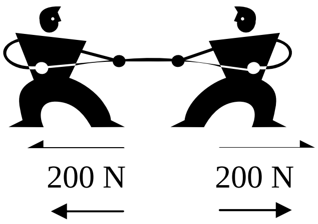
The "force arrows" should come from the centre of mass of the object even though the "road pushes up" and the "weight of the car pushes down".

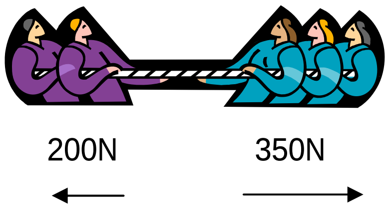
Force is measure in newtons, symbol (N).

The arrows show the **directions** in which the forces are acting. Forces that are **balanced will cancel each** other out. Unbalanced forces will cause an object to change its movement. The object may change its speed (ie accelerate or decelerate) and/or change its direction of movement.

Examples

Each person pulls with the same sized force but in opposite directions. The forces are **balanced**. If one competitor pulls with a bigger force than the other then the forces are unbalanced and the other competitor experiences a net force which causes it to move and change speed.



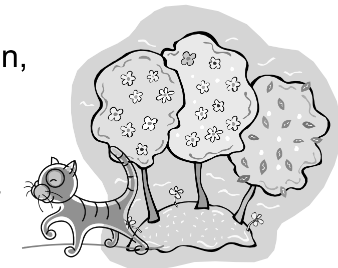


A net force of 150 N acts from left to right. These forces are **unbalanced**.

Weight
The force that pulls you towards the centre of the Earth.

Weight = m g   **m is the mass in kg and g is 10 ms^{-2}**

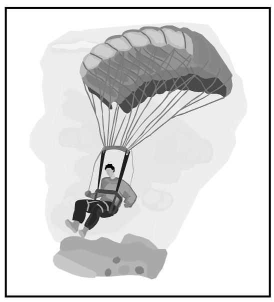
g is the acceleration caused by gravity on the Earth. If you go to the Moon, the g number would be smaller and the weight is smaller (about 1/6 that compared to the weight on Earth).



Example On Earth, Tiddles the cat has a mass of 2kg. Tiddles' weight = mg = 2 x 10 = **20 N**

In space, Tiddles still has a mass of 2kg but now has a weight of 0 N (because g = 0).

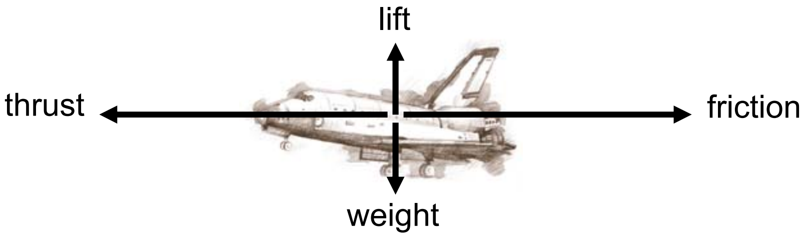
Friction – a force that **opposes the movement** of something.
A force of friction acts when an object moves through the air or water and/or when solid surfaces slide, or tend to slide, across each other. The direction of this force of friction is always opposite to the direction in which the object or surface is moving. Friction causes objects to heat up and to wear away at their surfaces. Without friction, the tyres of a car would not grip the road. The friction between solid surfaces is used in brakes which slow down and stop moving vehicles.

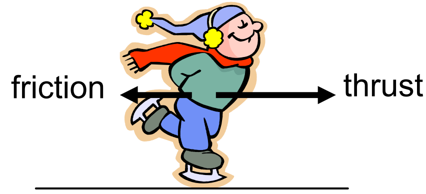


How do parachutes work?
As the parachutist starts to descend he speeds up and air resistance increases (as he displaces more air molecules per second). When the parachute opens it provides a larger upward force. When the air resistance (drag) equals the downward force of weight, the speed remains constant. Parachutes slow us to a speed where we can land safely.

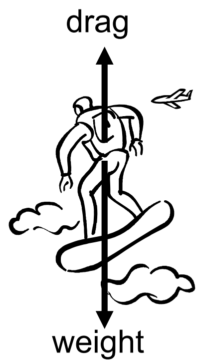
Examples of balanced & unbalanced forces

This skater is accelerating as thrust > friction. *Note: weight and reaction force have not been shown.* The forces are unbalanced.

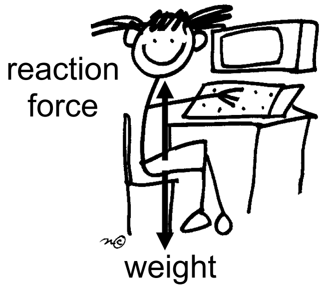




This shuttle flies at constant speed as thrust = friction. It is flying "level" as weight = lift. The forces are balanced.



This "sky surfer" is accelerating since weight > drag which means he has not yet reached terminal velocity (At terminal velocity drag = weight). The forces are unbalanced.



