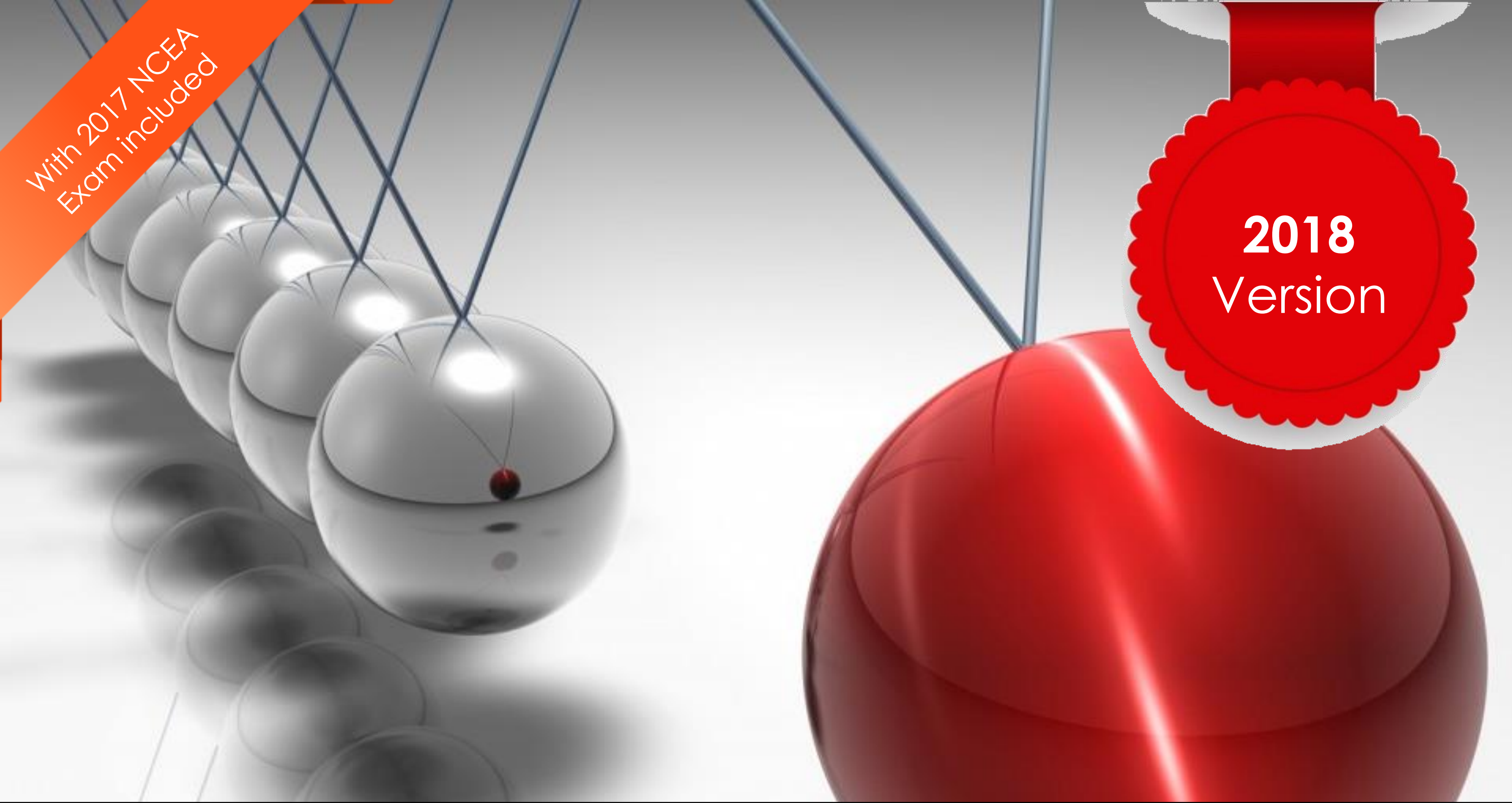

NCEA Science 1.1

Mechanics AS 90940

GZ Science Resources

Achievement Criteria

AS 90940
S1.1

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 . $v = \frac{\Delta d}{\Delta t}$ $a = \frac{\Delta v}{\Delta t}$.
- ❑ 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 $\Delta E_P = mg\Delta h$ $E_K = \frac{1}{2}mv^2$ $W = Fd$ $P = \frac{W}{t}$.

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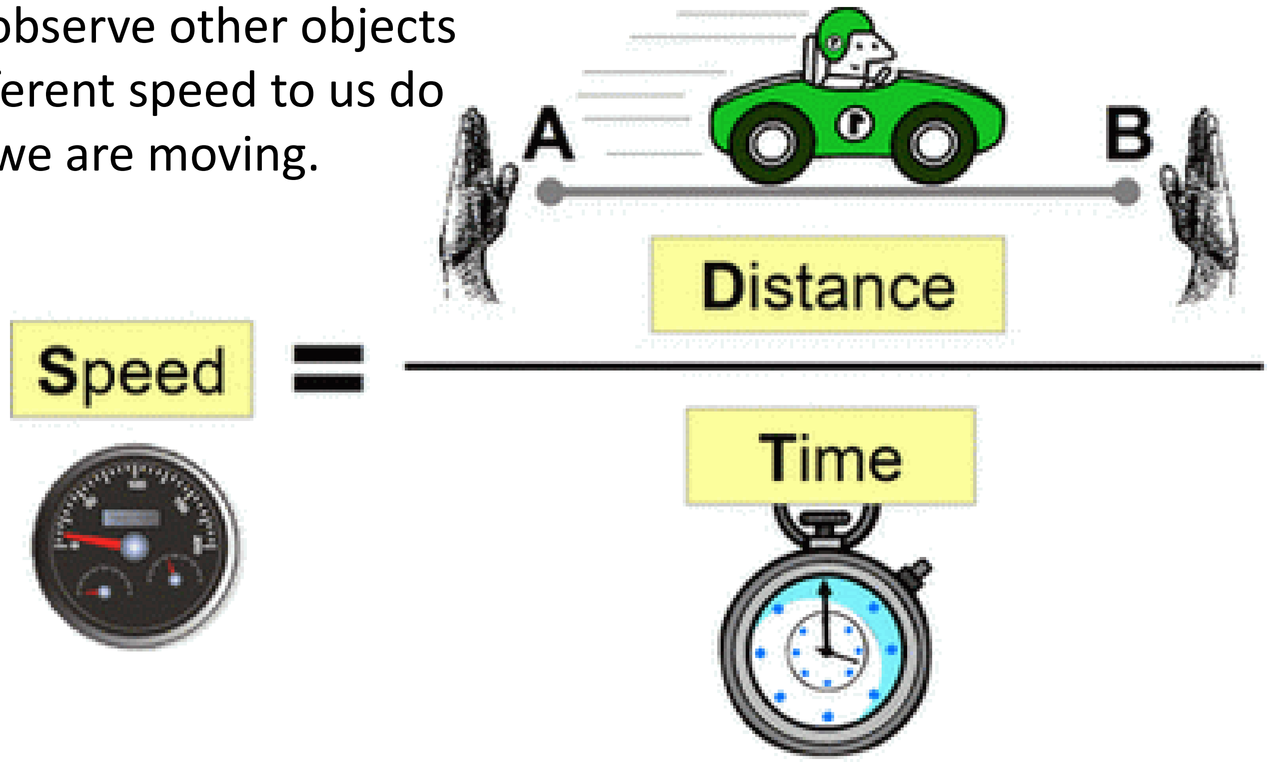
Definition of motion

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.



GZ Science Resources

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

GZ Science Resources

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

Background Knowledge

Errors may occur in measurements may be reduced by taking the average of a number of readings

When collecting and measuring data in investigations, such as that for calculating speed, errors can occur. This may be due to the measuring instrument and the way it is used. Data can also be recorded incorrectly.

Repeating the investigation a number of times and averaging out the measurements can help reduce random errors. This value is called the **mean**.

GZ Science Resources

The mean is the most common measure of average.

To calculate the mean add the numbers together and divide the total by the amount of numbers:

Mean = sum of numbers ÷ amount of numbers

Distance walked in 1 minute

	Trial 1	Trial 2	Trial 3
Distance (m)	113	121	119

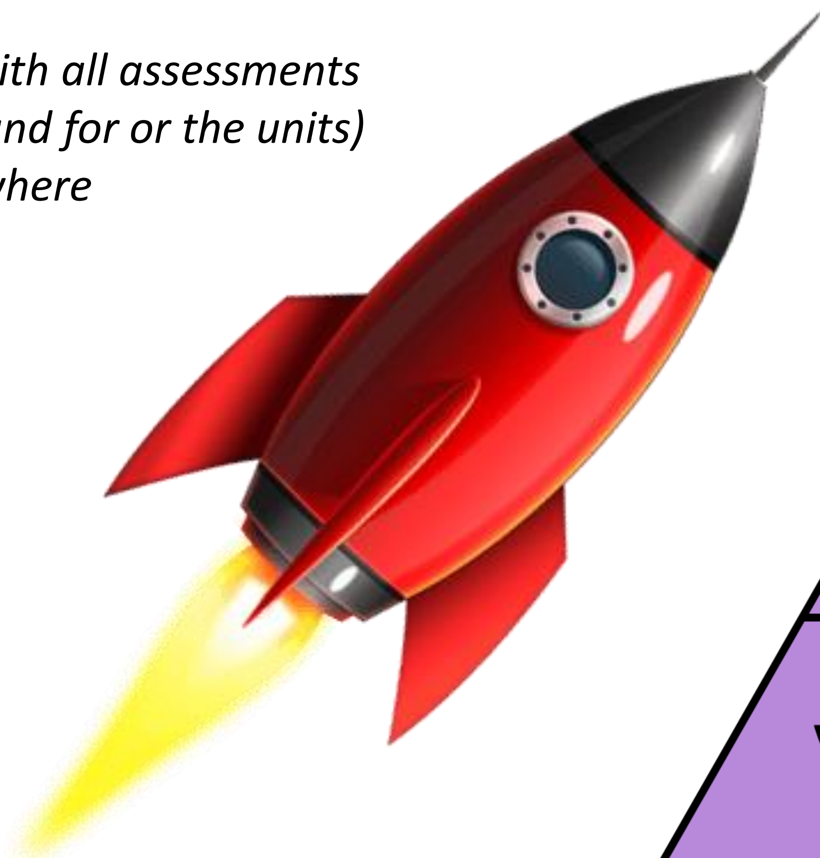
Mean = (113 + 121 + 119) ÷ 3

= **117.7** m

Calculating speed

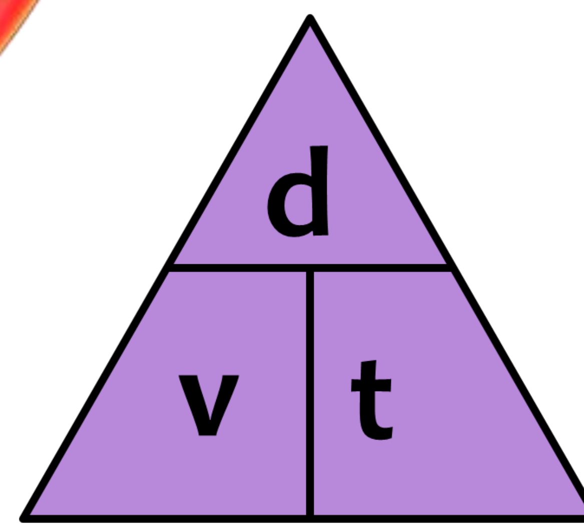
We use this **formula** to calculate speed by placing in the information we have about distance /time into it.
We can also rearrange the formula to calculate distance or time, as long as we know the other two values.
It is important to also use the units after any value in Science.

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.

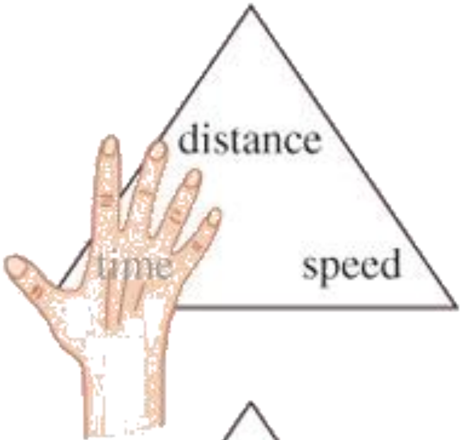


$$v=d/t$$

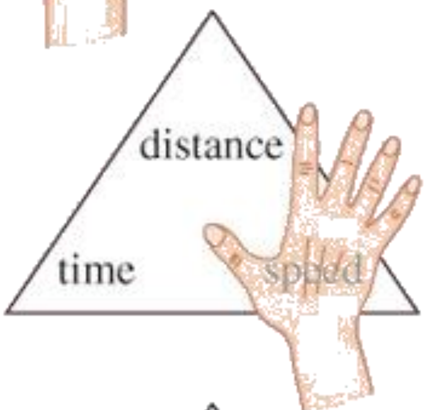
v = velocity (ms^{-1})
d = distance (m)
t = time (s)



Calculating speed using triangles



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



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

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

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.

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

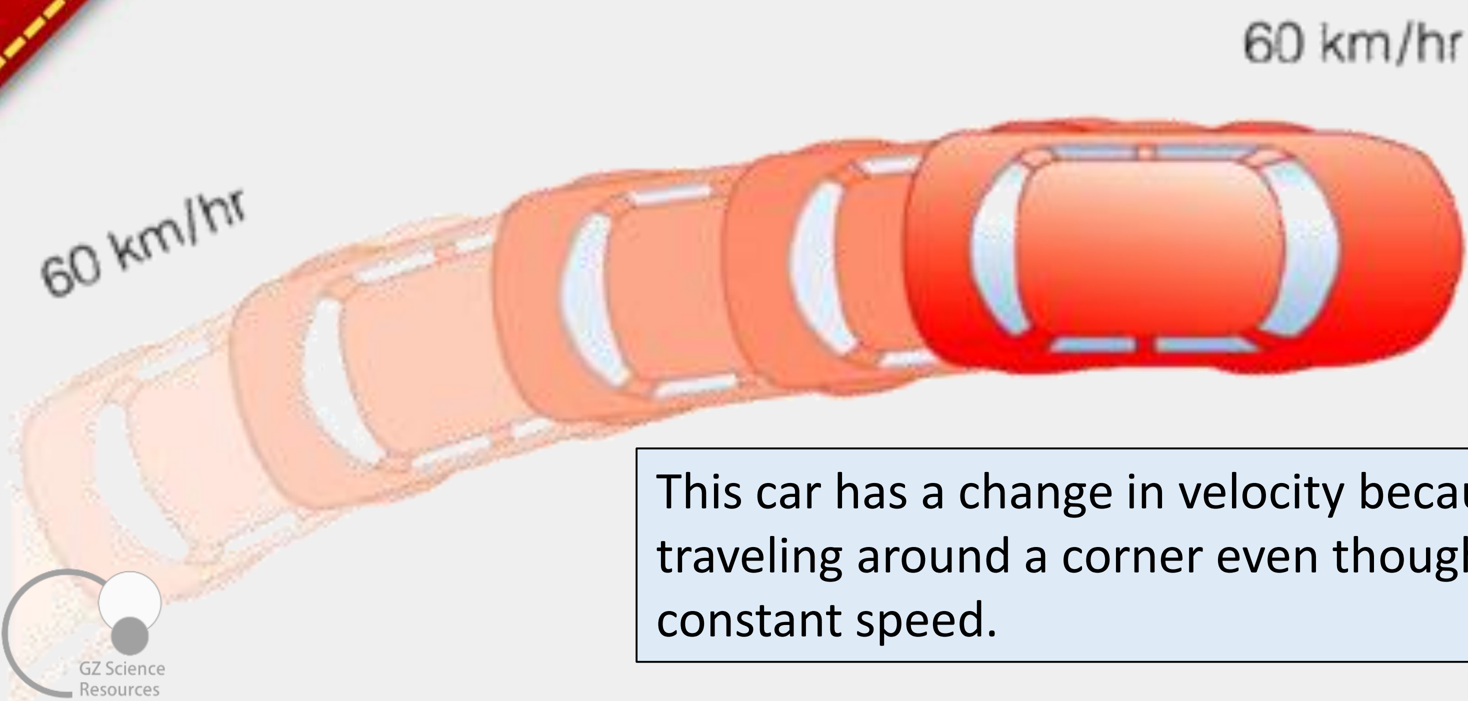
v = velocity (ms^{-1})
d = distance (m)
t = time (s)

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.

Background Knowledge

Speed and Velocity

Velocity measures the speed of an object **and** the direction it travels. Two objects can have the same speed but different velocities if they are not travelling the same direction. An object can have a constant speed but its velocity can change if it does not travel in a straight line.

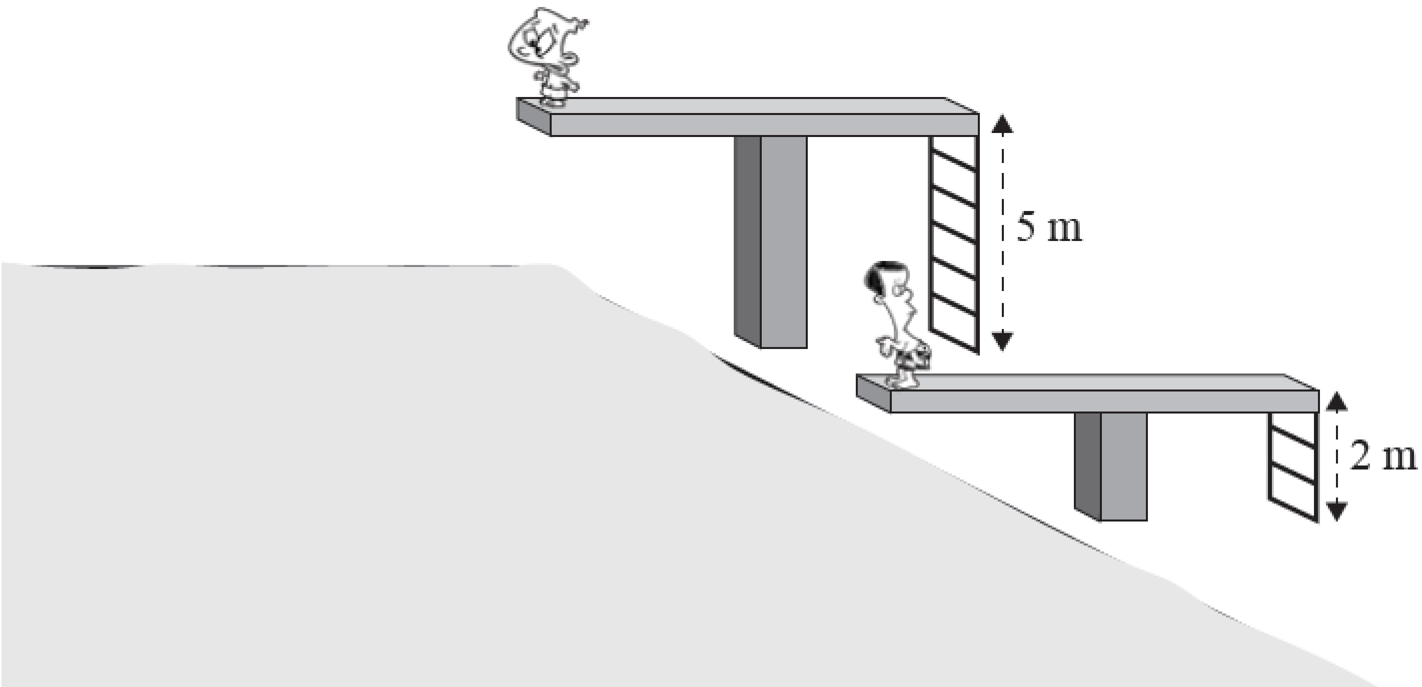


This car has a change in velocity because it is traveling around a corner even though it has constant speed.

NCEA 2015 Motion – The Diver

Question 1a: Chris and Ian were jumping off different platforms into a pool. It took Chris 0.60 s to reach the water once he had jumped from the 2 m platform. Calculate his average speed.

Achieved Question

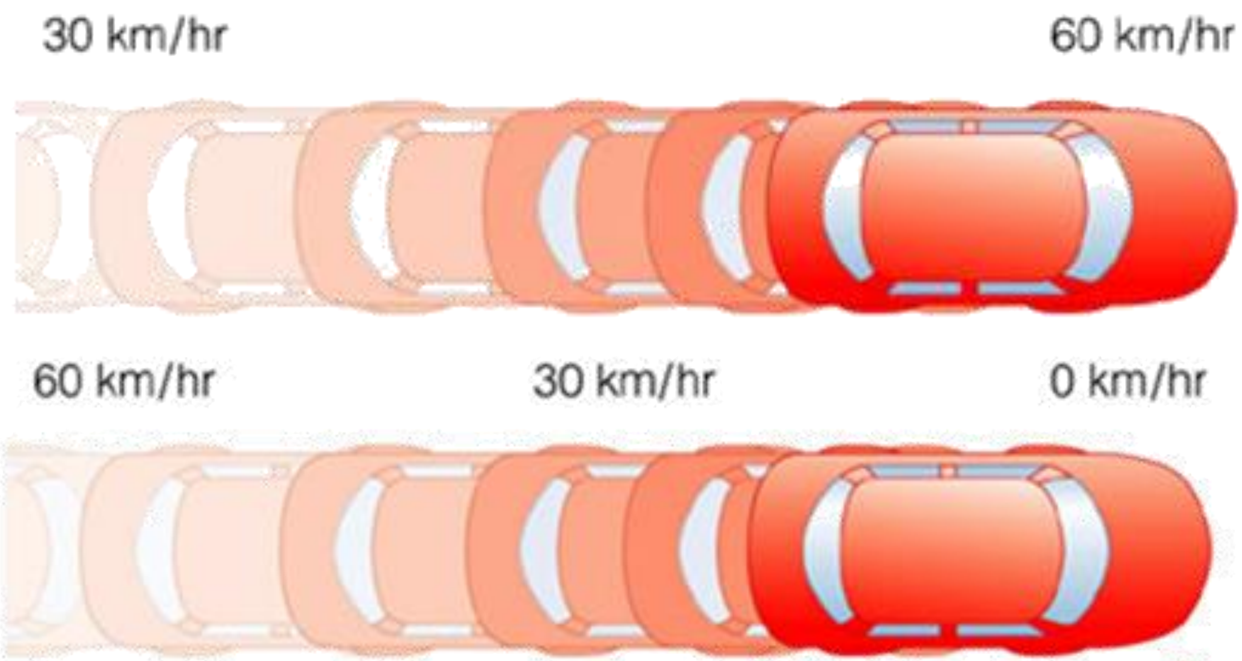


$$v = \frac{d}{t} = \frac{2}{0.60} = 3.3 \text{ m s}^{-1}$$

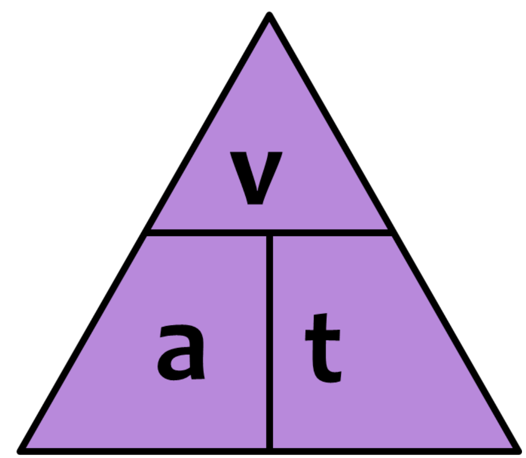
Acceleration is a change in velocity

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.



A change in direction while travelling a constant speed is also acceleration. But this is not covered in Level 1



Calculating Acceleration

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

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

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

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.

NCEA 2016 Motion – The Rocket

Question 3b: The rocket was fired vertically. It left the launch pad and after 1.2 s was travelling at 20 m s–1.
Calculate the rocket's acceleration.

Achieved Question

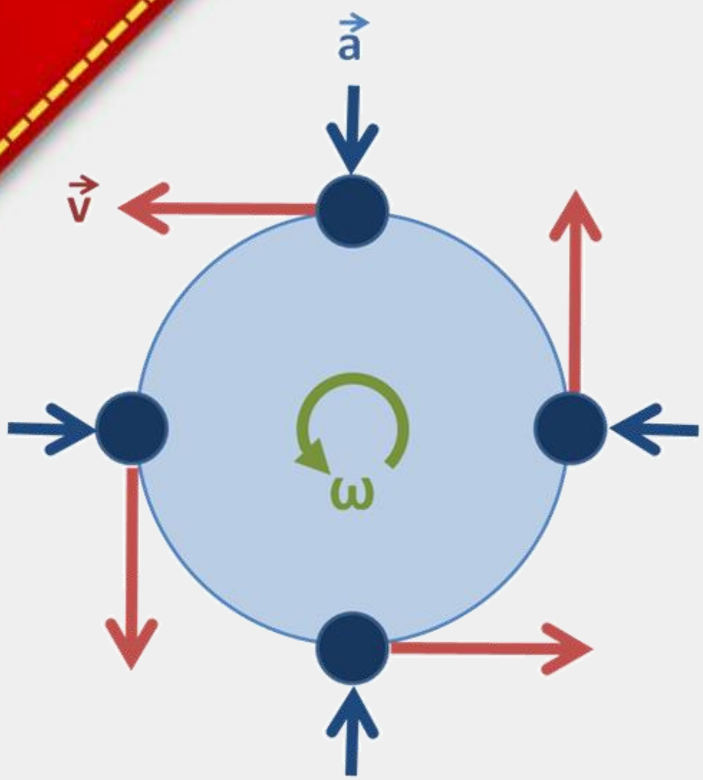
$$a = \Delta v / \Delta t$$

$$= \frac{20 - 0}{1.2 - 0}$$

$$= 16.7 \text{ ms}^{-2} \quad \text{or} \quad = 17 \text{ ms}^{-2}$$

Background Knowledge

The Earth accelerates around the Sun

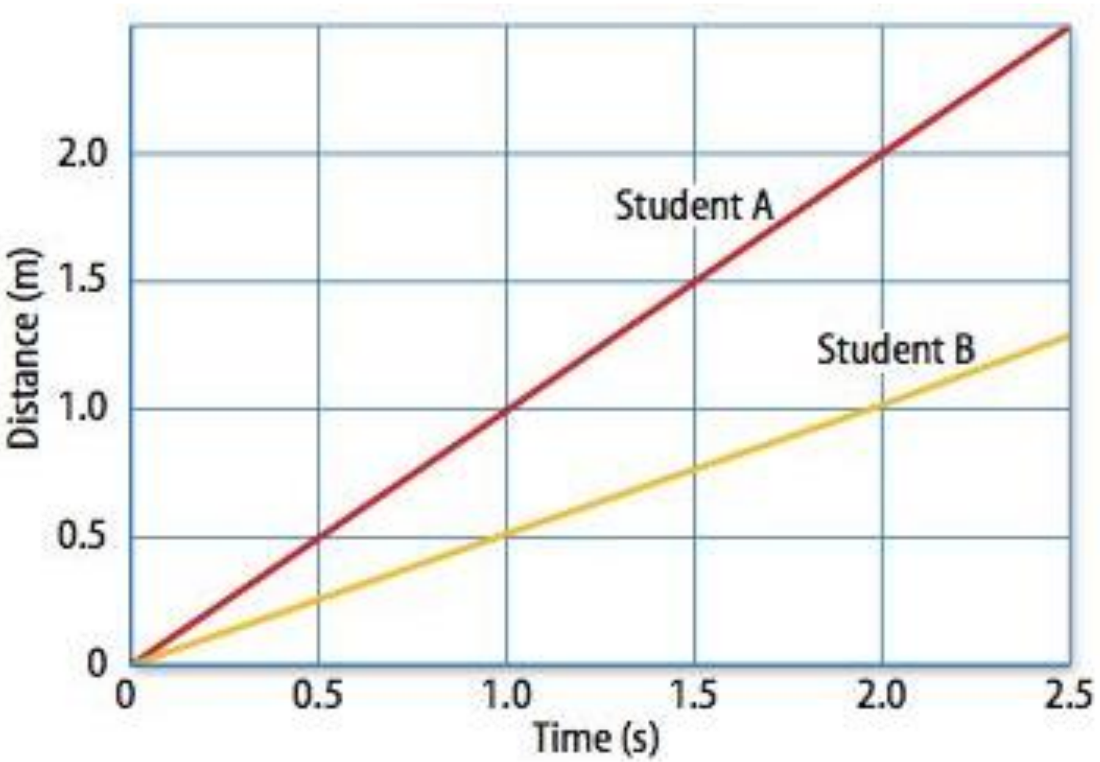


The Earth travels at a constant average speed around the Sun (the speed varies slightly due to the elliptical path) and yet it is accelerating. This is because the direction that the Earth is travelling is constantly changing as it moves around the sun. The gravity force from the sun acts on the Earth and causes a change in velocity or acceleration. The Earth's speed is fast enough so that it does not spiral into the Sun but not so fast that it continues in a curved line away from the Sun.
Satellites including the Moon also accelerate around the Earth. If the Speed of a satellites falls beyond a set limit then it will fall to the Earth.

GZ Science Resources

Distance-Time graphs

Distance verses Time graph

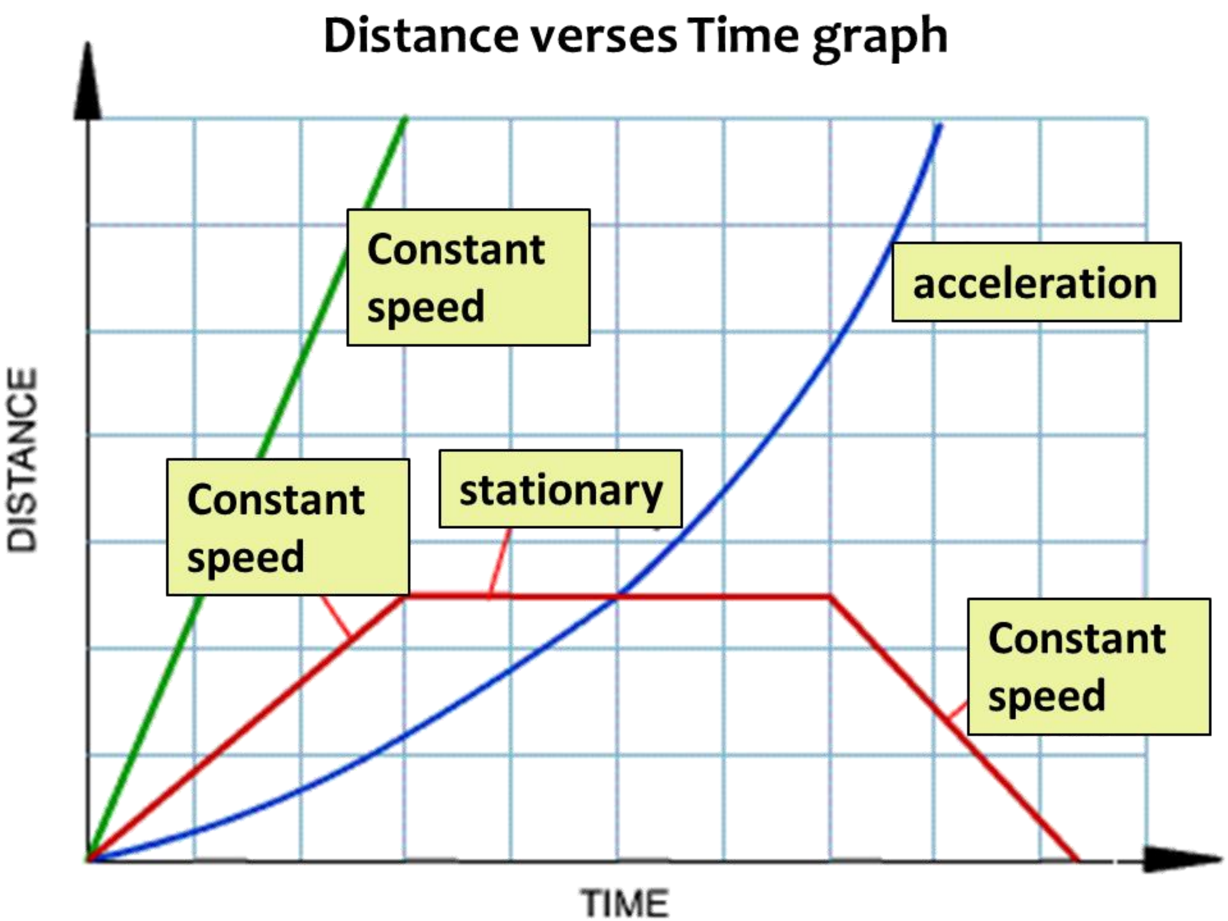


Distance (y axis) and time (x axis) data can be plotted on a line graph to show patterns and compare speeds.

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).

We only find curved lines on a Distance-time graph this year

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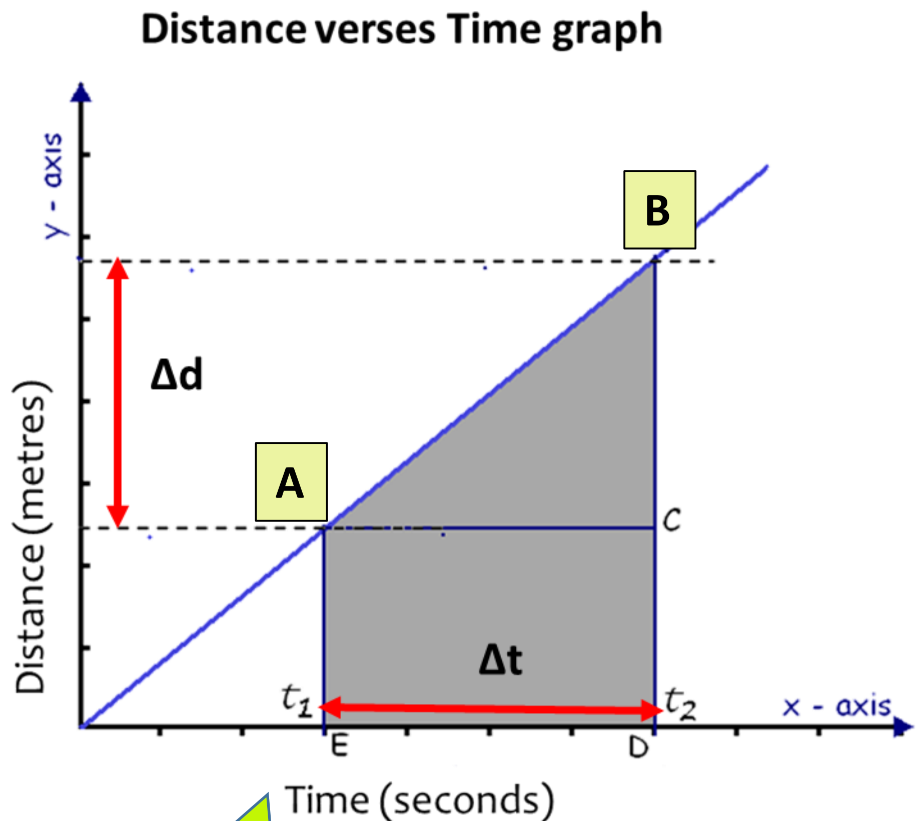
Velocity (speed) can be calculated from a Distance-time graph



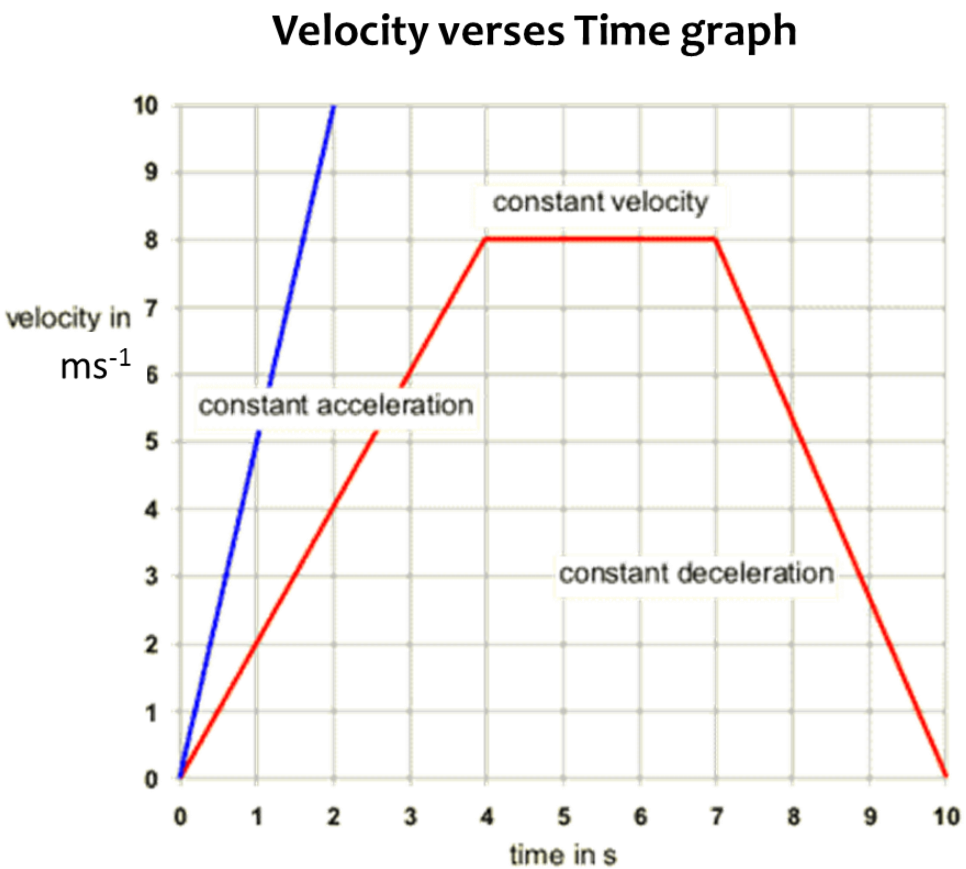
Make sure the part of the line you are using is straight

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

Speed-Time graphs



The blue line shows a velocity of 10ms^{-1} travelled in 2 seconds.
The acceleration would therefore be:

$a = \Delta v / \Delta t \quad = \quad 10ms^{-1} / 2s \qquad a = 5ms^{-2}$

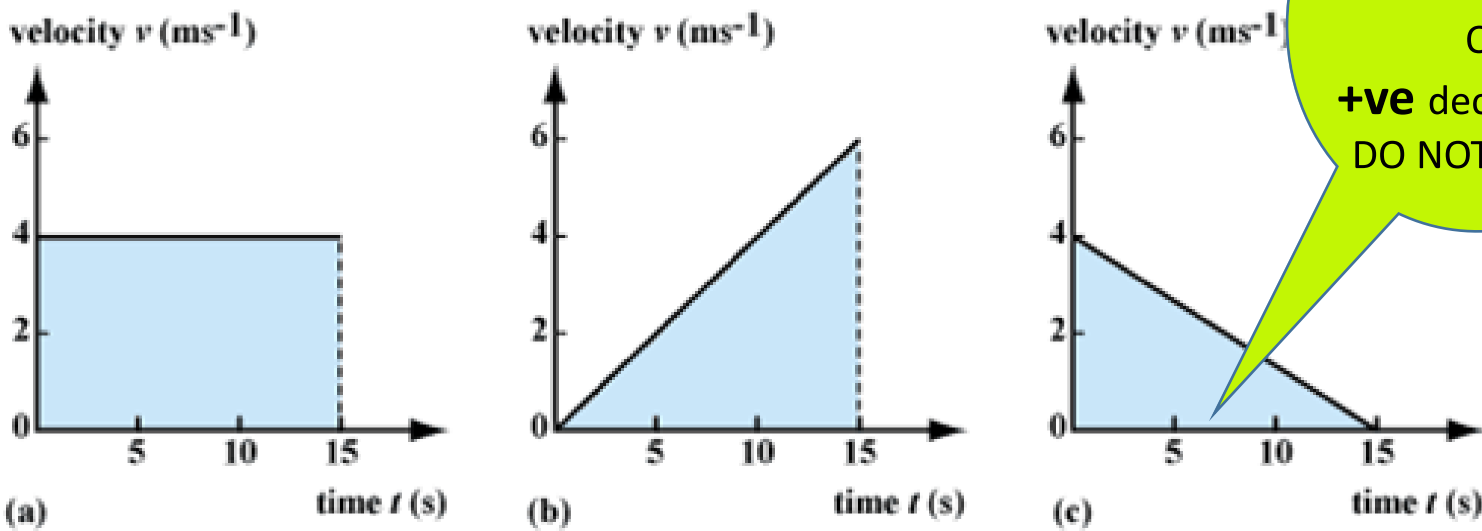
A speed - time graph can show **acceleration**.
The steeper the line (gradient), the faster the acceleration.

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

Deceleration is shown by a straight line sloping downwards.

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

Acceleration can be calculated from a speed-time graph



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

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

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

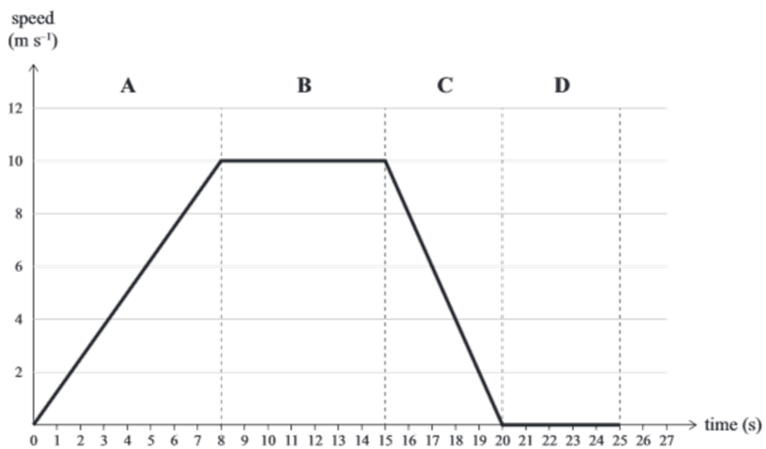
Use the start and finish points of the time and the velocity to work out the total change.
If the time starts from 0 use that as your start point.

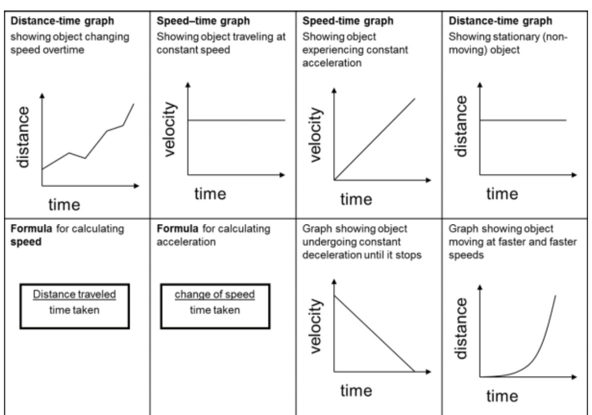
Remember: that Δ means change in.
The **line must be straight** in order to calculate acceleration

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

A runner's speed is recorded for 25 seconds and graphed below.





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.

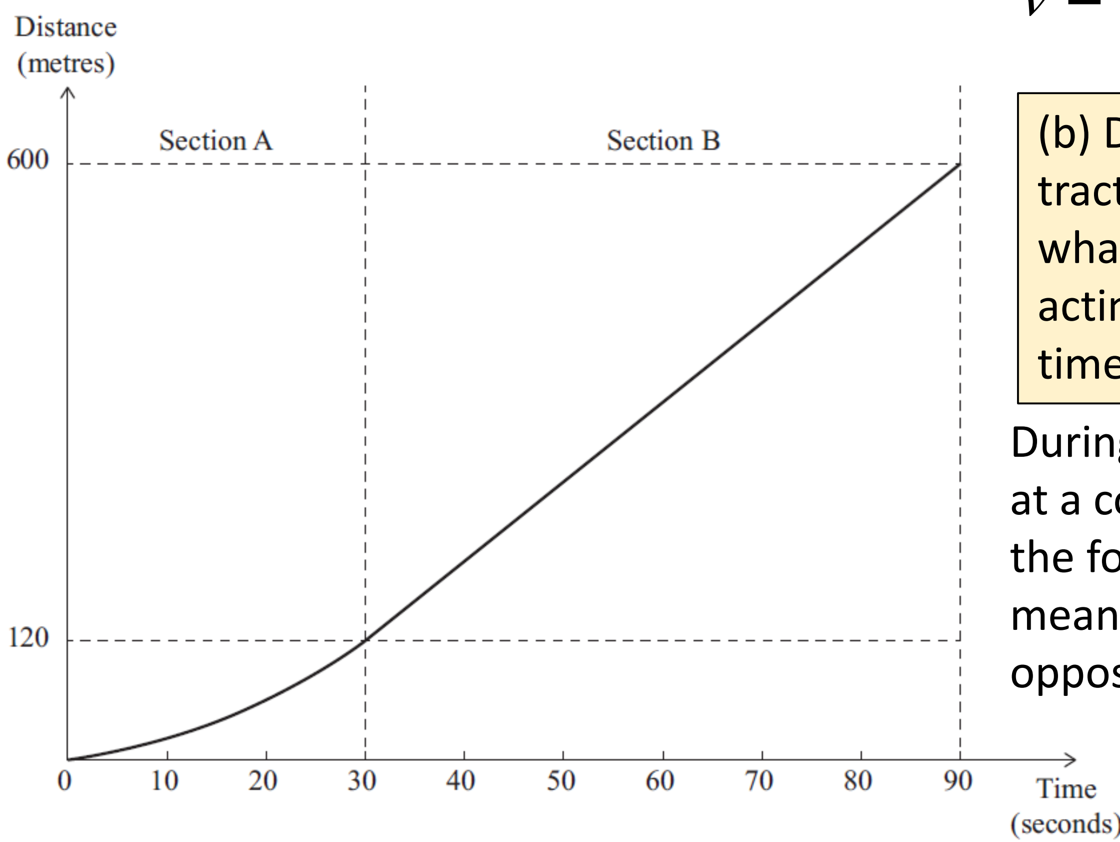
Make sure EVERY section is described and linked to data

NCEA 2012 Distance-time graph - The Tractor

Merit Question

A woman drives her tractor down a sandy beach to pick up her friend's boat. The distance-time graph below shows part of the journey. Use the information from the graph to calculate the **average speed** of the tractor during the 90 seconds.

$$v = \frac{\Delta d}{\Delta t} = \frac{600}{90} = 6.67 \text{ m s}^{-1}$$



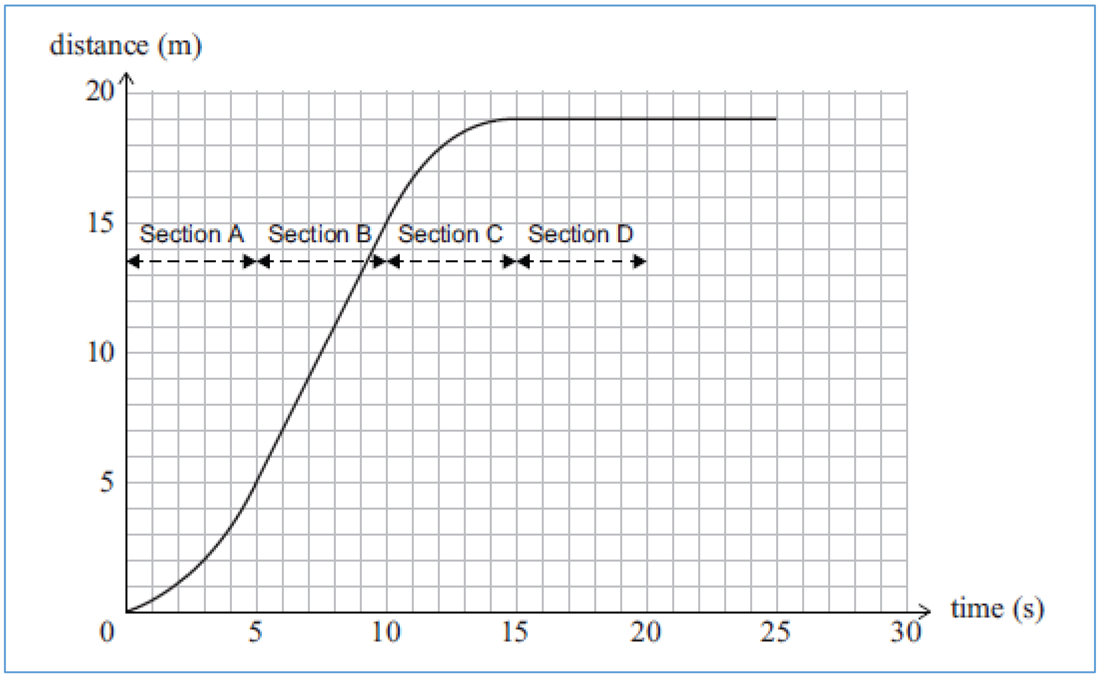
(b) Describe the **motion** of the tractor in **section B**, and explain what this tells us about the forces acting on the tractor during this time.

During section B the tractor is moving at a constant speed. This means that the forces acting are balanced. This means that they are equal and opposite.

***NOT** forces are equal – but can be forces are equal sizes with **opposite direction**.*

NCEA 2014 Distance-time graph – the cyclist

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}

Don't forget units

Q3: what is the total distance covered from 5 to 15seconds?

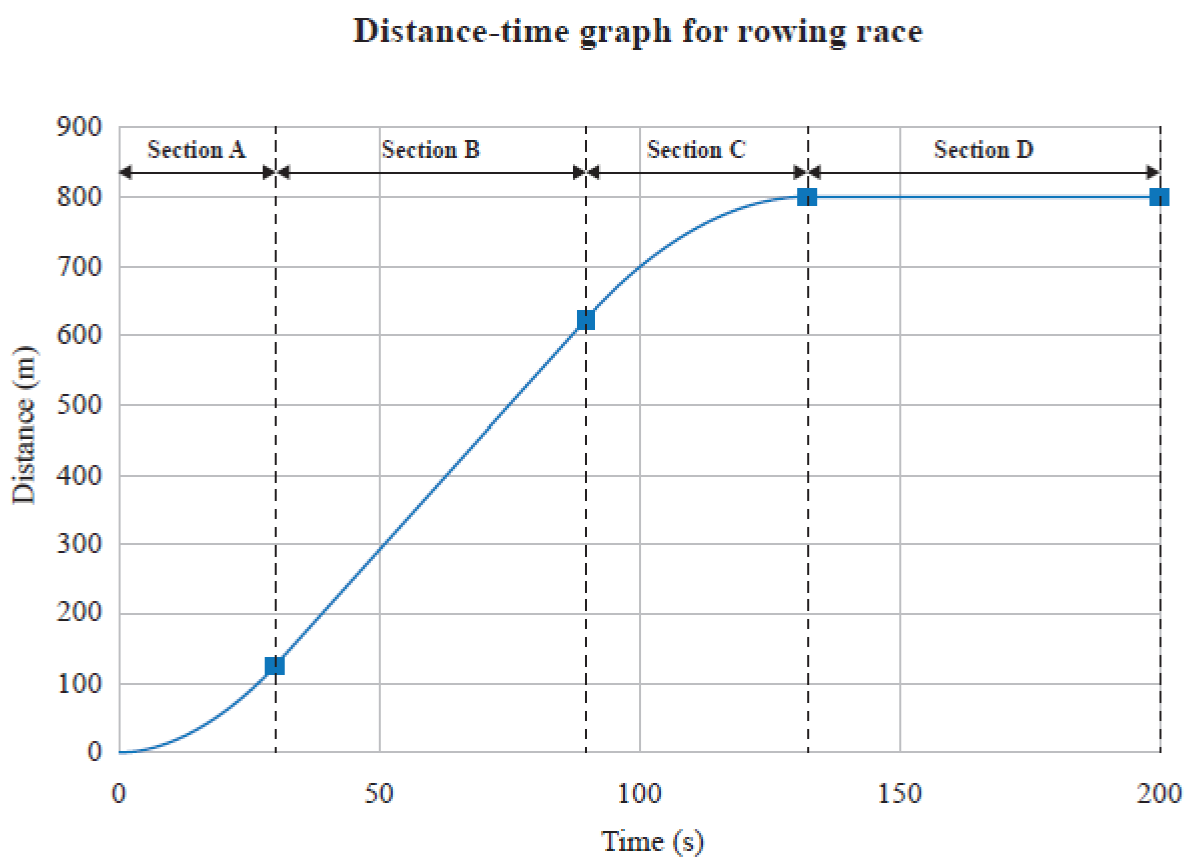
19m – 5m

= 14m in distance covered

NCEA 2015 Distance-time graph – the rower

Achieved Question

Question 3a : The distance-time graph below shows the journey of a rowing boat in a race.
Describe the motion of the boat throughout the journey.
No calculations required.



A: Acceleration / increasing speed
B: Constant speed /steady speed
C: Decelerating / decreasing speed
D: Stationary / stopped/at rest (NOT stopping or coming to a stop)

NCEA 2015 Distance-time graph – the rower

Merit Question

Question 3b : During the first 30 s of the race, the rowers' speed changed from 0.0 m s–1 to 8.3 m s–1.

During this time they covered 125 m. The total mass of the rowers and the boat is 140 kg.

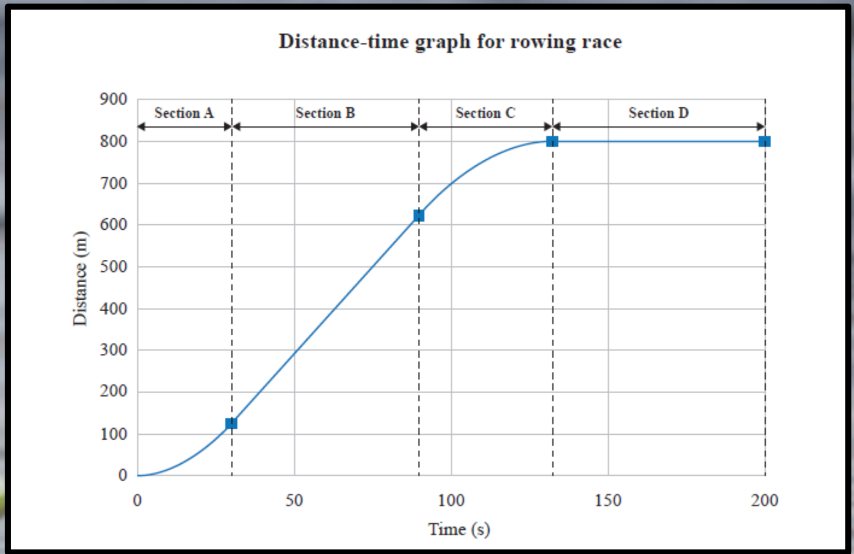
(i) Calculate the boat's **average acceleration** during the first 30 seconds.

Show your working.

$$a = \frac{\Delta v}{\Delta t} = \frac{(8.3 - 0)}{30}\ \text{m s}^{-2} = 0.277$$

$$F = ma = 140 \times 0.277 = 38.8\ \text{N}$$

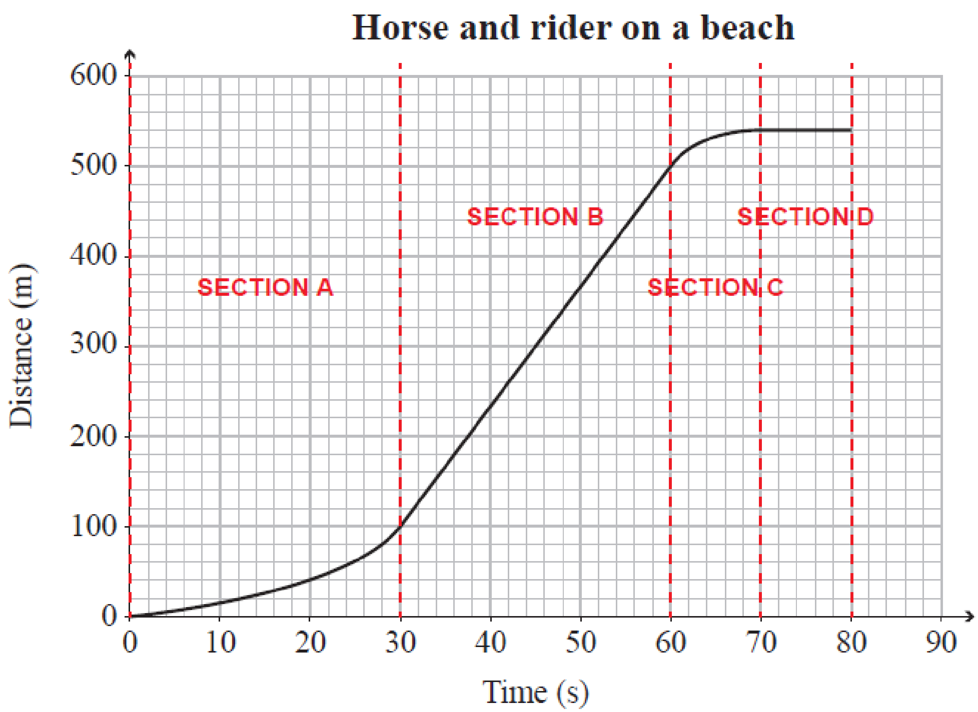
$$W = F \times d = 38.8 \times 125 = 4848\ \text{J}$$



NCEA 2016 distance-time graphs - The Horse

Merit Question

The graph below shows the motion of a horse and rider as they travel along a beach.



(a) Describe the motion of the horse and rider in each section of the graph.
(No calculations are required.)

Section A: Increasing speed / accelerating

Section B: Constant speed

Section C: Decreasing speed, decelerating

Section D: Stopped / stationary

(b) Calculate the speed of the horse and rider in Section B of the graph.

$v = \Delta d / \Delta t$

$= 400/ 30$

$\mathbf{= 13.3\ ms^{-1}}$

$\Delta d = 500\ m - 100\ m = 400\ m$

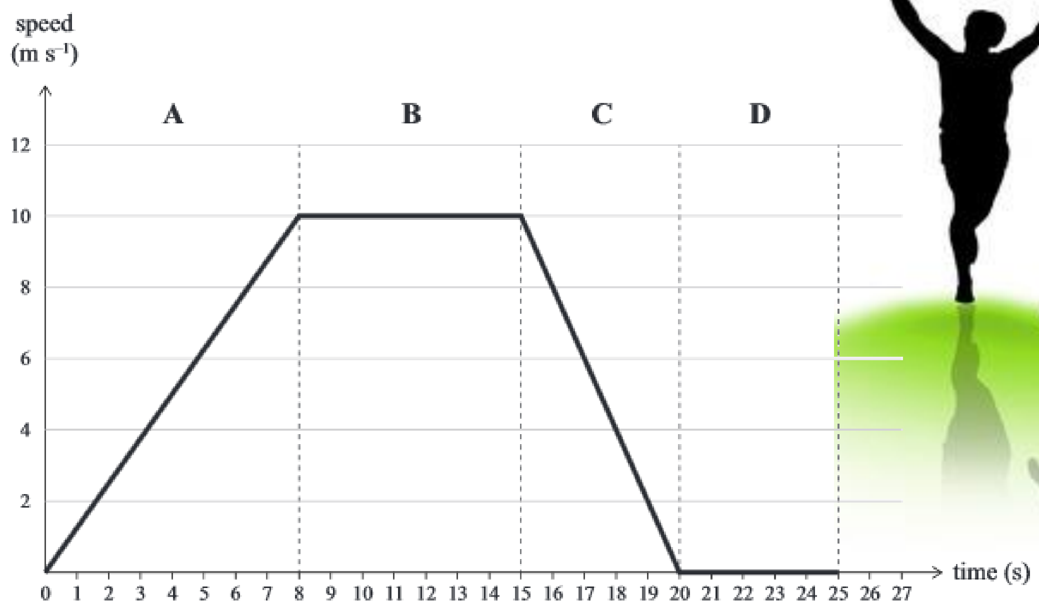
$\Delta t = 60\ s - 30\ s = 30\ s$

NCEA 2013 Speed-time graph - The Runner

Excellence Question

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

A runner's speed is recorded for 25 seconds and graphed below.



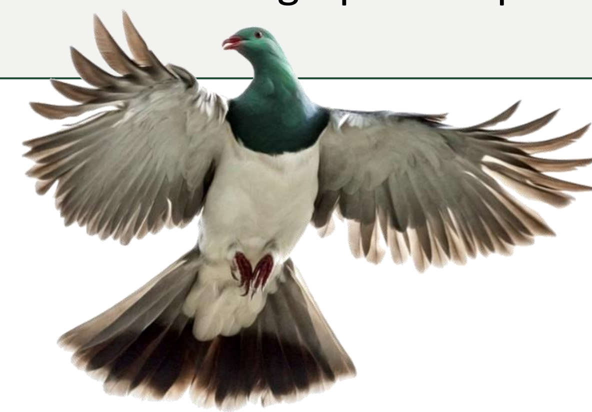
Using Data to back up answers

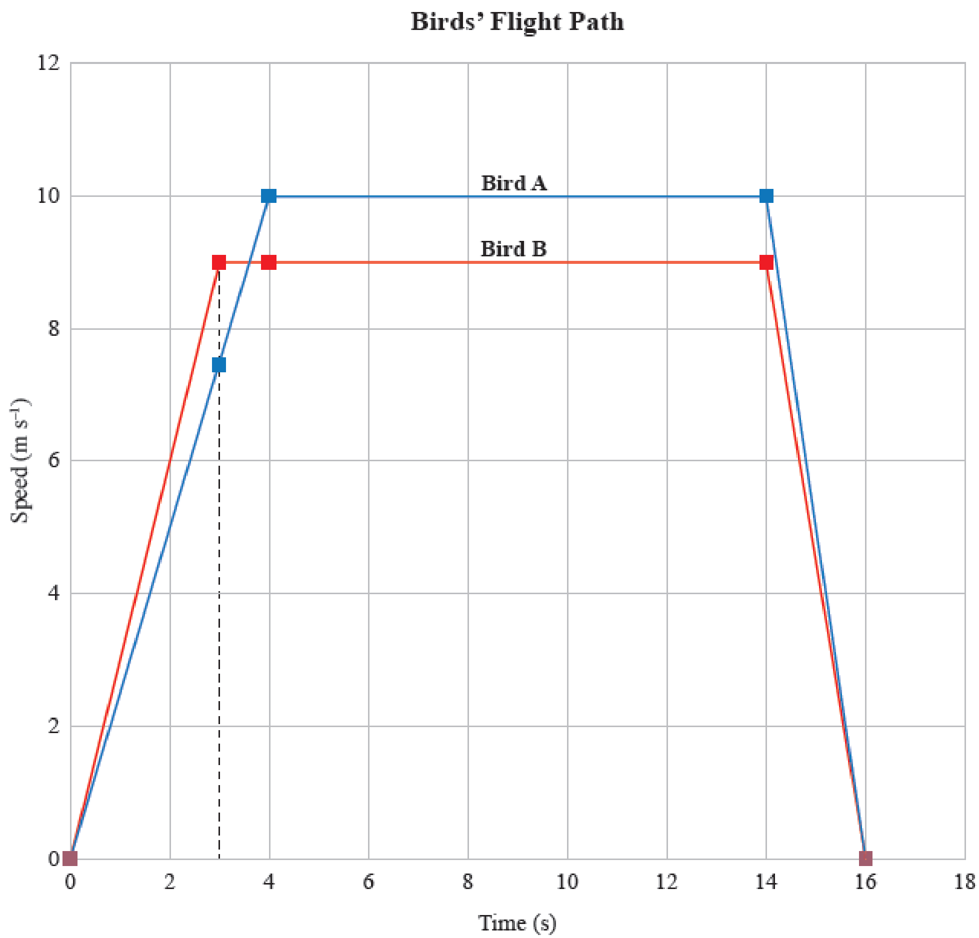
Section A: Accelerating at a constant rate of 1.25 m s^{-2}, from 0 m s^{-1} to 10 m s^{-1} in 8 seconds.
Section B: Constant speed of 10 m s^{-1} for 7 seconds.
Section C: Decelerating from 10 m s^{-1} to 0 m s^{-1} at a constant rate of 2 m s^{-2} (–2 m s^{-2} if discussing acceleration) for 5 seconds.
Section D: Stationary (constant speed of 0 m s^{-1}) for 5 seconds.

Achieved Question

NCEA 2015 speed-time graphs – kereru

Question 2c(i): The speed-time graph shows the flights of two birds. Use the graph to explain which bird has the greater acceleration in the first 3 seconds.





Bird B has the greater acceleration – the gradient / slope of the line is greater.

Bird A has an acceleration of:

$$a = \frac{Dv}{Dt} = \frac{10}{4} = 2.50 \text{ m s}^{-2}$$

Bird B has an acceleration of:

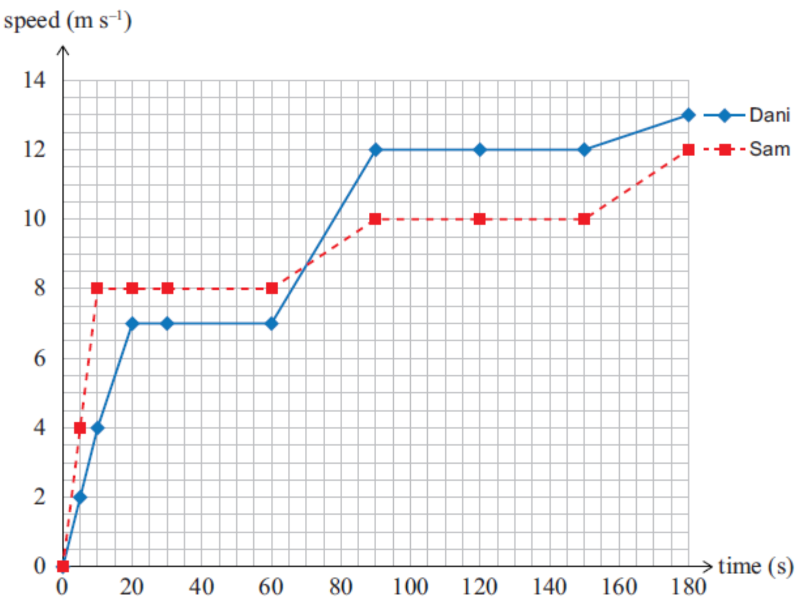
$$a = \frac{Dv}{Dt} = \frac{9}{3} = 3.00 \text{ m s}^{-2}$$

Merit Question

NCEA 2017 speed-time graphs – horse racing (Part ONE)

Question 1a: Two horses, ridden by Dani and Sam, are racing against each other. The speed-time graph of their two horses is shown below.
Use the information in the graph to compare the speed AND acceleration of Dani and Sam in the **first 60 seconds**.


Cambridgejockeyclub.co.nz



Sam accelerates at 0.8 m s–2 for 10 seconds, reaching a speed of 8 m s–1.
Stays at constant speed of 8 m s–1 for next 50 seconds.
Dani accelerates at 0.35 m s–2 for 20 seconds, reaching a constant speed of
7 m s–1. Stays at constant speed of 7 m s–1 for next 40 seconds.

Comparison: Sam has a greater acceleration during first 10 seconds, but does not accelerate for as long as Dani. Between 20 and 60 seconds, neither accelerated; they both had a constant speed. Sam had a higher constant speed during this time.

Merit Question

NCEA 2017 speed-time graphs – horse racing (Part TWO)

	Speed	Acceleration
Sam	First 10 s: increasing speed / accelerating to $\bar{v} = 8 \text{ m s}^{-1}$ 10–60 s: Constant speed of $v = 8 \text{ m s}^{-1}$	First 10 s: $a = 0.8 \text{ m s}^{-2}$ 10–60 s: $a = 0 \text{ m s}^{-2}$
Dani	First 20 s: increasing speed / accelerating to $\bar{v} = 7 \text{ m s}^{-1}$ 20–60 s: Constant speed of $v = 7 \text{ m s}^{-1}$	First 20 s: $a = \frac{7}{20} = 0.35 \text{ m s}^{-2}$ 20–60 s: $a = 0 \text{ m s}^{-2}$

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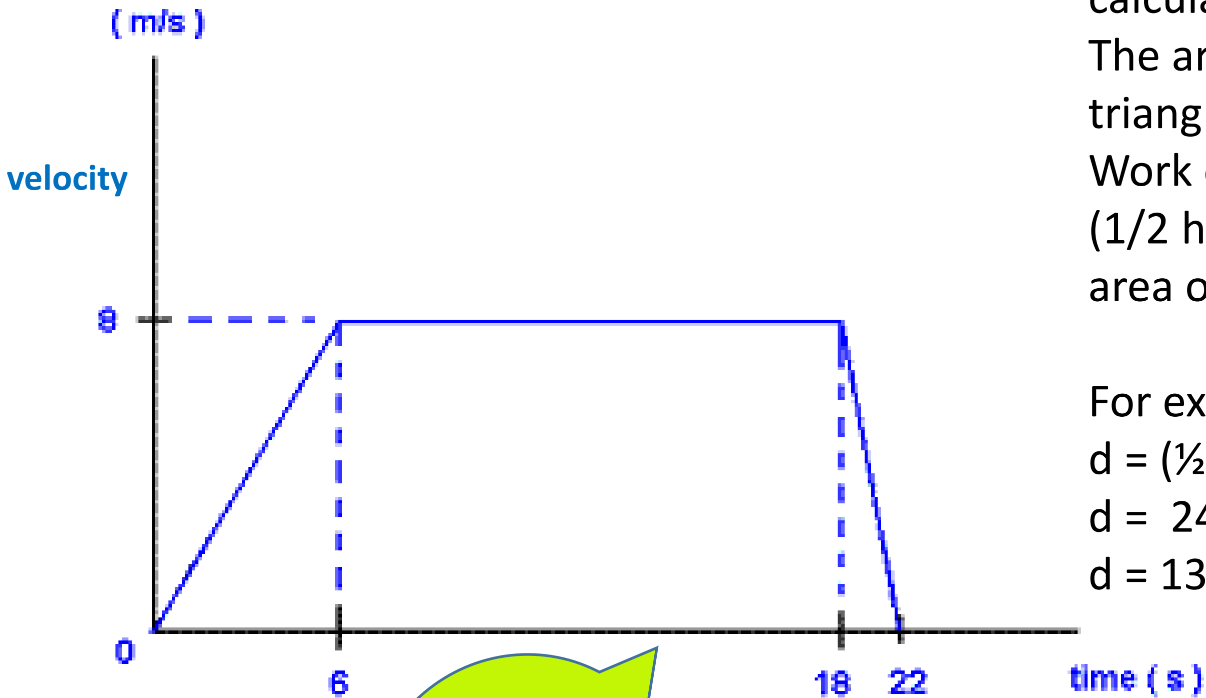
Question 1a: Two horses, ridden by Dani and Sam, are racing against each other. The speed-time graph of their two horses is shown below.
Use the information in the graph to compare the speed AND acceleration of Dani and Sam in the **first 60 seconds**.

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

Velocity verses 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 = 136metres

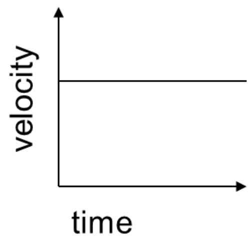
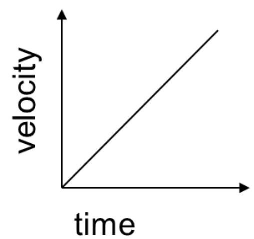
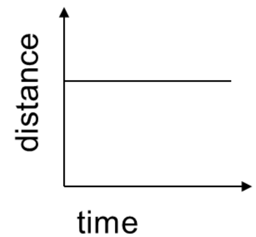
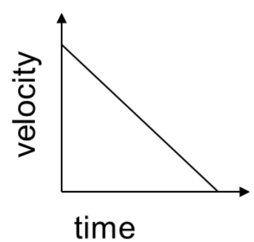
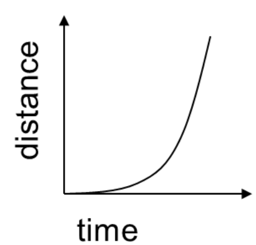
Remember:
Area for rectangle
Base x height

Remember:
Area for triangle
½ x Base x height

GZ Science Resources

Summary of Motion

- Motion can either be stationary, constant speed or changing speed (acceleration).
- Distance-time graphs can be used to determine speed
- Speed-time graphs can be used to determine acceleration
- Area under a speed-time can determine distance.

Distance-time graph showing object changing speed overtime 	**Speed–time graph** Showing object traveling at constant speed 	**Speed-time graph** Showing object experiencing constant acceleration 	**Distance-time graph** Showing stationary (non-moving) object 
Formula for calculating **speed** — Distance traveled / time taken	**Formula** for calculating acceleration — change of speed / time taken	Graph showing object undergoing constant deceleration until it stops 	Graph showing object moving at faster and faster speeds 

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

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

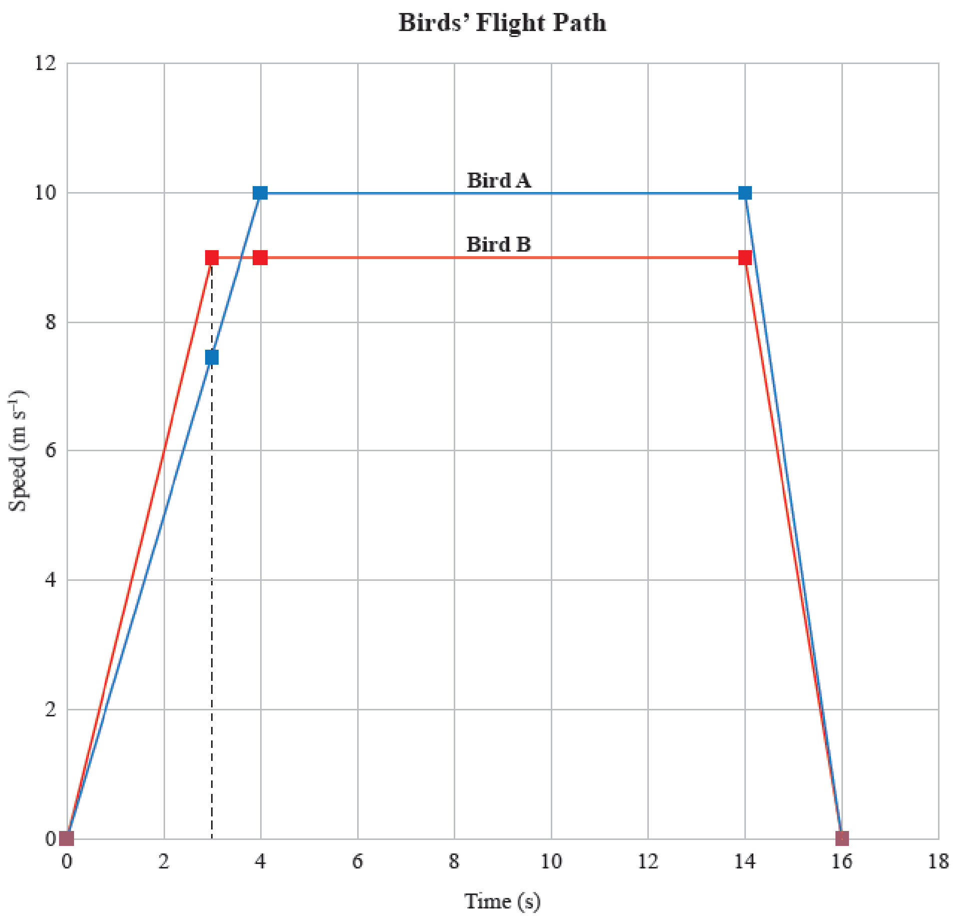
$$a_{ave} = \Delta v / \Delta t$$

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

NCEA 2015 distance in a speed-time graph - the kereru

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.*

Excellence Question



Bird A travelled:

(A) 0 – 4 s:

(B) 4 – 14 s:

(C) 14 – 16 s:

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

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

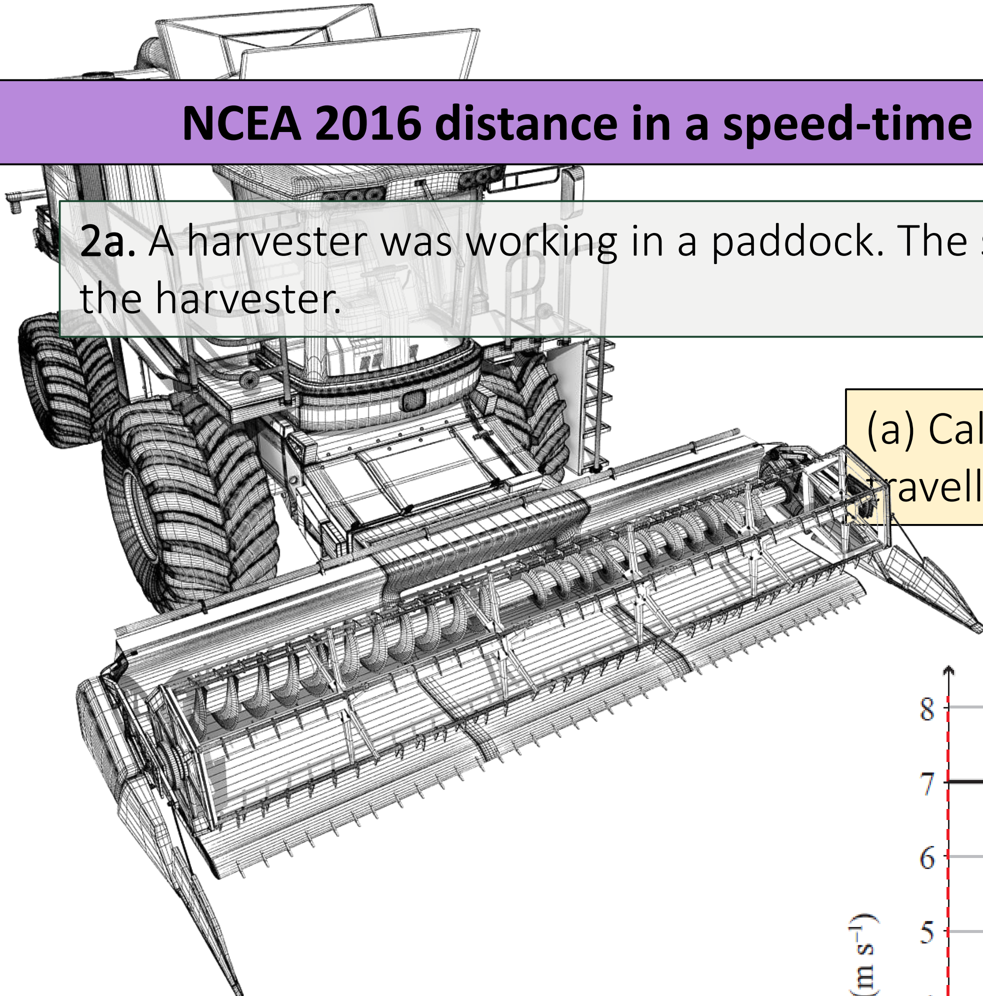
$$d = \frac{1}{2} \times 2 \times 10 = 10 \text{ m}$$

Total distance = 130 m

So Bird A has flown 8.50 m further.

(130 – 121.5 = 8.50 m)

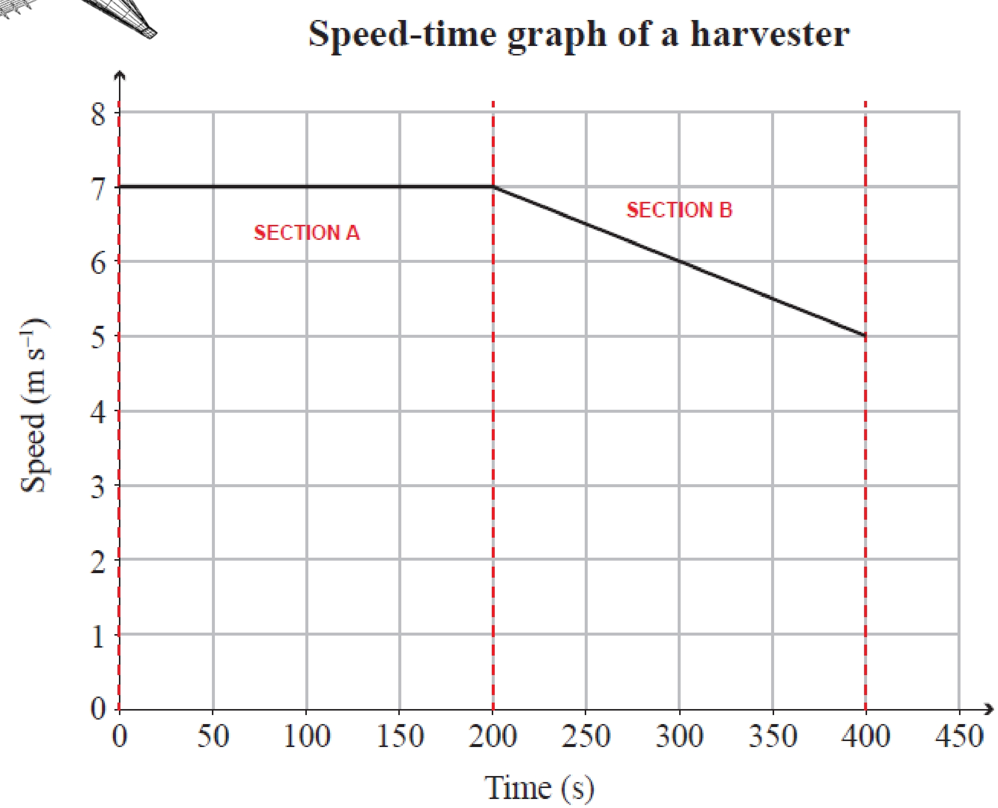
NCEA 2016 distance in a speed-time graph - The combine harvester



2a. A harvester was working in a paddock. The speed-time graph shows the journey of the harvester.

Merit Question

(a) Calculate the distance the harvester travelled in the first 200 seconds.

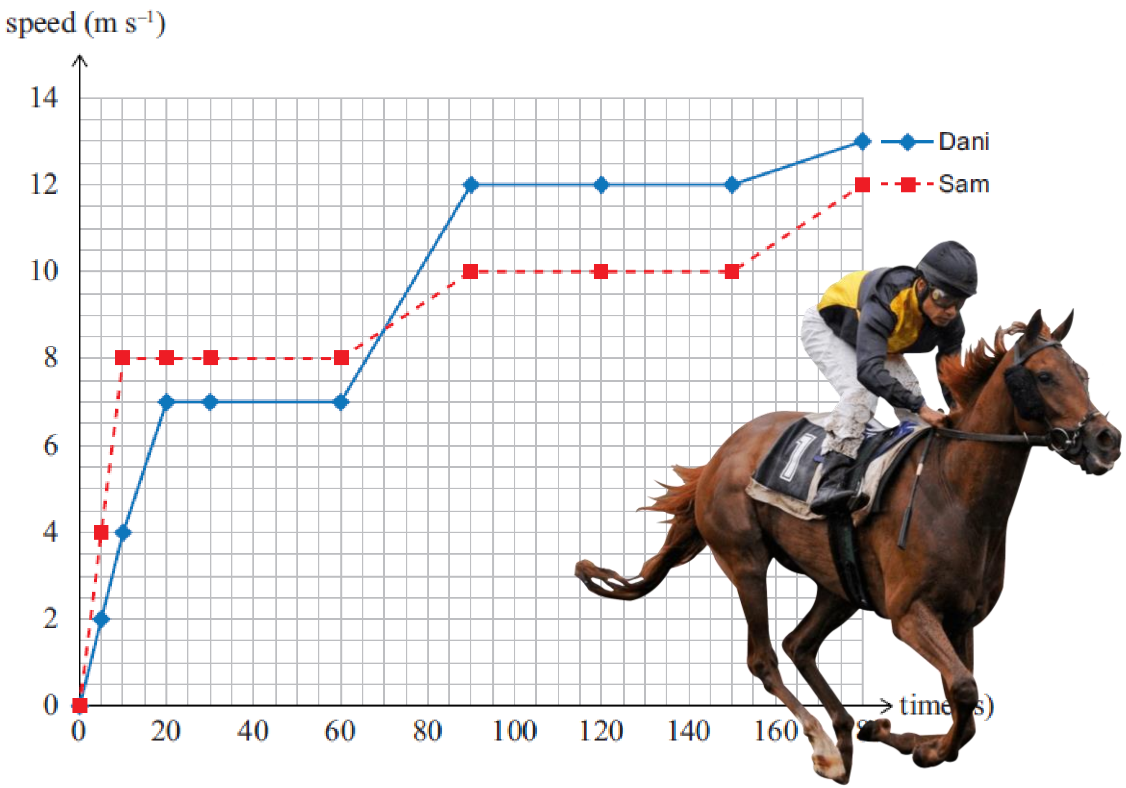


The harvester has travelled:
(section A) 0 – 200 s:
7(h) x 200(b) = 1400 m
Total distance = **1400m**

Excellence Question

NCEA 2017 distance in a speed-time graphs – horse racing

Question 1d: After 90 s, Sam and his horse had travelled 710 m.
How much further had they travelled compared to Dani and her horse at this stage in the race?
Use the information in the graph and any necessary calculations to answer.



Dani travelled:

(A) 0 – 20 s:
d = ½ x 7 x 20 = 70m

(B) 20 – 60 s:
d = 7 x 40 = 280m

(C) 60 – 90s:
d = 30 x 7 = 210m

(D) 60 – 90s:
d = ½ x 30 x 5 = 75m

Total distance = **635 m**

So Sam and his horse had travelled **75 m** more than Dani after 90s
(710 – 635 = 8.50 m)

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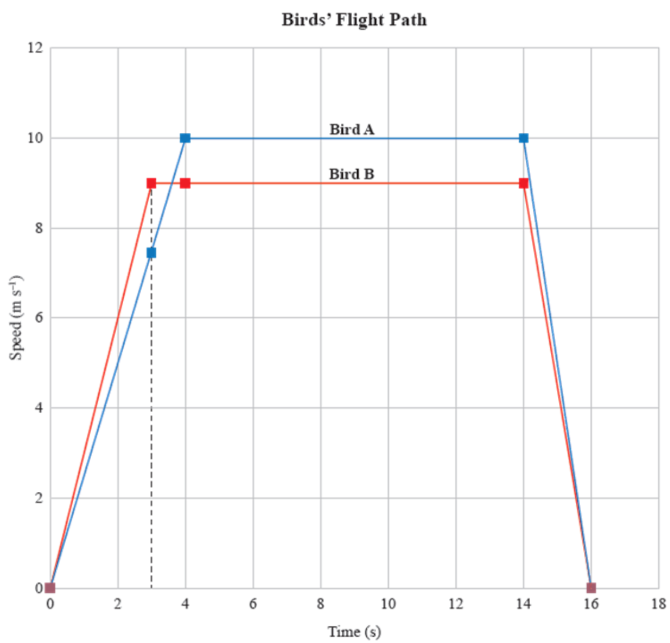
Distance from Speed/time graph

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.*



Remember:
Area for rectangle
Base x height

Remember:
Area for triangle
½ x Base x height

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.

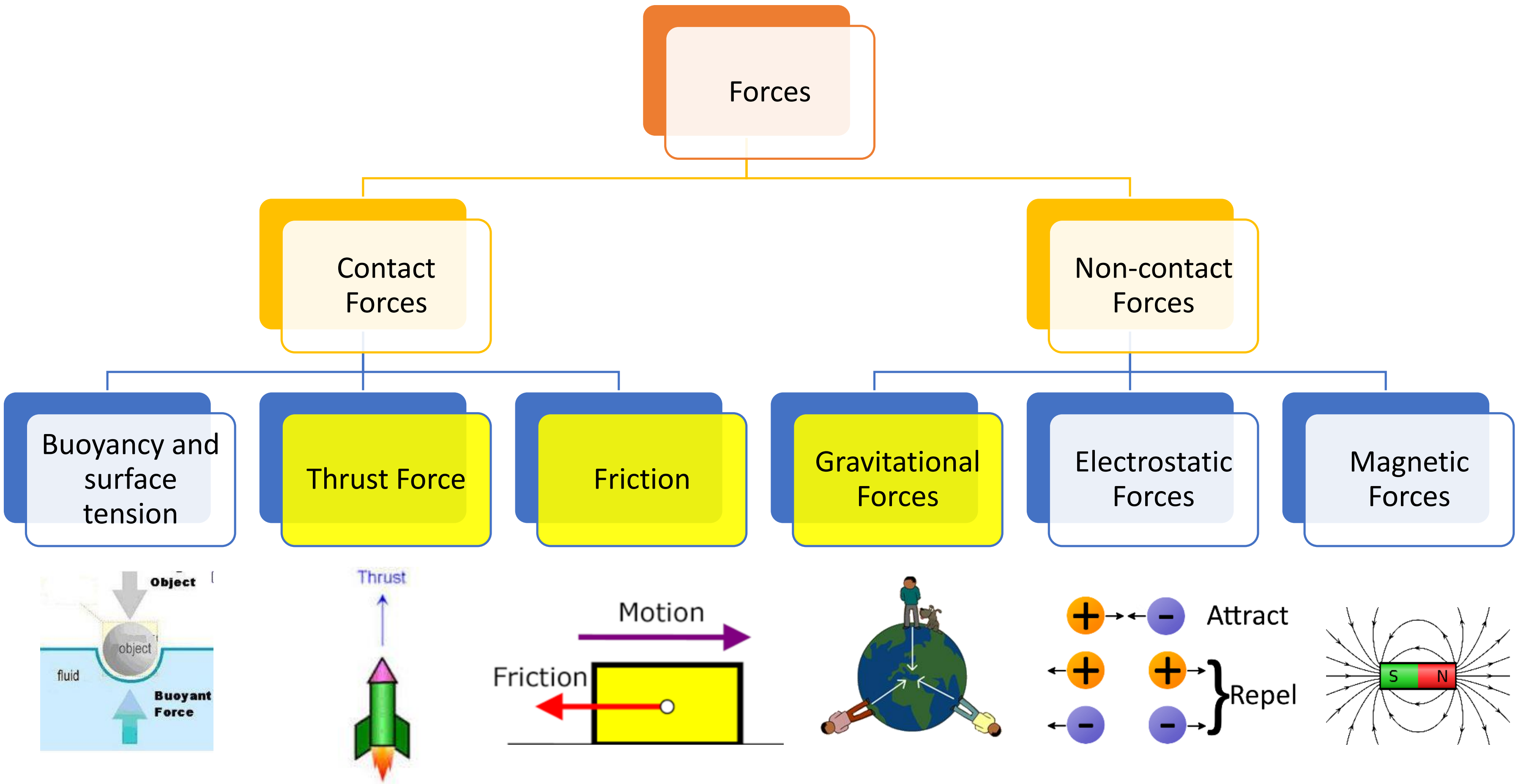
Forces change:

- 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.

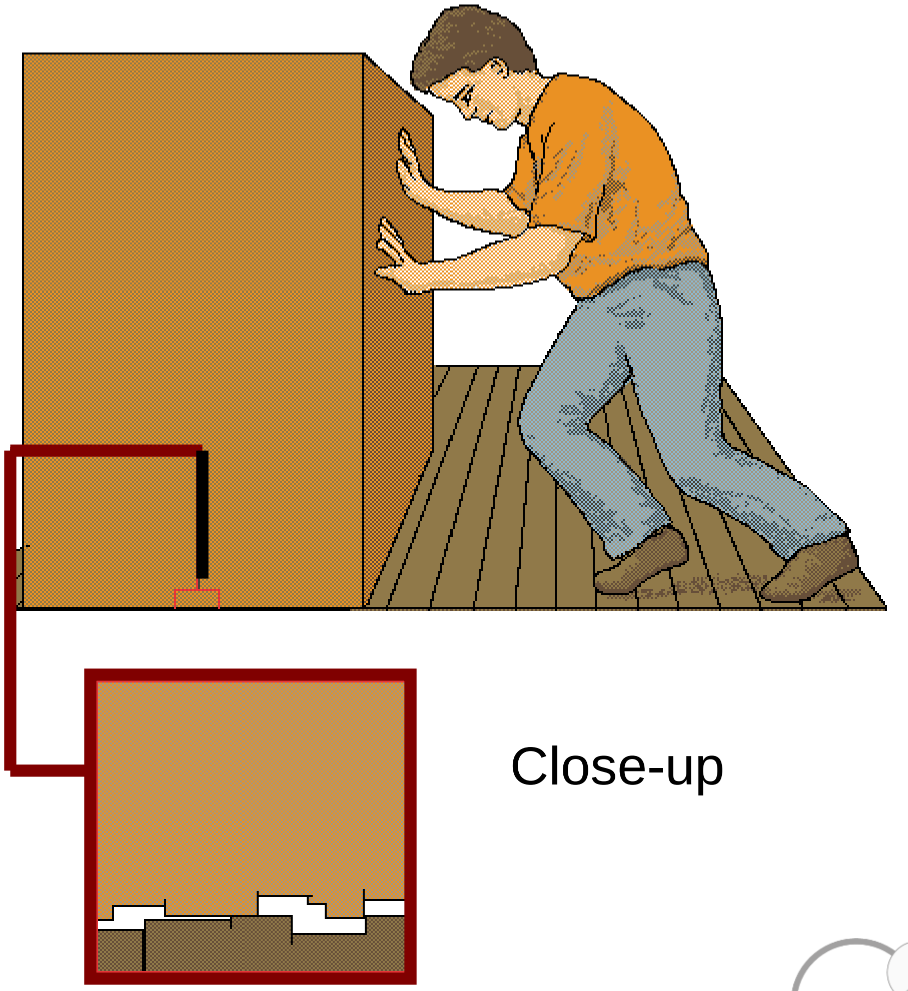
Thrust and friction are “paired forces” that act in opposite directions on an object

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

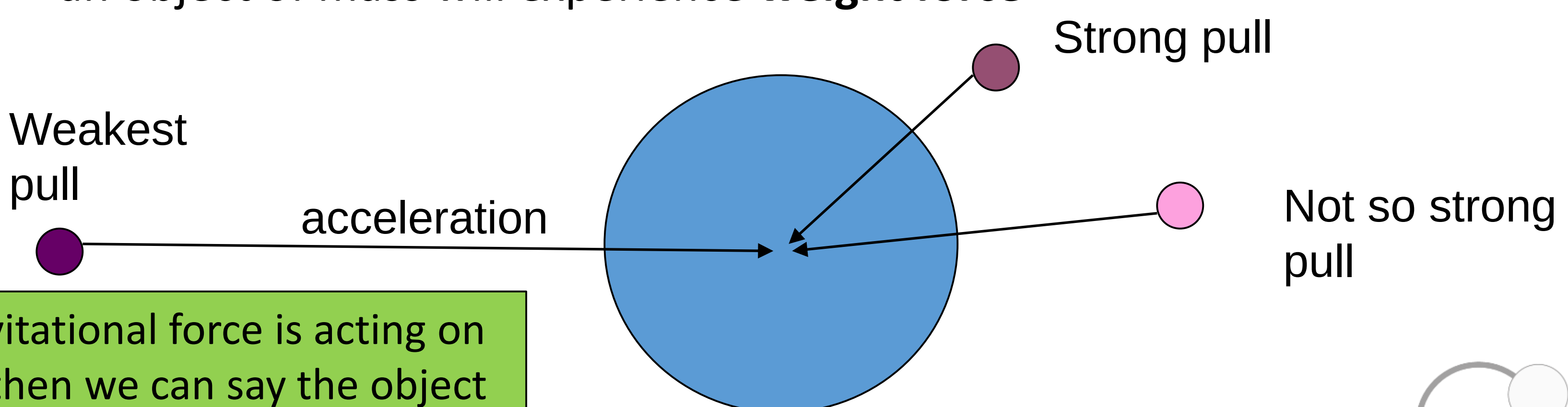
Objects create a gravitational field around them. Gravity gives objects of mass in the field a **weight force**. If the object is not in a gravitation field, it is “weightless”

- ❑ 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

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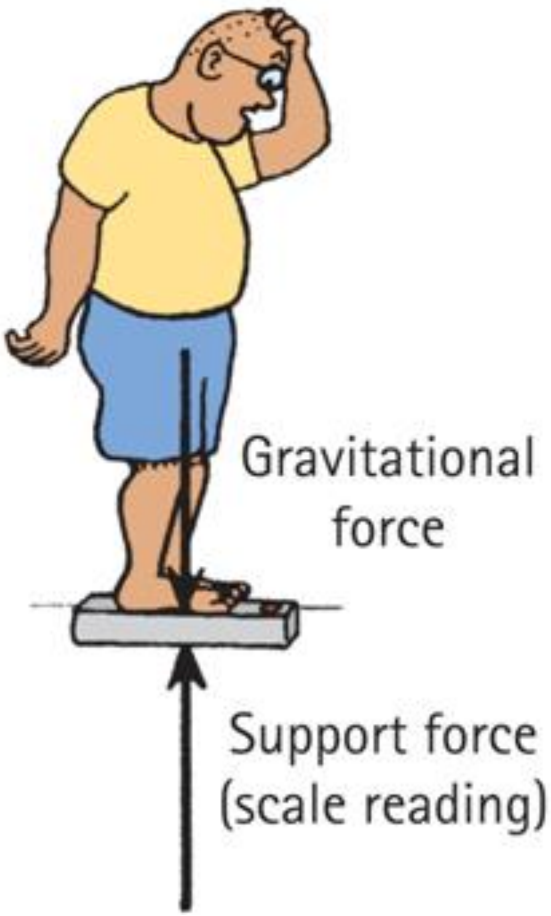
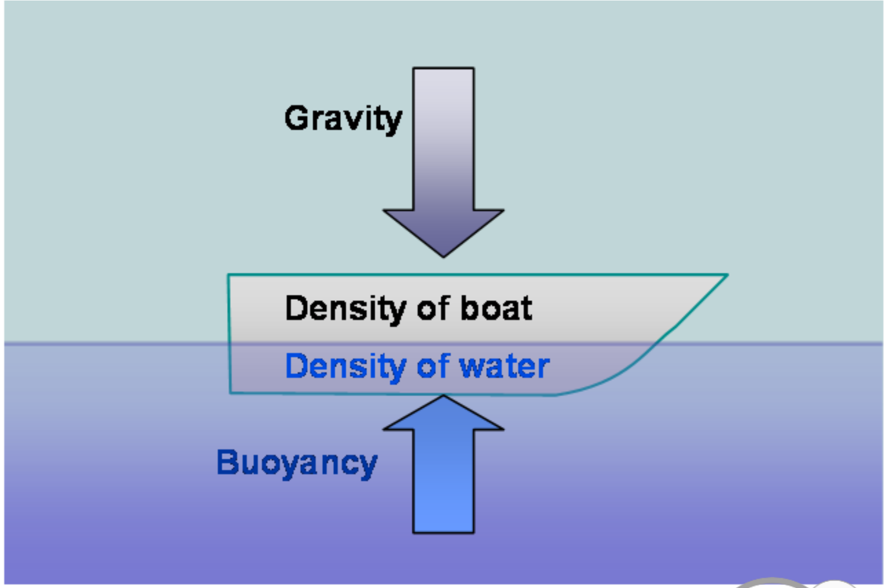
Support forces

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.**

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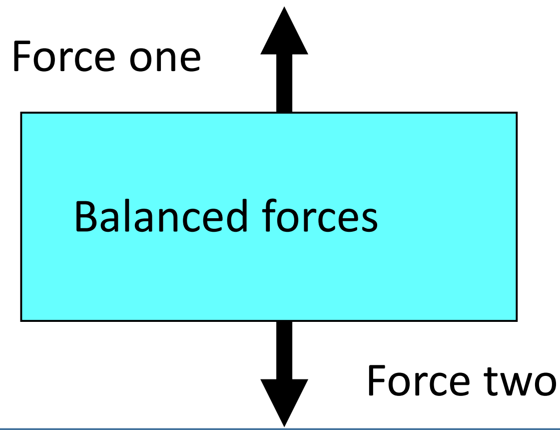
Newton's Laws

First Law

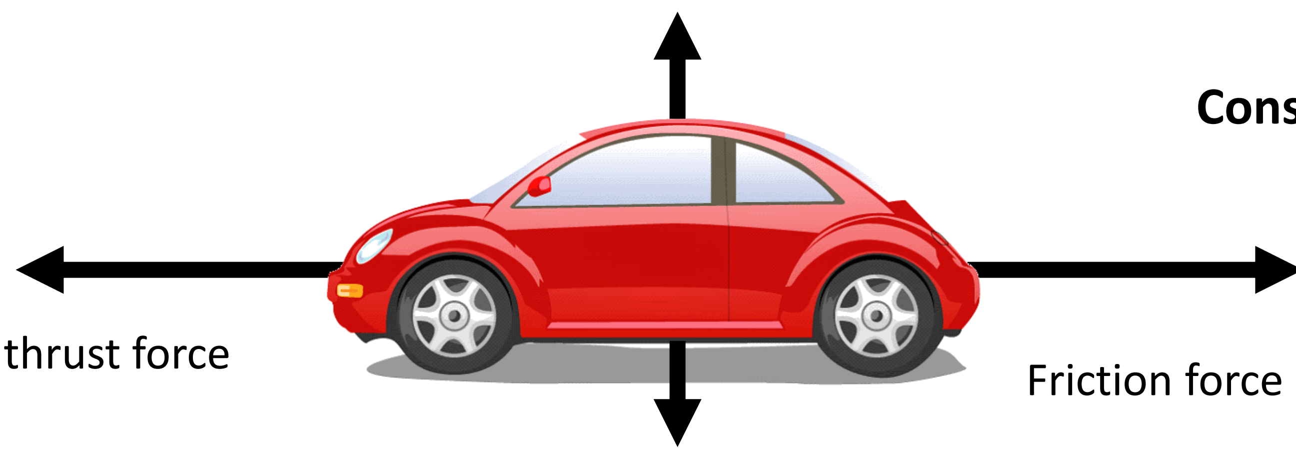
If the forces acting on an object are balanced, then the object will remain stationary or carry on at the same speed in the same direction.

Force diagrams show the magnitude and direct of each force

Stationary



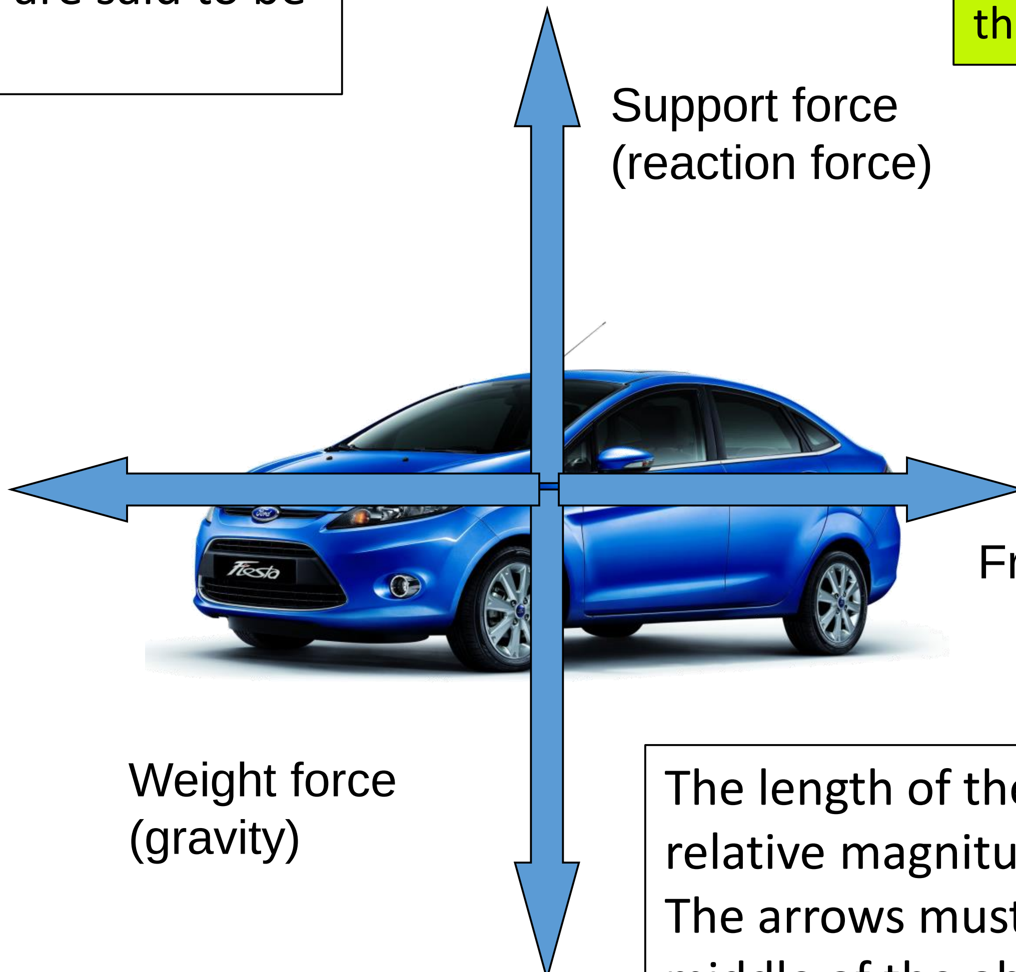
Constant speed



Force diagram showing balanced forces

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

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.

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

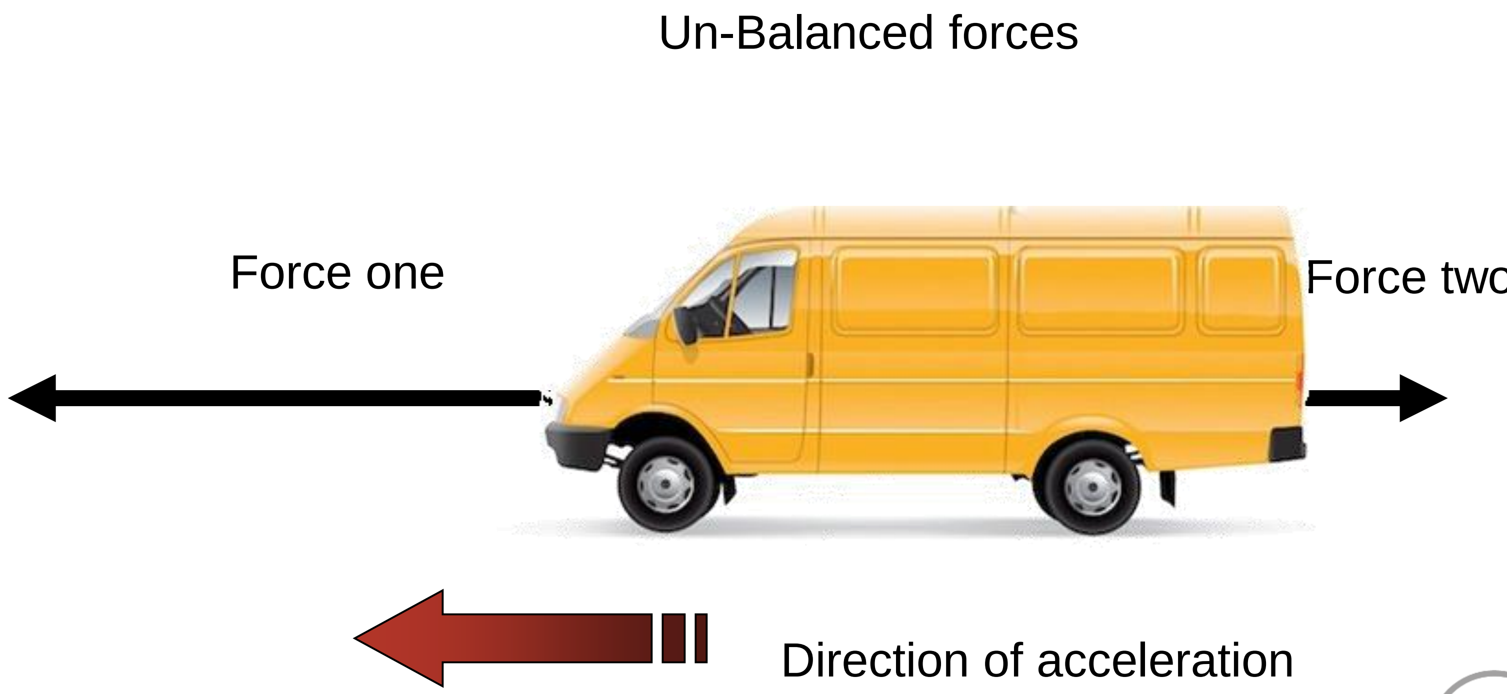
Did you know

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.

Second Law

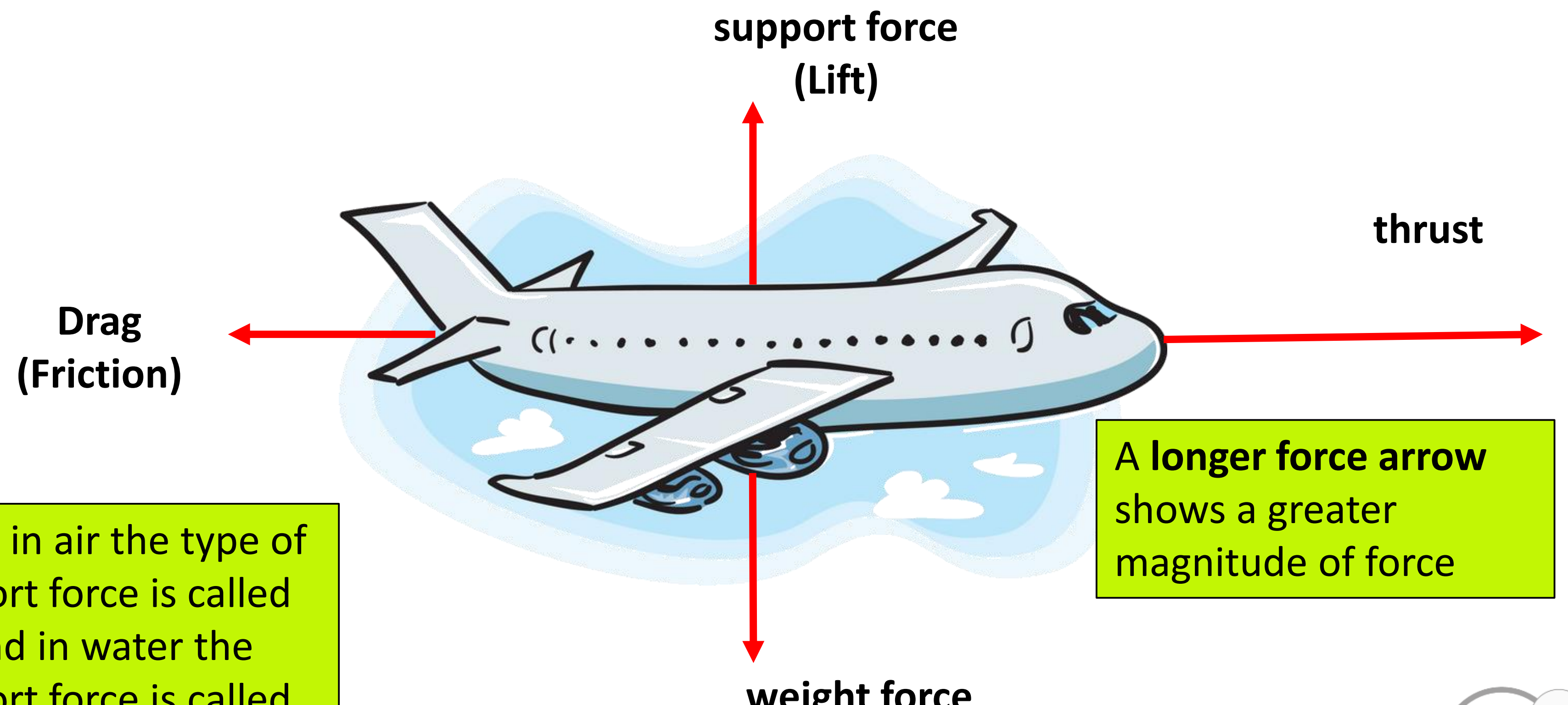
If unbalanced forces act on an object, then the object will accelerate in the direction that the net force acts.

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)



A **longer force arrow** shows a greater magnitude of force

Note: in air the type of support force is called **lift** and in water the support force is called **buoyancy**

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Net Force

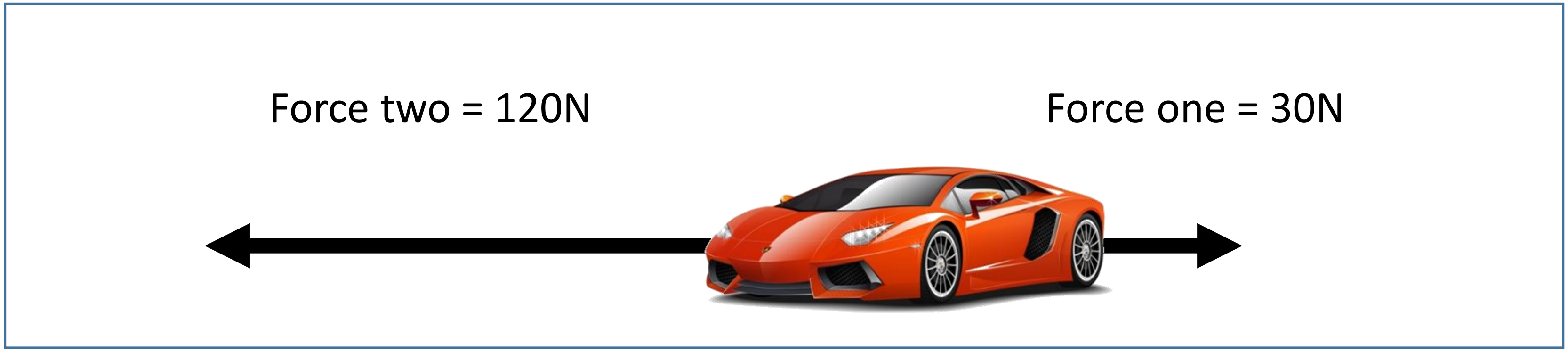
A net force is the resultant force when multiple forces interact. When forces are balanced on an object, the net force is **zero.** If there is zero net force, the object maintains **constant speed or is stationary.**

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.

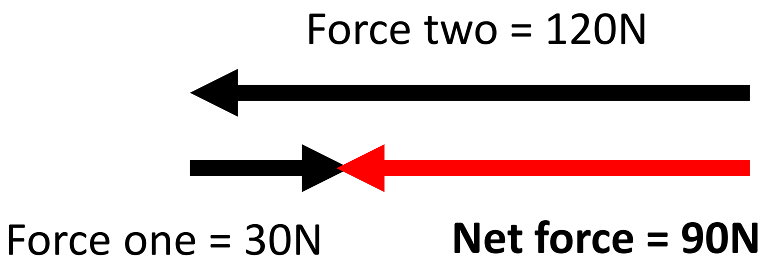
Calculating Net Force

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



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NCEA 2013 Force diagrams – The Runner

MERIT question

Q 1b: On the diagrams below, draw and label the thrust and friction forces acting on the runner in sections A, B, and C. (see below)
In your answer you should:
- use arrows to show the directions of the thrust and friction forces
- beside each diagram, state if thrust is greater than friction, thrust is equal to friction,

or

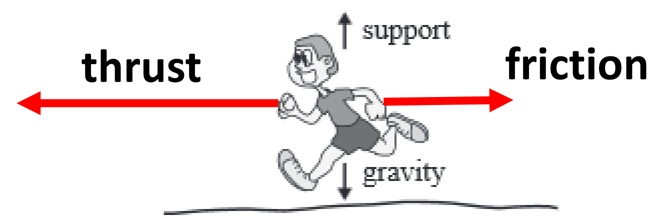
if thrust is less than friction.

The gravity and support forces have been done for you

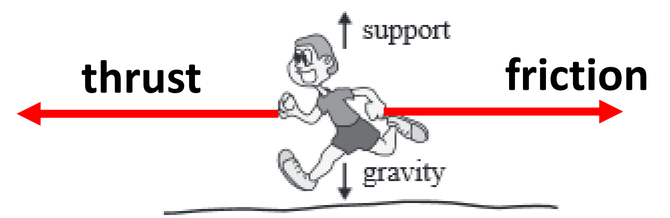
Section A: Accelerating
Section B: Constant speed
Section C: Decelerating

From previous question

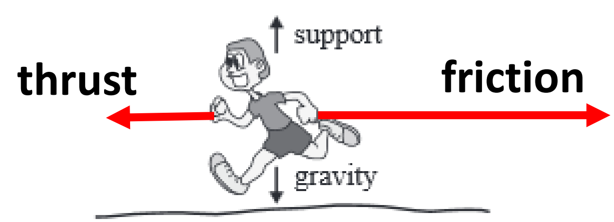
Section A



Section B



Section C



NCEA 2013 Net Force - The Runner

Excellence question

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.

A: 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 a zero 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.

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.

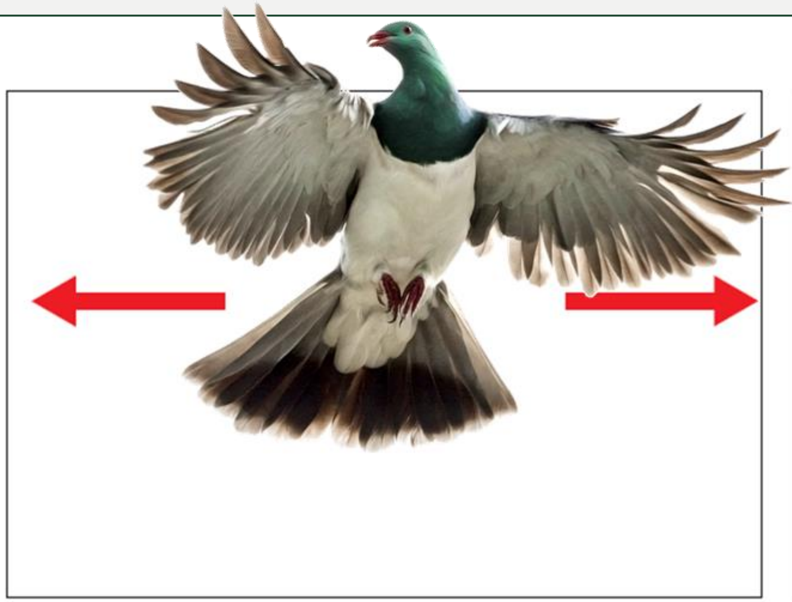
Section B:
The runner has constant speed. This is because there is no overall net force. This occurs when the thrust force is equal to friction.

Section C:
The runner is decelerating. This is because there is a net force pointing in the opposite direction to the motion.

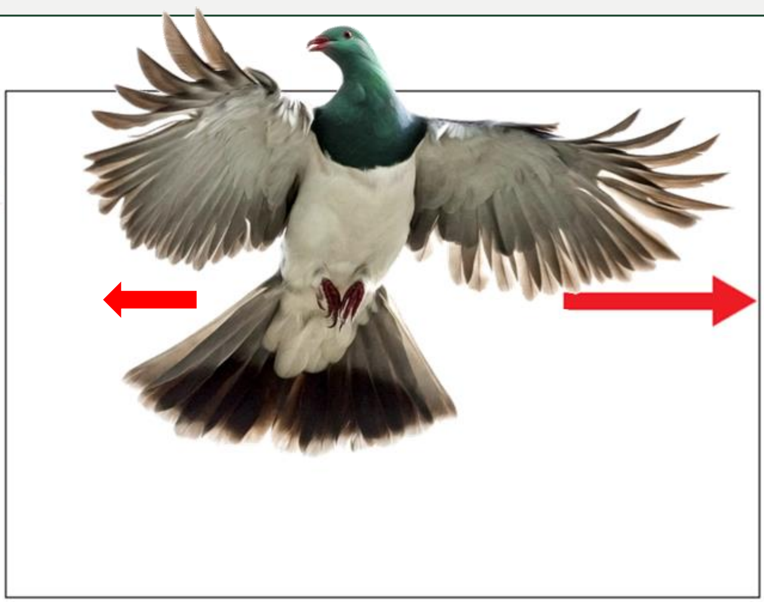
NCEA 2015 Force diagrams – the kererū

Excellence Question

Question 2b: The force diagrams below show another kererū flying at a constant speed, but then slowing down. Only horizontal forces are shown in these diagrams. Assume any other forces are balanced.



Constant speed



Slowing down

Explanation of motion

Diagram A: The bird has constant speed, so the net (horizontal) force is zero.

Diagram B: The bird is slowing down, so is decelerating. An unbalanced force is required to make an object's speed change, therefore, as there is an unbalanced force, the speed will decrease, and the net (horizontal) force is in the opposite direction to the motion of the bird.

NCEA 2015 the kererū - the kererū

Question 2c: Referring to the force diagrams of the kererū, explain the link between the horizontal net force acting on the bird, and the type of motion produced.
In your answer you should:
• describe what is meant by net force
• explain the link between the horizontal net force and motion for each situation described
• compare the direction of the horizontal net force and the direction of the motion for the bird in each diagram.

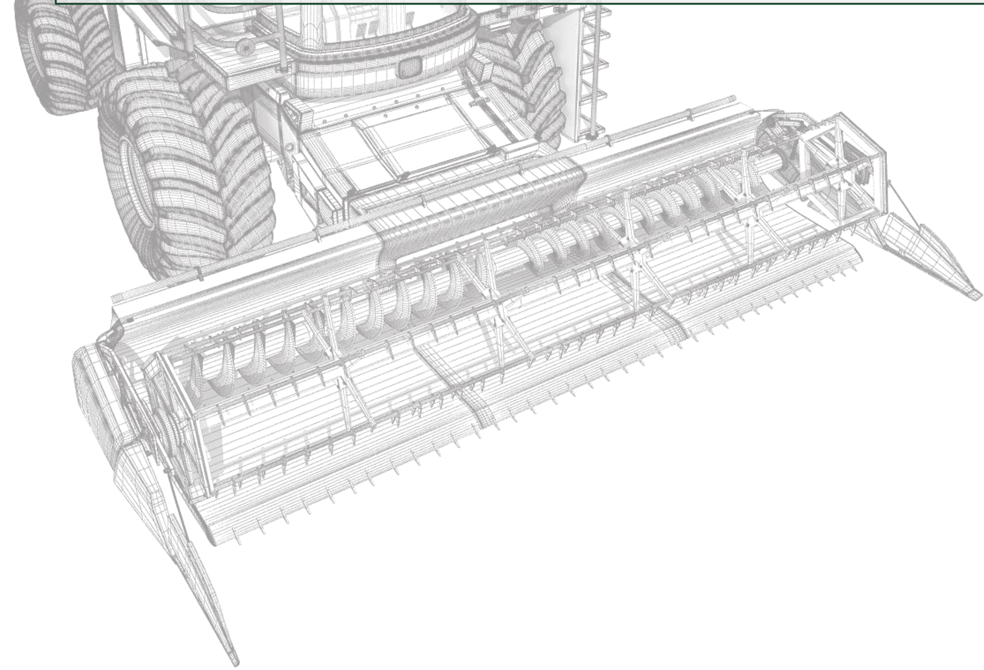
Net Force:
A **net force is the resultant** (overall/total/sum of) **force** on an object (when multiple forces interact). If the forces are pointing in the **same direction**, the **forces add**, giving a larger net force. If the forces are in **opposite direction**, the **forces subtract**, giving a smaller net force (including a zero net force).
Net forces determine whether the bird 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 bird decelerates. If there is **no net force**, the bird maintains **constant speed or is stationary.**

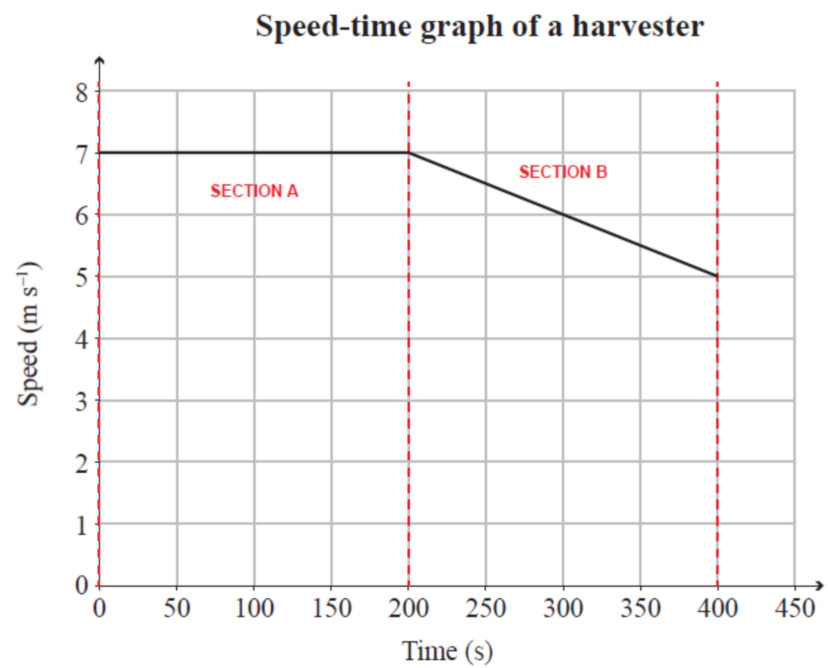
Excellence Question

NCEA 2016 Net Force - The combine harvester

Merit Question

2 (b) Explain how the **forces** acting on the harvester result in the motion shown in the graph (no calculations are needed). Include reference to the **net force**.





Section A: Constant speed. The thrust force is equal to the friction force. The Net force is 0 N and the forces are balanced.

Section B: Decelerating (accelerating). The friction force is greater than the thrust force. The Net force is not 0 N and the forces are unbalanced.

NCEA 2017 Net Force – The Crane

Excellence Question

Question 3c: Referring to the force diagram below, explain the link between the vertical net force acting on the container, and the type of motion produced, while the container is **being lowered**.

In your answer, you should:

- describe what is meant by net force
- explain the link between the direction of the vertical net force and motion.

Force diagram

<u>A net force is the resultant force when multiple forces interact</u>. 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 forces determine whether the container 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.

The container is accelerating towards the ground . An unbalanced force is required to make an object's speed change, therefore, as there is an unbalanced force, the speed will increase, and the net (vertical) force is in the same direction as the motion of the container.

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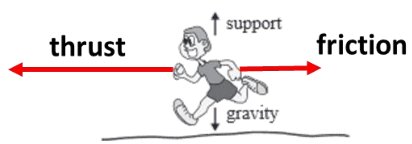
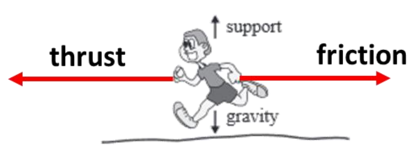
Net Force

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.

Section A

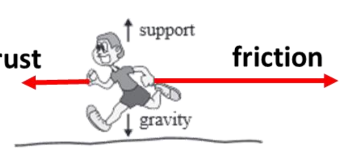


Section B



Section C

From previous question



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

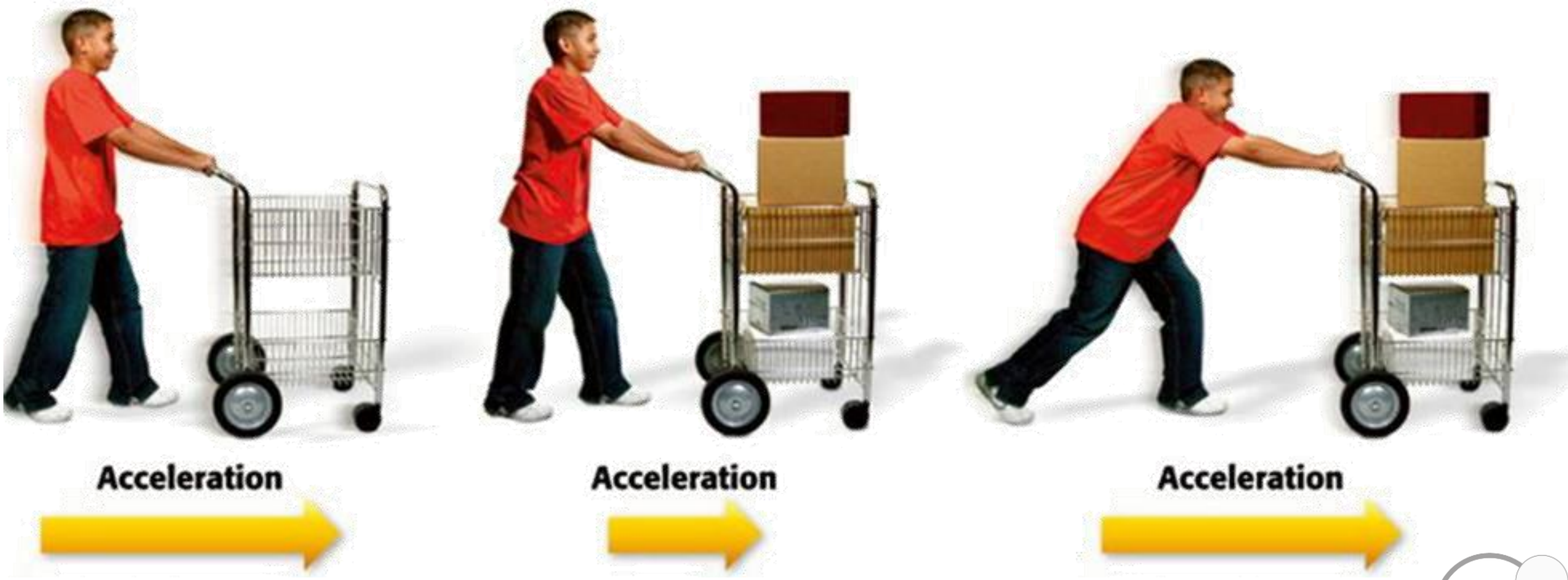
$$F=ma$$

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

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.



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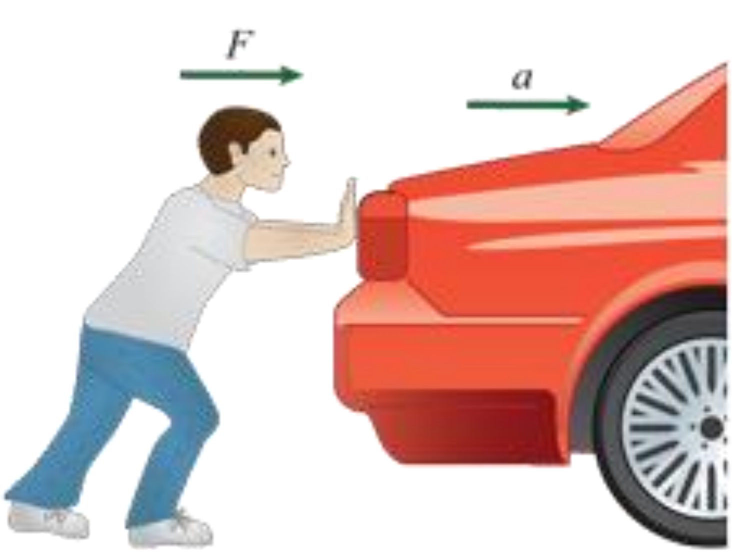
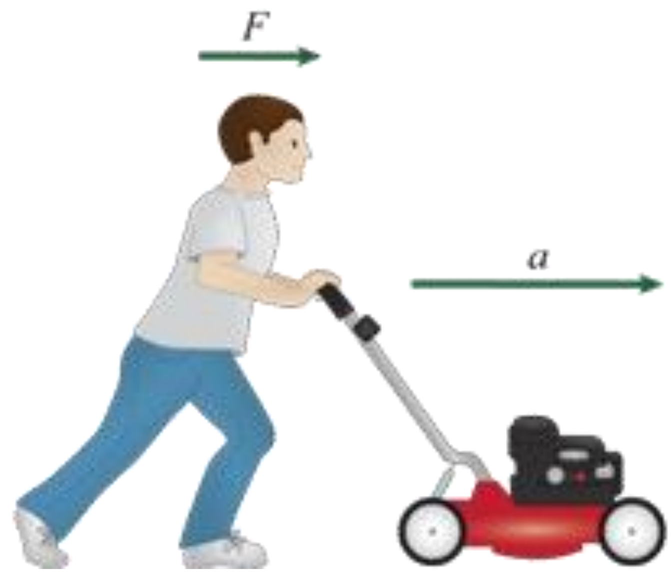
F = ma calculations





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?

F=ma

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

Car
F=ma
F=950kg x $0.5ms^{-2}$
F= 475N

lawn mower
F=ma
F=10kg x $0.5ms^{-2}$
F= 5N

GZ Science Resources

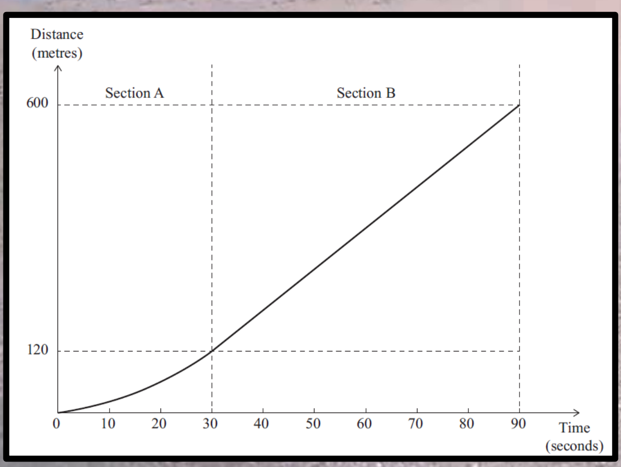
Excellence Question

The total mass of the tractor and driver is 1660 kg.
Calculate the **speed** of the tractor at the **end** of section A, and then calculate the **net force** acting on the tractor during **section A** of the graph.

Slope of section B = speed of tractor at end of section A = rise/run = 480 / 60 = 8 m s^{-1}

$a = \Delta v / \Delta t = (8 - 0) / 30 = 0.27$ m s^{-2}

$F = ma = 1660 \times 0.27 = 448.2$ N

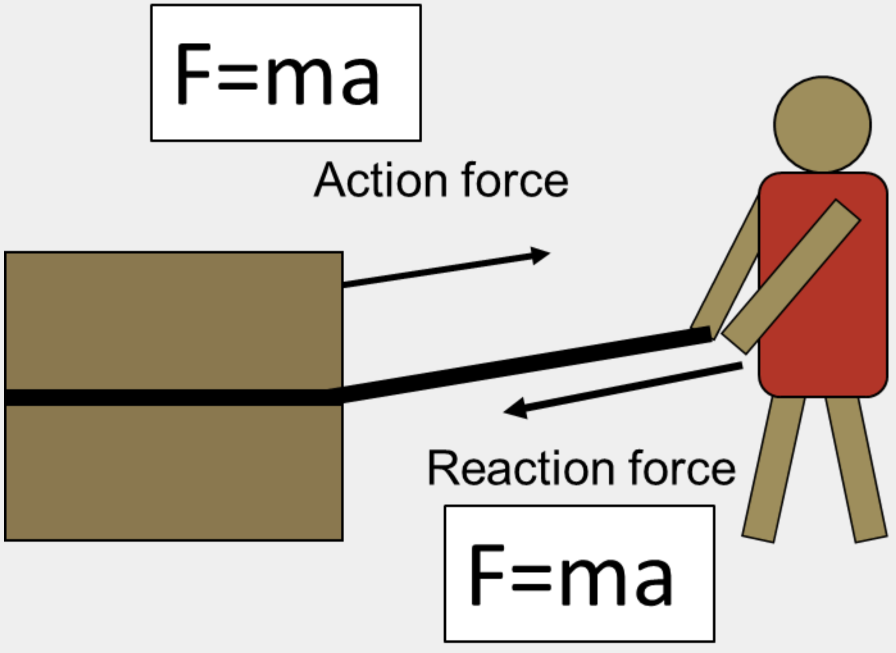


Background Knowledge

Newton's Laws

Third Law

When a force acts on an object, an equal and opposite reaction force occurs. This is called action-reaction.



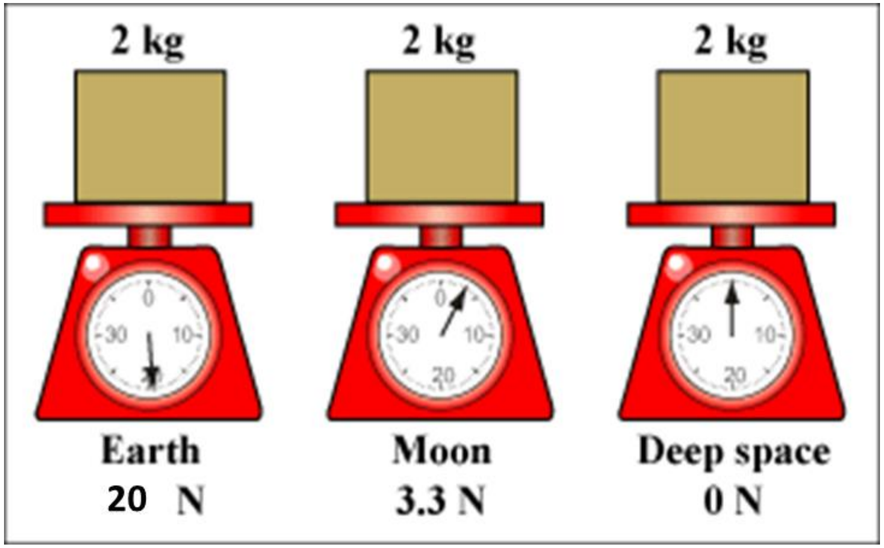
Mass and Weight

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 $\mathbf{F_w}$ (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)

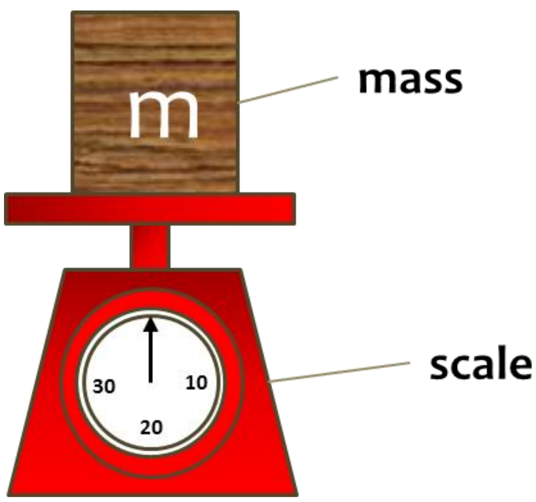
This is still the **F = ma** formula

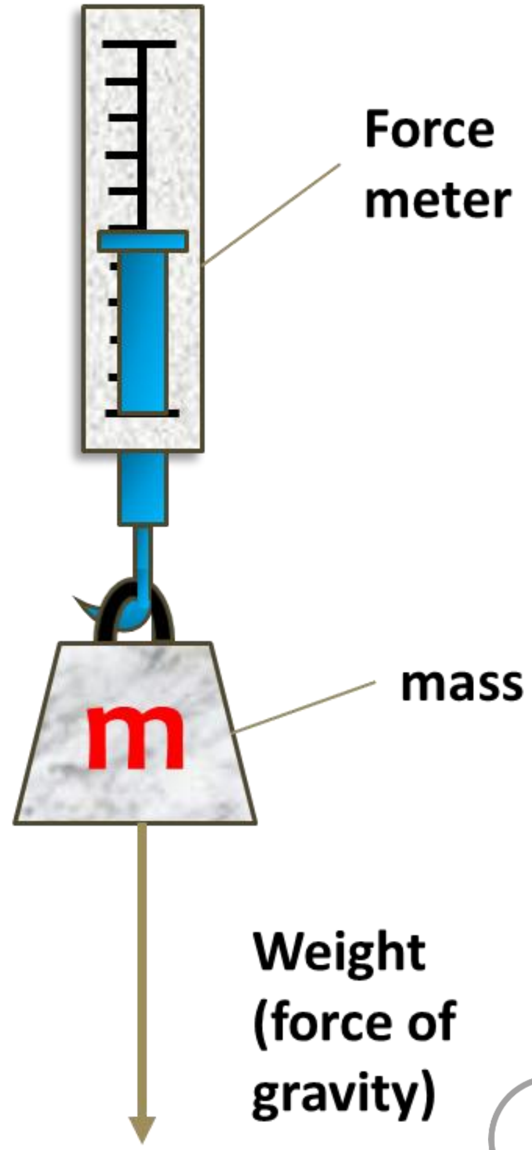
Measuring Mass and weight

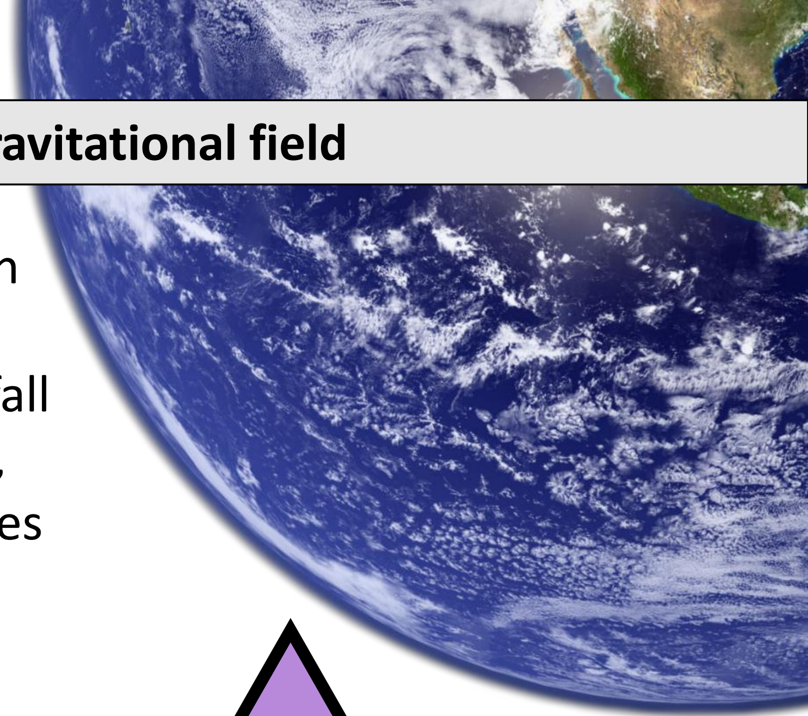
Weight can be measured with a spring balance, where the mass can vertically hang and the weight can be read off the force meter. The scale will be in Newtons (N).

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)





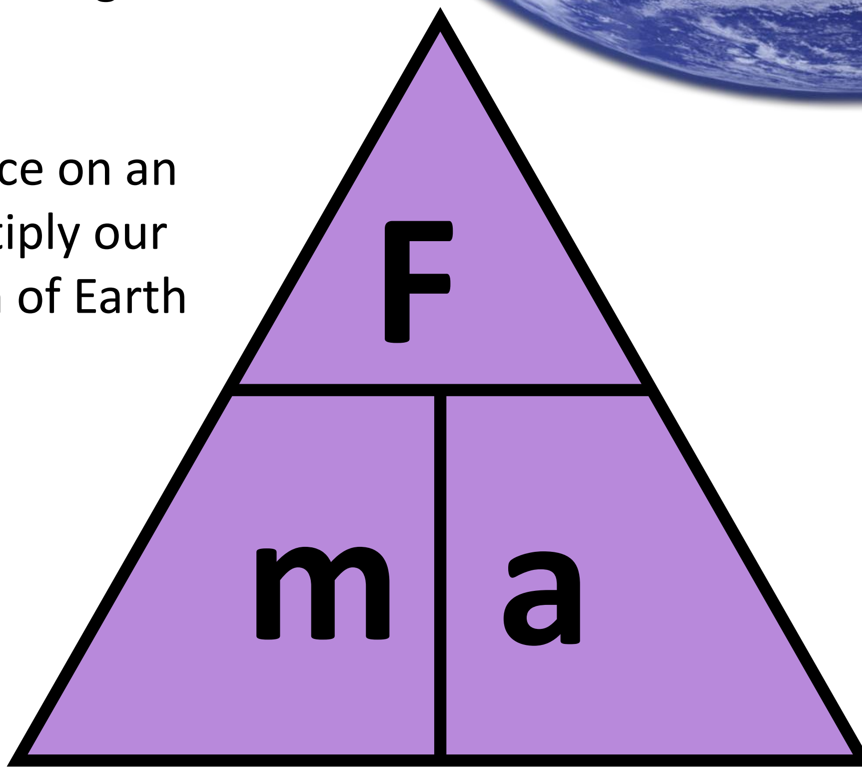


The Earth is the source of a gravitational field

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})

We use a g value of 10ms^{-2} at this level



GZ Science Resources

Background Knowledge

The Earth is the source of a gravitational field

Isaac Newton was also famous for his work on gravity. His law of **universal gravitation** states that objects with mass attract each other with a force that varies directly as the product of their masses and decreases as the distance between them increases.

This gravitation force causes objects to accelerate towards the centre of the Earth (remember F = m x a). Once they reach solid ground the **support force** prevents them falling any further. Because we also have mass the Earth feels a gravitational attraction and accelerates towards us but our mass is so tiny compared to the Earth and the effect is not noticed.

GZ Science Resources

NCEA Mass and Weight – the warehouse

Q1: A box in a warehouse has a mass of 2 500 kg. assuming $g=10ms^{-2}$
(a) Explain the difference between weight and mass.
(b) Calculate the weight of the box.

Weight is the downward force due to gravity that an object experiences, while mass is a measure of the amount of matter that an object has.

$$F_{\text{weight/gravity}} = mg$$

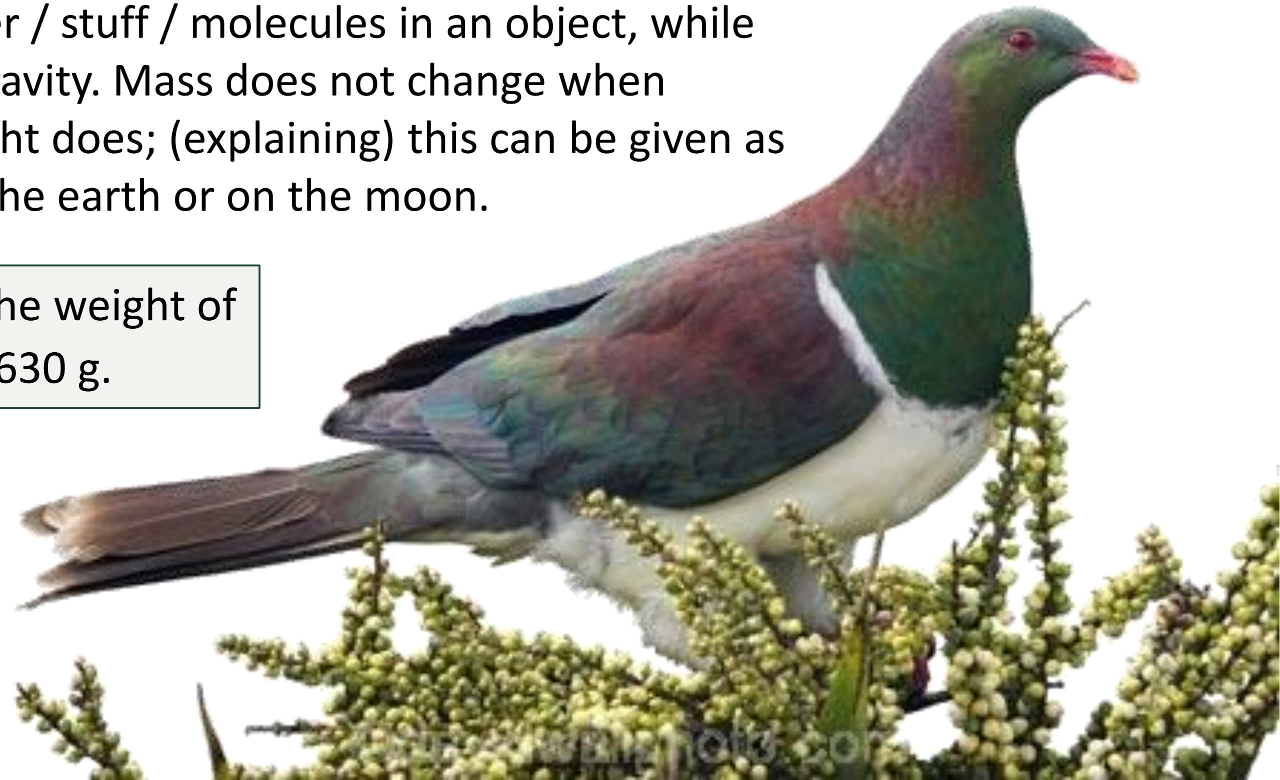
$= 2\,500 \times 10 = 25\,000$ N

NCEA 2015 Mass and Weight - The kererū

Merit Question

Question 2a(i) : The kererū (also known as New Zealand wood pigeon or kūkupa) is one of the largest pigeons in the world.
Explain the difference between mass and weight.

Answer 2a: Weight is the downward force due to gravity that an object experiences due to its mass, while mass is a measure of the amount of matter that an object has.
OR mass is amount of matter / stuff / molecules in an object, while weight is the force due to gravity. Mass does not change when location changes while weight does; (explaining) this can be given as an example of a person on the earth or on the moon.



Question 2a (ii): Calculate the weight of a kererū that has a mass of 630 g.

$$F_w = m \times g$$
$$= 0.630 \times 10$$
$$= 6.30 \text{ N}$$

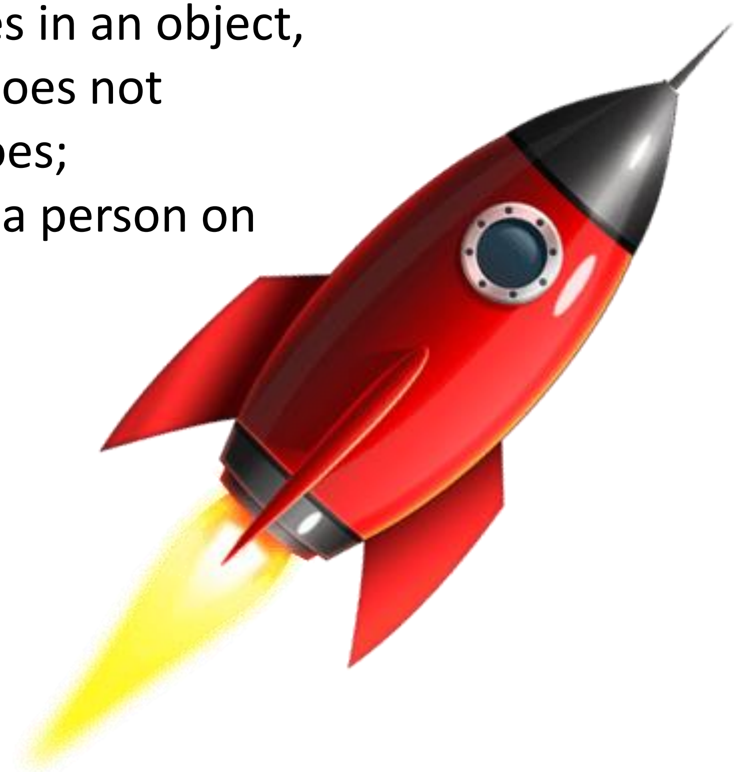
Merit Question

NCEA 2016 Mass and Weight - The Rocket

Merit Question

Question 3a: A small rocket has a mass of 2.60 kg and a weight of 26.0 N.
(a) Explain the difference between mass and weight.

Answer 3a: Weight is the downward force due to gravity that an object experiences due to its mass, while mass is a measure of the amount of matter that an object has.
OR mass is amount of matter / stuff / molecules in an object, while weight is the force due to gravity. Mass does not change when location changes while weight does; (explaining) this can be given as an example of a person on the earth or on the moon.



Merit Question

NCEA 2017 Mass and Weight – Waka Ama

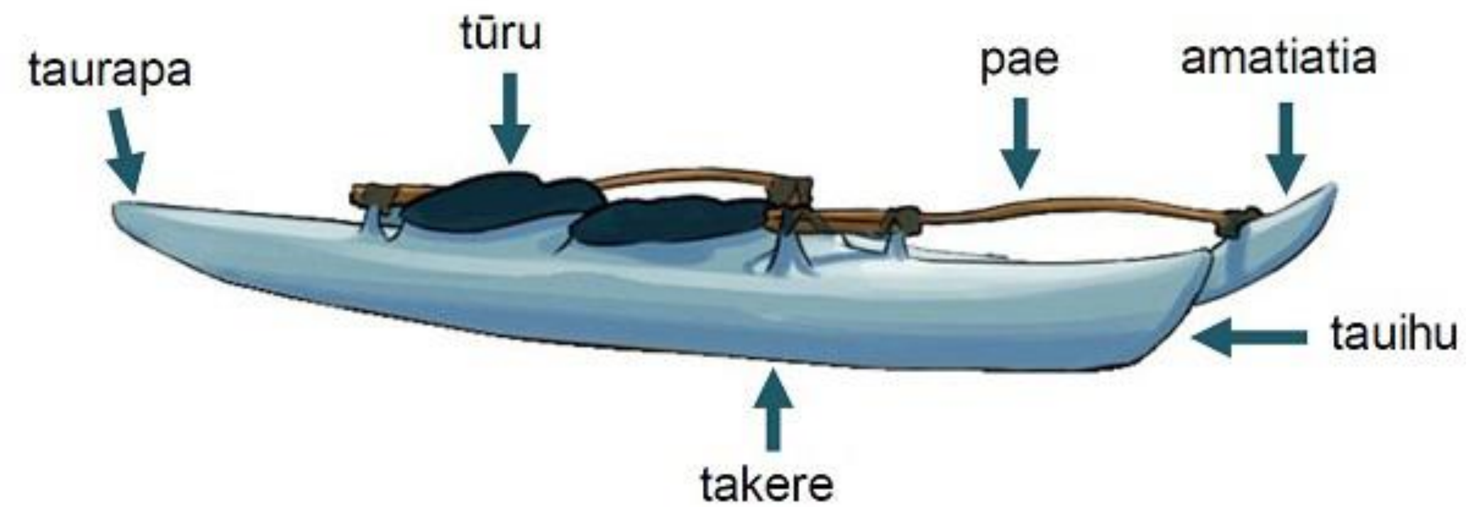
Question 2a: A lightweight waka ama (outrigger canoe) has a mass of 9.90 kg.
(a) What is the difference between **mass** and **weight**?
Use the waka ama as an example, and include a calculation for weight.

Weight is the downward force due to gravity that an object experiences due to its mass, while mass is a measure of the amount of matter that an object has.
(OR mass is amount of matter / stuff / molecules in an object, while weight is the force due to gravity) Mass does not change when location changes while weight does; this can be given as an example of a the waka ama that has a mass of 9.90kg but due to gravity (g = 10Nkg^{-1}) then the weight is

$F_w = m \times g$

$= 9.90 \times 10$

= 99.0 N



http://eng.keitemohiokoe.tki.org.nz/Overview-of-Physics/Canoes-2

Mass and Weight

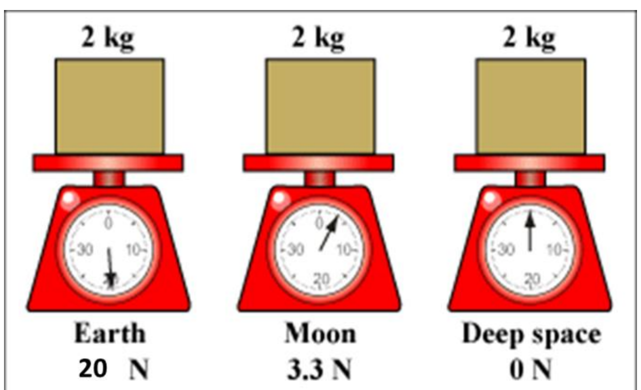
Question 2a(i) : The kererū (also known as New Zealand wood pigeon or kūkupa) is one of the largest pigeons in the world.
Explain the difference between mass and weight. Calculate the weight of a kererū that has a mass of 630 g.

Converting mass to weight

$$F_w = mg$$

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

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



How do we answer this question?
Weight is the downward force due to gravity that an object experiences due to its mass, while mass is a measure of the amount of matter that an object has.

Define and Compare Mass with Weight

Mass does not change when location changes while weight does; (explaining) this can be given as an example of a person on the earth or on the moon.

Explain Mass does not change but weight can

Mass is measured in kg while weight is a force measured in N

$$F_w = m \times g$$
$$= 0.630 \times 10$$
$$= 6.30 \text{ N}$$

Show working and remember units

Units of Force, Motion and Energy in Science

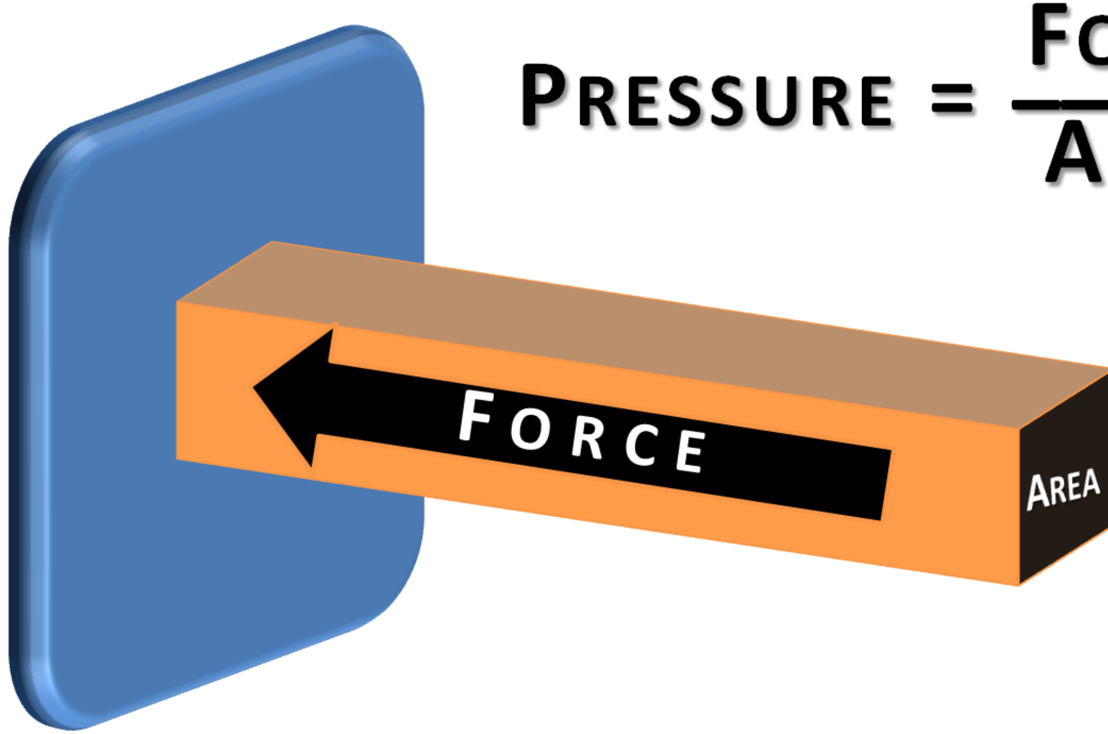
Quantity	Unit	Symbol	Equipment used
Force (weight)	Newton	N	Spring balance
Mass	Kilogram	kg	scales
Motion	Kilometres per hour (velocity)	khr^{-1}	odometer
	Metres per second (velocity)	ms^{-1}	Ticker timer
	Metres per second per second (acceleration)	ms^{-2}	Ticker timer
Energy (work)	Joule	J	
Power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

Remember:
These two units are shown as capitals

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.

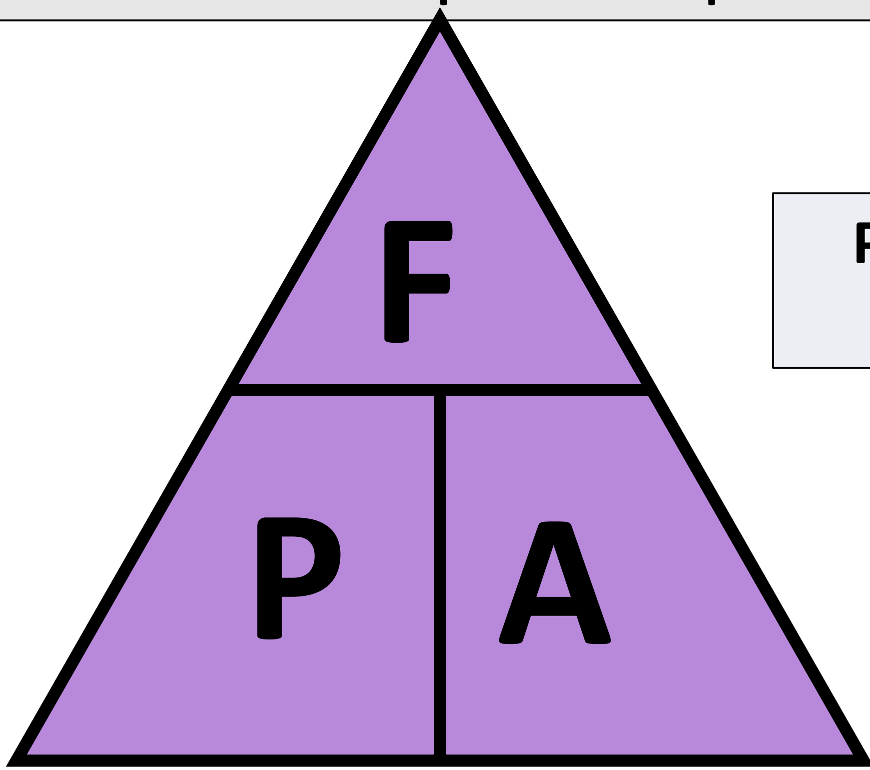
$$\text{Pressure} = \frac{\text{Force}}{\text{Area}}$$



$$P=F/A$$

P = pressure(Nm^{-2})
F = force (N)
a = surface area (m^2)

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



Pressure = Force / Surface Area

P= F/A

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

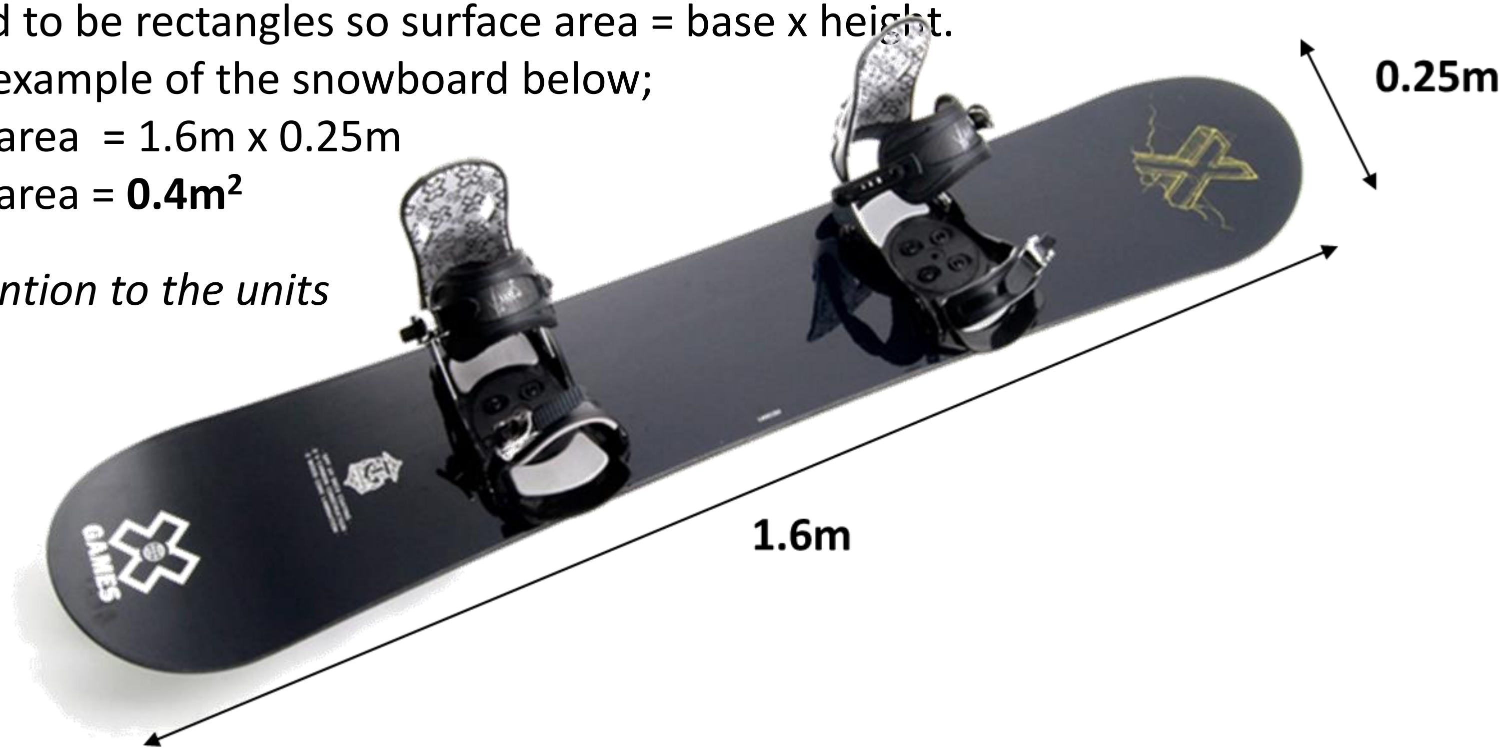
Surface Area is given in m^2. Sometimes this area must be calculated first. Objects are assumed to be rectangles so surface area = base x height.

For the example of the snowboard below;

Surface area = 1.6m x 0.25m

Surface area = **0.4m²**

Pay attention to the units



Because the value of P is in N m^{-2}, the surface area must be in **m^2**, not cm^2. If the base and height measurements are given in cm then to change cm to m, divide by 100;
If the surface area is given in cm^2 then to change cm^2 to m^2, divide by 100^2 (10 000)

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

NCEA Pressure – Chairs and footstools

Q 1: The chair (15.0 kg) has four legs in contact with the floor, whereas the base of the footstool (15.0 kg) does not have legs and is entirely in contact with the floor. The area of each chair leg in contact with the floor is 0.001 m^2. Calculate the pressure that the chair (mass 15.0 kg) exerts on the carpet.

In your answer you must determine:

- the area of the chair legs in contact with the floor
- the weight force of the chair
- the pressure acting on the carpet.

Surface area of the chair legs:

$4 \times 0.001 = 0.004$ m^2

Weight of chair:

$Fw = m \times g = 15 \times 10 = 150$ N

Pressure exerted:

$P = F/A = 150 / 0.004 = 37\,500$ Pa (Nm^{-2})

Area must be in m^2

Q 2: A person sat on the chair and then sat on the footstool for the same period of time. They noticed that the chair legs left deeper marks in the carpet than the footstool did, although both the chair and footstool have the same mass.

Explain these differences in terms of pressure, force, and surface area.

The footstool has a **much larger surface area** in contact with the floor than the chair.

The **force applied to both** the chair and the footstool **are the same** because the same person sits on both.

P = *F* / *A*, so **if *Area* is bigger then the pressure must be smaller** (or vice versa).

Include formula in explanation

NCEA 2012 Pressure - Car and Tractor tyres

Excellence Question

While on the sandy beach the woman sees a car (*m* = 1100 kg) that is stuck in the sand.
The photos below show the tread patterns of the tractor's rear tyre and the car's rear tyre.

tractor tread

car tread

The car's tread pattern has a greater surface area in contact with the ground than the tractor.

The car's weight force (*F* = *mg*) will be less than the tractor's.

Since *P* = *F*/*A*, a smaller force divided by a larger surface area will lead to less pressure exerted on the ground than the tractor. Whereas the tractor having a larger force divided by a smaller area will apply far more pressure on the ground causing it to sink more.

On the beach grip / traction is achieved by sinking into the sand.

As the car applies a smaller amount of pressure on the sand it will not sink in therefore giving it less grip / traction and as a result it gets stuck in sand.

NCEA 2013 Pressure – Snowboard and skis

Q 1: A family decides to spend a day at a snow field. The father hires a snowboard for himself and a pair of skis for his daughter. Assume the snowboard and skis are **rectangular** in shape.

The father and snowboard have a combined mass of 80 kg.

(a) Calculate the pressure exerted by the father and snowboard on the snow.

Your answer should include:

- an area calculation
- a calculation of the pressure.

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

Area $= b \times h = 0.25 \times 1.6 = 0.4$ m^2

$P = F / A = 800 / 0.4 = 2\,000$ Pa (Nm^{-2})

Don't forget units

NCEA 2013 Pressure– Snowboard and skis (part 2)

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.

Sinking depends on pressure – the greater the pressure, the further the person sinks.

$P = F/A$

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.

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'.

$P_{dad} = 800/0.4 = 2\ 000$ Pa

$F_{daughter} = 58 \times 10 = 580$ N $A_{daughter} = 2 \times 0.08 \times 1.75 = 0.28$ m^2

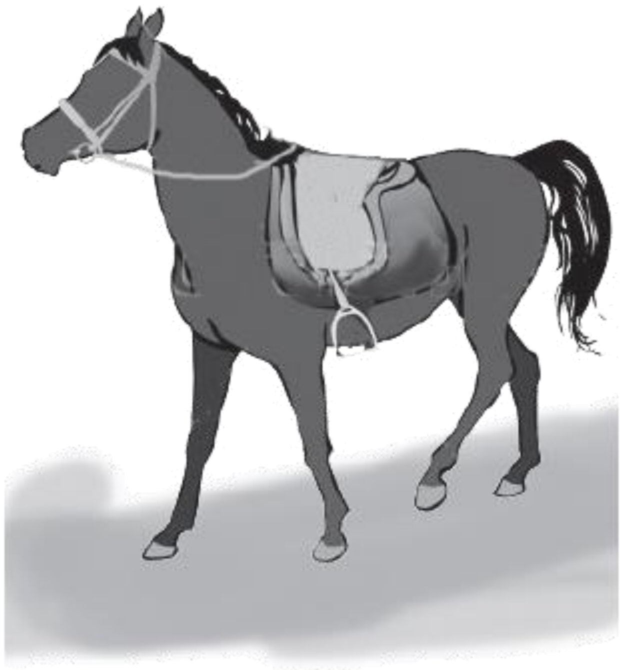
$P_{daughter} = F / A = 580 / 0.28 = 2071$ Pa

$P_{daughter} > P_{dad}$ so daughter sinks further into the snow.

Remember to double area if 2 feet or boots

NCEA 2016 Pressure - The Horse

Q1c Each of the horse's hooves has a surface area of 44 cm2 (0.0044 m2) and sinks into the sand when the horse stops. The hooves exert a pressure of 200155 Pa. Calculate the weight of the horse.



$F = P \times A$

$F = 200155\ \text{Pa} \times (0.0044 \times 4)$

$F = 200155\ \text{Pa} \times 0.0176\ \text{m}^2$

$\mathbf{F = 3522.7\ N}$

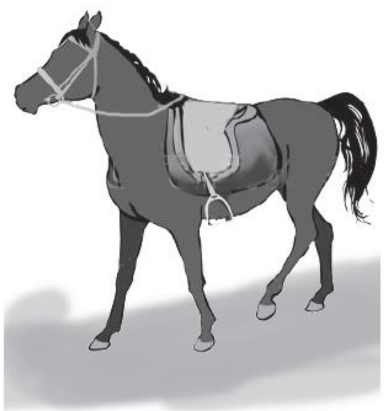
Force is the weight exerted by the horse

This question requires you to work backwards from pressure.
Calculate F (weight) by F = P x A and remember to multiply area by 4 hooves

NCEA 2016 Pressure - The Horse (part 2)

Excellence Question

1d. The rider walks beside the horse and then gets onto the horse. Explain why the horse's hooves sink further into the sand when the rider gets onto the horse.
In your answer you should consider the **pressure applied** and the **forces acting**.
(No calculations are necessary.)



As the horse by itself applies a smaller amount of weight (and therefore pressure) on the sand it will not sink in as deep.

The horse with or without the rider has the same surface area in contact with the ground.

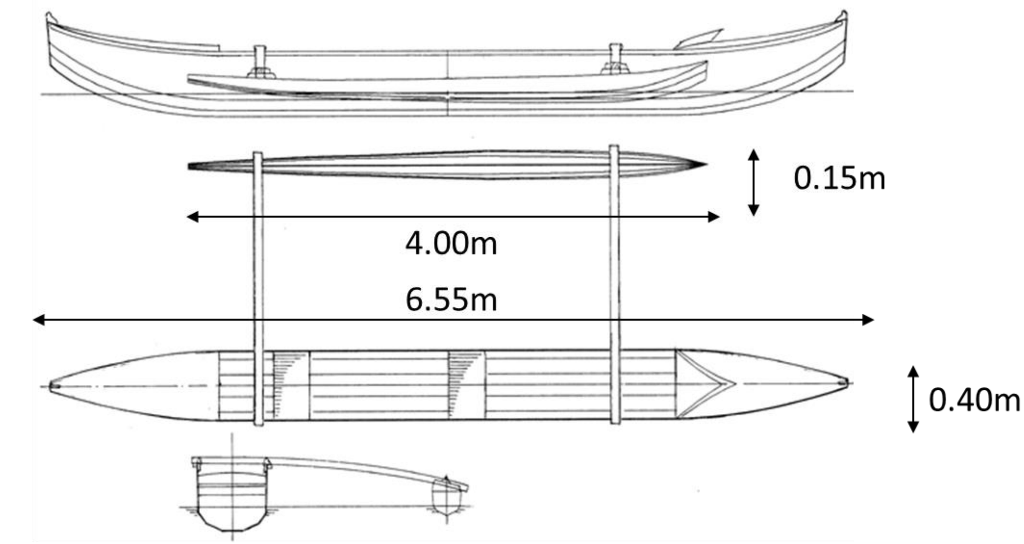
With the horse by itself, the weight force ($F = mg$) will be less than the horse with a rider.

Since $P = F/A$, a smaller force (horse only) divided by the surface area will lead to less pressure exerted on the ground than the horse with rider. Whereas the horse with rider having a larger force divided by the same surface area will apply far more pressure on the ground causing it to sink more.

NCEA 2017 Pressure – Waka Ama (part ONE)

Excellence Question

Question 2b: A sketch of the waka ama hulls is shown below right.
(b) Calculate the pressure exerted by the waka ama (both hulls) on the water.
Your answer should include:
- an area calculation (assume both waka ama hulls are rectangular in shape, and the measurements above show the area in contact with the water)
- a calculation of the pressure. (A lightweight waka ama has a mass of 9.90 kg.)



Surface area of the waka ama large hull:
6.55m × 0.40m = 2.62 m^2
Weight of waka ama hull :
$F_w = m \times g$ = 9.90 × 10 = 99.0 N
Pressure exerted of the waka ama (both) hull :
$P = F/A$ = 99.0 / 3.22 m^2
= 30.7 Pa (Nm^{-2})

Surface area of the waka ama small hull:
4.00m × 0.15m = 0.60 m^2
Total surface area of BOTH hulls:
=2.62 m^2 + 0.60 m^2 = 3.22 m^2

Excellence Question

NCEA 2017 Pressure – Waka Ama (Part TWO)

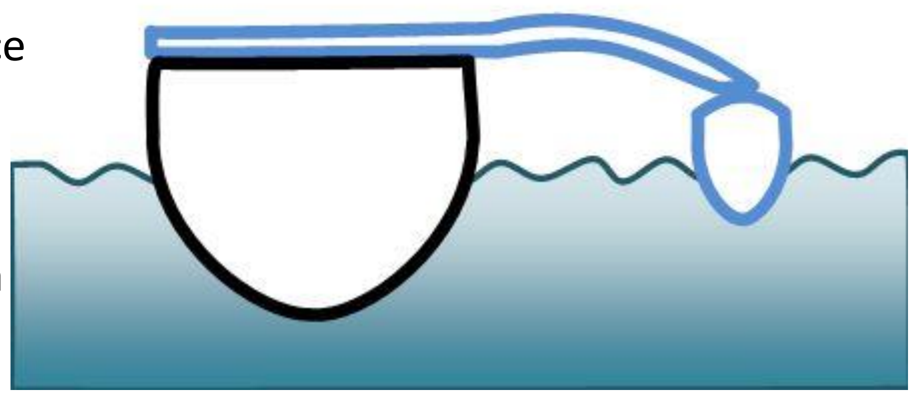
Question 2c: The waka ama sinks further into the water when a 67 kg paddler sits in it. Explain why the waka ama sinks further into the water when the paddler sits in it. Use calculations to support your answer.

Sinking depends on pressure – the greater the pressure, the further the waka ama sinks.
P = *F*/*A*
A 'heavier' waka ama (with the person in) will have more weight force than a 'lighter' person. The weight in total after will be Fw (total) = $m \times g$ = 76.9 × 10 = 769 N

$P = F/A = 769 / 3.22\ m^2 = 238.8(Nm^{-2})$

Sinking into the water depends on pressure – the greater the pressure, the further the waka ama sinks. *P* = *F*/*A*
A 'lighter' waka ama will have less weight force than a 'heavier' waka ama.
In this example, the waka ama has the same area but a greater weight
when the paddler is in the canoe, so the waka ama sinks deeper into the water because the pressure has increased.

Cross-section of a waka with a round hull



http://eng.keitemohiokoe.tki.org.nz/Overview-of-Physics/Canoes-2/Outrigger-canoes

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 = $b \times h = 0.25 \times 1.6 = 0.4$ m^2

$P = F / A = 800 / 0.4 = 2\,000$ Pa (Nm^{-2})

P=F/A

P = pressure(Nm^{-2})
F = force (N)
a = area (m^2)

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 m^2

$P_{daughter} = F / A = 580 / 0.28 = 2071$ Pa

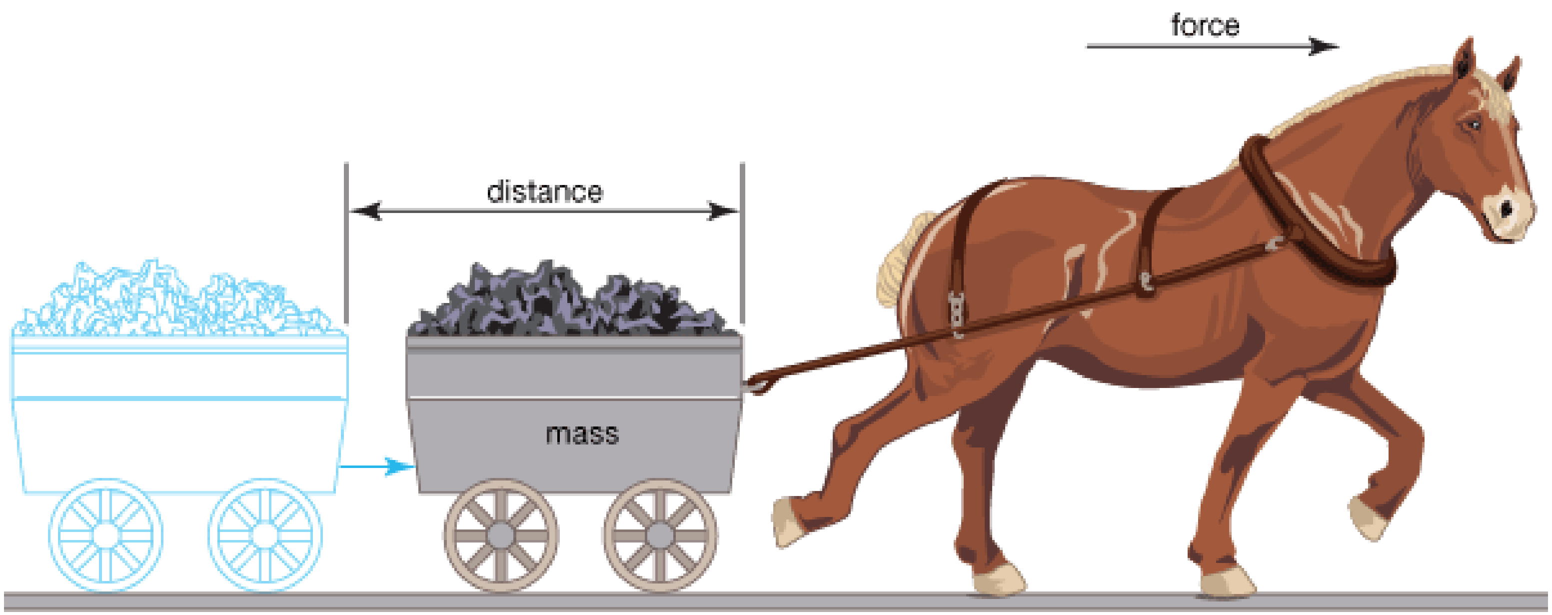
$P_{daughter} > P_{dad}$ so daughter sinks further into the snow.

Use calculations to back up statement

Work

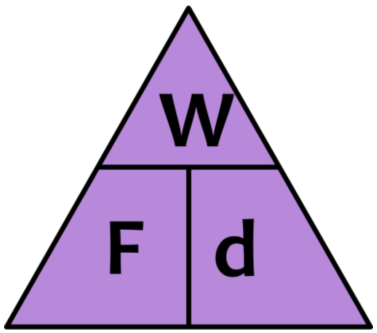
When a force is applied to an object of mass and moves it over a distance then **work** has been done. If an object does not move, no matter how much force is applied, then no work has been done.
Work is proportional to the force applied (weight force) and the distance travelled so *Work = Force* $\times$ *distance.* Work is needed to transfer energy.

*Work is measured in **joules**.*
To do 1 joule of work you need 1 joule of energy.

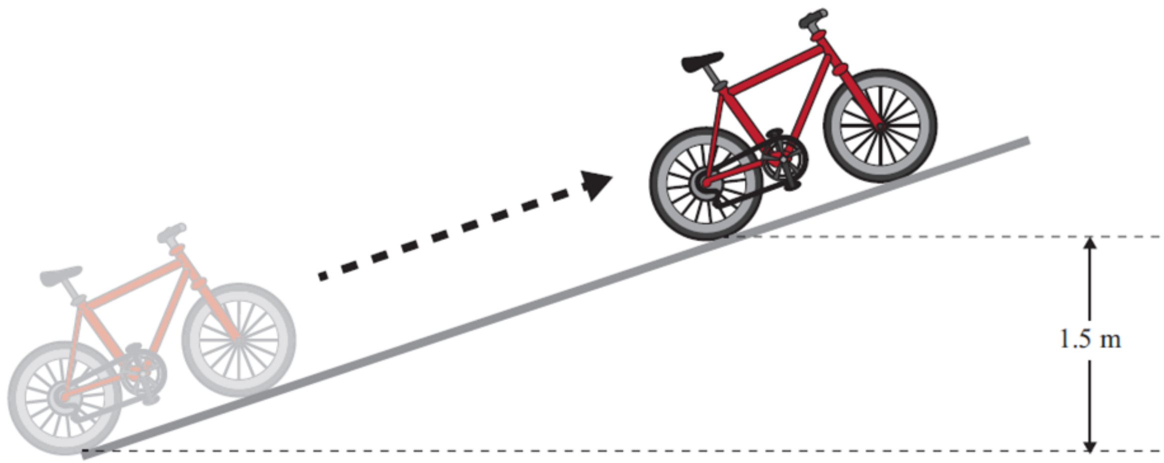


Calculating Work

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 <u>NOT</u> the length of the ramp.

NCEA 2015 Work - Diving

Question 1b: How much work did Chris (48 kg) do when he climbed up the stairs to the 2 m platform?

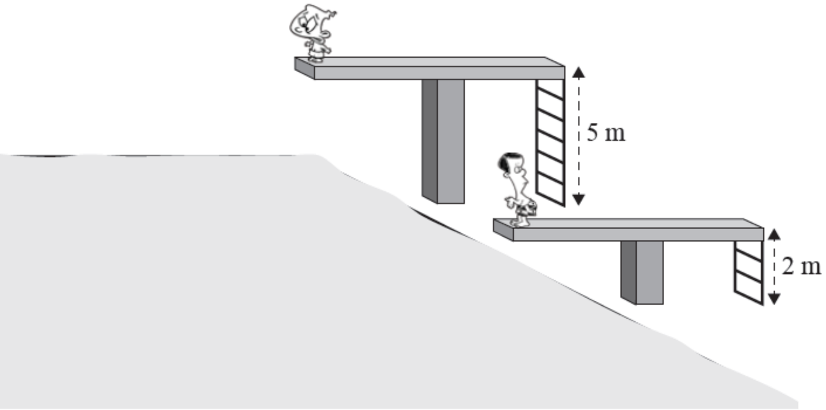
Merit Question

$F = m \times g$
$= 48 \times 10$
$= 480$ N
$W = F \times d$
$= 480 \times 2$
$= 960$ J
OR
$E_p = mgh$
$= 48 \times 10 \times 2$
$= 960$ J

Question 1c: Ian's mass is 52 kg.
Why did Ian do more work climbing up the 5 m ladder compared to Chris climbing up the 2 m ladder?

Merit Question

Answer 1c: Work is proportional to the force applied (weight force) and the distance travelled.
OR $W = F \times d$ (formula or words)
OR work is needed to transfer energy, as Ian has more mass and weight, he also climbs longer distance, more energy transferred therefore more work done.
Ian completes a greater amount of work because he had a mass of
52 kg, compared with Chris with a mass of 48 kg
Ian climbs a greater distance, 5 m, compared with Chris, who climbed only 2 m



NCEA 2014 Work – Construction

Achieved Question

Question 3a: During the construction of a building, a long beam was lifted into place using a crane.
Calculate the work done in lifting the beam with a weight of 6000 N through a distance of 50 m.

$W = F \times d = 6\,000 \times 50 = 300\,000$ J

Merit Question

Question 3b: Explain why there is no work being done when the beam is hanging in the air without moving.

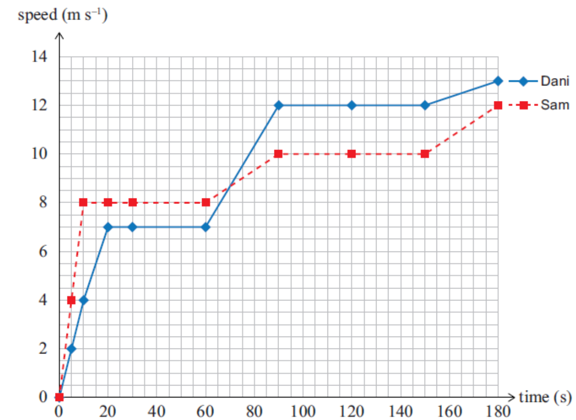
Work is done when a force causes the beam to move in a direction of the force. The force is not causing the object to move, so no work is being done.

(No distance travelled in the direction of the force)

Merit Question

NCEA 2017 Work – horse racing

Question 1b: Sam's horse accelerates for the first 10 s of the race AND covers a distance of 40 m. Sam and his horse have a total mass 308 kg.
(b) Use the acceleration to calculate the work that Sam and his horse have done in the first 40 m.



$a = \Delta v / \Delta t$

$= \dfrac{8 - 0}{10 - 0}$

$= 0.8\ \text{ms}^{-2}$

$F_w = m \times a$

$= 308 \times 0.8\ \text{ms}^{-2}$

$= 246.4\ \text{N}$

$W = F \times d$

$= 246.4 \times 40 =$ **9856J** **(9.86 kJ)**

https://www.cnet.com/news/horse-racing-genetics-training-kentucky-derby-improve-the-odds/

Excellence Question

NCEA 2017 Work and Power – horse racing

Question 1c: Explain the effect on **work** AND **power** if a new, heavier jockey was on Sam's horse, which had the same speed and acceleration over the race.
Calculations are not required.

Work is proportional to the force applied (weight force) and the distance travelled.
OR $W = F \times d$ (formula or words)
Work is needed to transfer energy, if there is a heavier jockey there will be more mass and therefore more weight force, more energy transferred therefore more work done.
The horse and the heavier jockey completes a greater amount of work than a lighter jockey.

The energy (Work) used by the heavier jockey is greater, but the time taken to cover the same distance is the same as the speed and acceleration is the same. As $P = W / t$ *and* $W = P \times t$, a greater weight would mean **more power is required** if more work is done in the same time.

https://www.thesun.co.uk/sport/horseracing/4499030/sandown-yarmouth-beverley-kelso-steve-mullen-horse-racing-tips/

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}

GZ Science Resources

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.

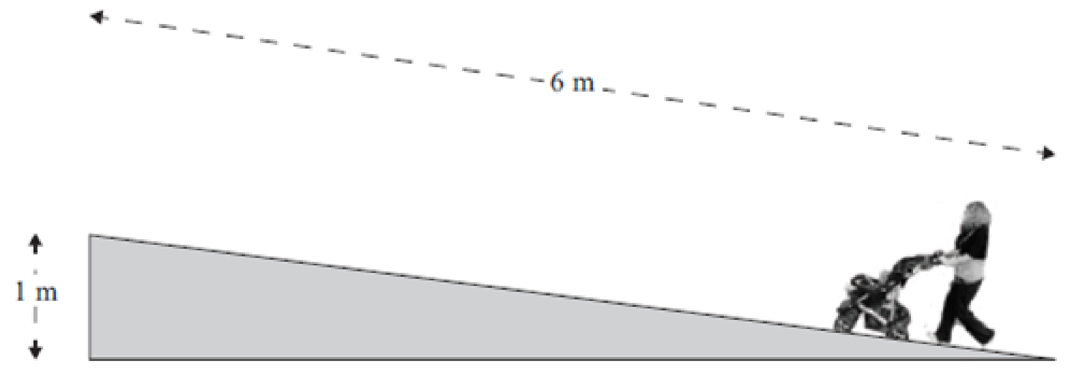
Ramps make moving masses 'easier' as allows the same amount of work to be done with a smaller force over a greater distance. In addition, ramps require less power to be used for the same weight (force) if it takes longer to reach the same height.

$$P = W/t$$

W = work done (J)

P = power (W)

t = time (s)



Calculating Power

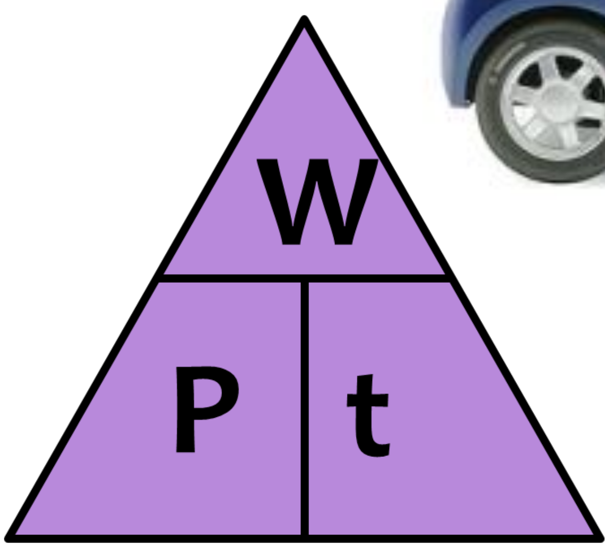
Calculating power is normally completed in three steps:

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 $P = W / t$

Force = 20N

Time = 25seconds

Distance = 5 metres

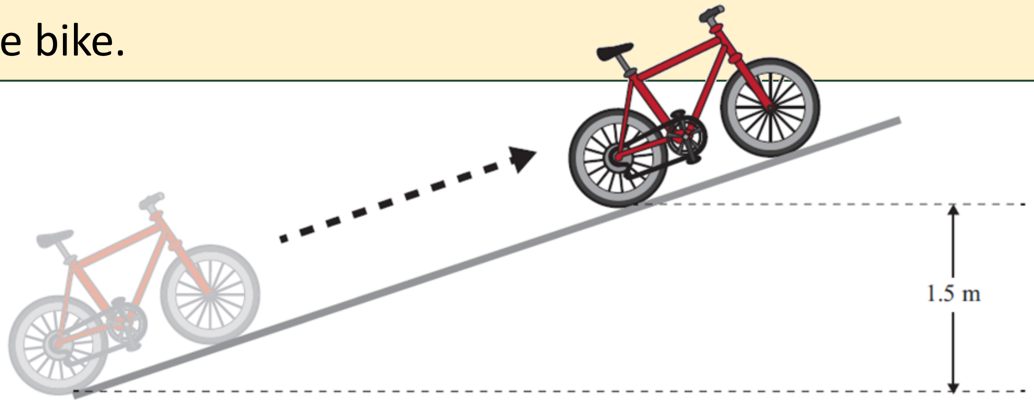


A car is pushed with a force of 20N and travels 5 metres.
The work done is W= f x d   w = 20 x 5   =   100 joules
The power used to push the car is p = W/t p = 100/25   =
4 Watts

NCEA Work and power – the bike

Q1: A bike with a mass of 20 kg is lifted onto a shelf that is 1.5 metres high. It takes 3 seconds to lift the bike. Calculate the power required to lift the bike onto the shelf. Before you calculate the power, you will need to:

- determine the weight force of the bike
- calculate the work done in lifting the bike.



F = 20 x 10 = 200 N

$W = F$ x d = 200 x 1.5 = 300 J

$P = W / t$ = 300 / 3 = 100 W

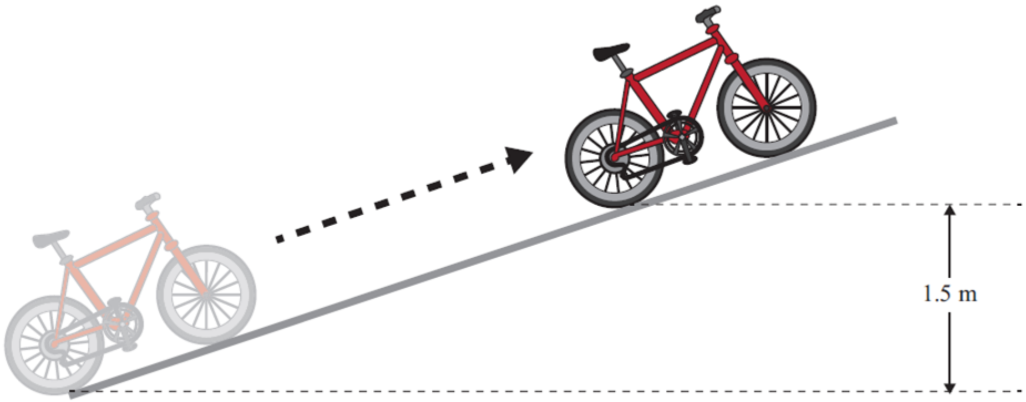
Q2: A person pushed the same bike up a ramp that it was also at a height of 1.5m. It then took them a longer time to do this than lifting the bike. Explain whether the power needed to push the bike up the ramp is more or less than when it is lifted straight up to the same height. Refer to force and energy.

As the height above the ground is the same, **the same work is required** to travel up the ramp as lifting the bike straight up. If the same amount of work is done, the same amount of energy is gained. As $W = F$ x d, if d is increased, the amount of force required to do the same amount of work will be less, ie a ramp allows the same amount of work to be done with a smaller force over a greater distance.

NCEA Work and power – the bike (part 2)

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

The same work is required overall but going up the ramp, the push force required is against a only 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.



The same work is done in both cases but because the ramp spreads the work out over a longer time it seems "easier"

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**.

NCEA 2013 Work and power - the forklift

Q3: A box in a warehouse has a mass of 2 500 kg.
(a) Explain the difference between weight and mass.
(b) Calculate the weight of the box.

Weight is the downward force due to gravity that an object experiences, while mass is a measure of the amount of matter that an object has.

$F_{weight/gravity} = mg = 2\,500 \times 10 = 25\,000$ N

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.

Excellence Question

$F = 25\,000$ N

$W = Fd = 25\,000 \times 4 = 100\,000$ J

$P = W / t = 100\,000 / 5 = 20\,000$ W

NCEA 2013 Work and power - the forklift (part 2)

Excellence Question

Q3: (d) Find the **average speed** of the box as it moves up to the 4 m high shelf.
(e) Explain how the power needed to lift the box would be affected if the box was lifted at twice the speed.
In your answer you should consider how increased speed affects the time taken.

$v = d / t = 4 / 5 = 0.8 \text{ m s}^{-1}$

The power needed will increase. This is because if the speed is doubled, the time to lift the load is halved.

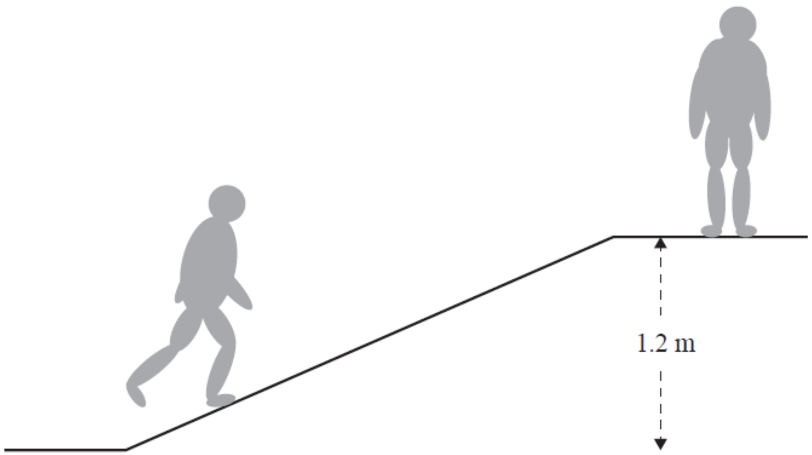
Since the work done does not change and power is a measure of the amount of work done per second, if the time is halved the power is doubled.

Link increased speed to decreased time to lift the box. Then clearly show the **link between time and power** when explaining why power has increased. (This could be done either stating the equation $P = W / t$ or describing that relationship through words).

NCEA 2016