The forces are balanced.

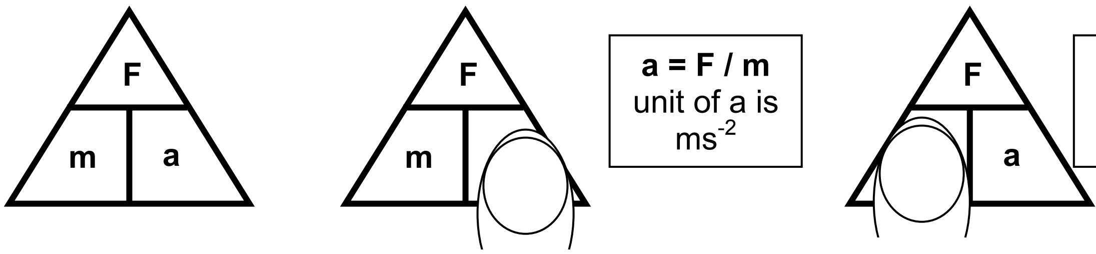
Force, mass and Acceleration

An object accelerates if the forces on it are unbalanced. The link between the mass of the object, the size of the unbalanced force and the acceleration caused is given by this equation: **F= ma** (force = mass x acceleration)
F is in Newtons, mass is in kg and acceleration in ms^{-2}.

Example A student with a mass of 50 kg is accelerates at 5 ms^{-2}.
Calculate the unbalanced force acting on the student.

F = ma so F= 50 kg x 5 ms^{-2} **= 250 N**. (Don't forget the units).

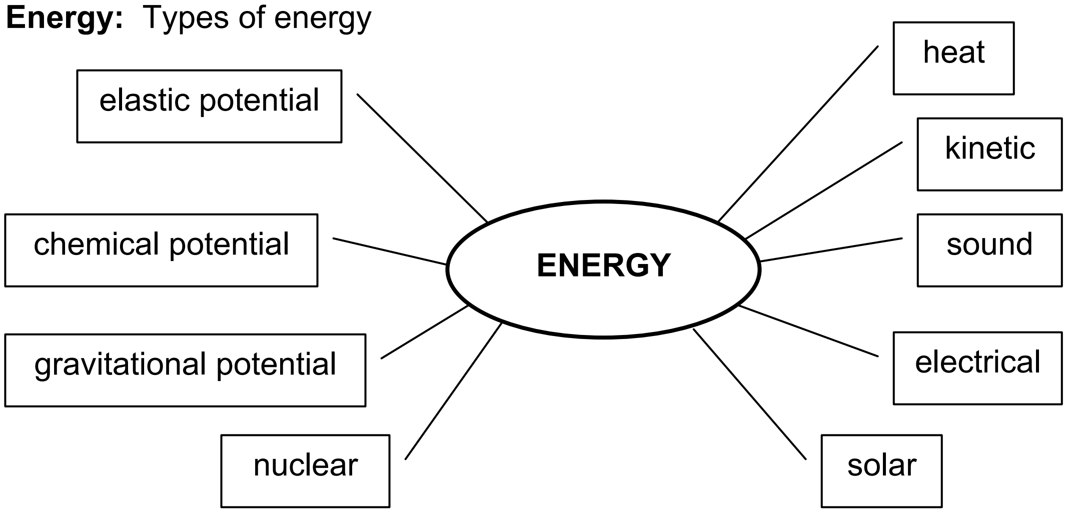
You need to know how to rearrange the equation to obtain other values. Some people use the triangle method. Cover up the symbol you want to know and the triangle give you the equation to use (don't forget the units).

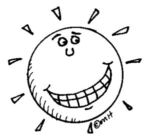


a = F / m
unit of a is ms^{-2}

m = F / a
unit of mass is kg

Energy: Types of energy





Energy is transformed from one type to another. It cannot be created or destroyed. If you have energy you can "do something". In Science, this is called **work.**
Energy is measure in **joules** (symbol **J**). 1000 J = 1 kJ (One thousand joules = 1 kilojoule).

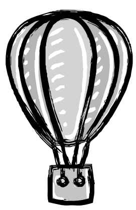
Examples of some energy transformations

Event	Starting Energy	Finishing Energy
 explosion	chemical (chemical potential)	heat, light, sound & kinetic
 fire	chemical (chemical potential)	heat & light.
 cell	chemical	electrical
 windmill	kinetic	electrical

<u>Gravitational Potential Energy</u>.

The energy you have because of your position. An increase in height = a gain in gravitational potential energy. A decrease in height is a loss of gravitational potential energy.
How to calculate it: $\mathbf{E_p = mgh}$
E_p is energy and is measured in **joules**, symbol **J**
m= mass in kg, g = 10 ms^{-2} and h = change in height in metres (m).

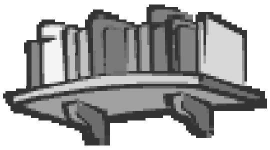
<u>Example</u>



A balloon rises 15 m into the air. It has a mass of 150 kg. Calculate the gain in gravitational potential energy.

$\mathbf{E_p = mgh}$
E_p = 150 kg x 10 ms^{-2} x 15 m
E_p **= 22500 J or 22.5 kJ**

<u>Example</u>



A book is dropped off a shelf onto the floor. The book has a mass of 1.5 kg and falls 2 m. Calculate the decrease in gravitational potential energy.

$\mathbf{E_p = mgh}$

$E_p = 1.5\ kg \times 10\ ms^{-2} \times 2\ m$

$\mathbf{E_p = 30\ J}$.

<u>Example</u>

A person has a mass of 40 kg. She is pulled back on her seat and raised 50 cm. What is the increase in her potential energy?

$\mathbf{E_p = mgh}$

$E_p = 40\ kg \times 10\ ms^{-2} \times 0.5\ m$ (height is in metres)

$\mathbf{E_p = 200\ J}$.

Kinetic Energy - moving objects have this type of energy.
Calculate the kinetic energy by using the formula $\mathbf{E_k = ½ mv^2}$

E_k is kinetic energy (**unit is joules, J**), m is the mass of the object in kilograms, kg, and v is the velocity (speed) in ms^{-1}).

Looking at the equation it is easy to see that:

- ✓ If the **mass is bigger** then the **kinetic energy will be bigger**
- ✓ If the **speed is bigger** then the **kinetic energy will be bigger**
- ✓ If the **mass is doubled** and the speed stays the same the **kinetic energy is doubled.**
- ✓ When the **speed doubles** and the mass stays the same, the **kinetic energy** increase by 2^2 which is **4 times greater**
- ✓ When the **speed triples** and the mass stays the same **the kinetic energy increases 9x** (3^2).

<u>Example</u> Calculate the kinetic energy of a car moving at 10 ms^{-1}. The mass of the car is 500 kg.

$\mathbf{E_k = ½ mv^2}$

$E_k = ½ \times 500 \times (10^2)$

$E_k = ½ \times 500 \times 100$

$\mathbf{E_k = 25\ 000\ J = 25\ kJ}$

<u>Example</u> Calculate the kinetic energy of Joe Rokocoko. Mass 98 kg. Speed down the wing is 10 ms^{-1}.

$\mathbf{E_k = ½ mv^2}$

$E_k = ½ \times 98 \times (10^2)$

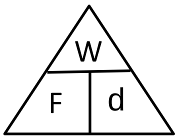
$\mathbf{E_k = 4900\ J = 4.9\ kJ}$

Work – are you working hard enough?

In Science, work is done when a force moves an object. This can be done by pushing, lifting and pulling. It is easy to calculate the amount of work that is done.

Work = Force x distance moved. **W = F. d**
Work is measure in joules because when an object is moved it gains energy.

Force is measured in newtons (N) and distance in metres (m). Use the triangle method to obtain the formula for the quantity you want to calculate.



W = F.d unit of work is J (joule)
F = W/d unit of force is N (newton)
d = W/F unit of distance is m (metre)
Don't forget the units!

Note: if something has no forces acting on it *__in the direction of motion__* (no change in speed & so no change in energy), then no work is done. E.g. carrying some shopping

Examples:

On the way to Palmerston North the car breaks down. You and a mate push the car 15 metres to a safe place. You pushed with a combined force of 200 newtons.
How much work was done in moving the car?
W = F . d
W = 200 N x 15 m
W = 3000J = 3 kJ. (This is the energy gained by the car)

A bag of rice was pushed 2m along a kitchen bench. The bag gained 150 J of energy.
What force was used to push?
F = W/d = 150/2 = 75 N

A man lifts 100 kg from the floor to a height of 2 m. How much work did he do? Here the distance is the vertical distance (height) and the force is the weight of the thing being lifted. The 100 kg mass has a weight of 1000 N.
W = F . d W = 1000 N x 2 m W = 2000J = 2 kJ

__Power__ - measuring the rate (how quickly) which energy is transferred. Power is calculated using this equation:- P is power and is measured in Watts, symbol W (or joules per second, Js^{-1}). E is the energy in joules, J and t is the time taken in seconds, s.
1000 W = 1 kW and 1000000 W (1000 kW) = 1MW (a megawatt).

Power can be calculated for other examples in which energy is transferred.

Remember this equation? **W = F d** work done = force x distance.

You run up a flight of steps. Your weight is 500 N and the height from bottom to top is 5 m. It takes you 5 s.
Calculate your power.

Step 1 Calculate the <u>work done</u> in running up the steps.
W = F d = 500 N x 5 m = 2500 J.

Step 2 Calculate the <u>power</u> – the rate of energy change

$P = \frac{E}{t}$ = 2500/5 = **250 W**.

If you are given your mass (eg 50 kg) instead of your weight you would have to use the equation **$F_{gravity}$= mg** to calculate your gravity force (weight!) first.

$F_{gravity}$ = mg = 50 kg x 10 ms^{-2} = **500 N.**

Extra notes: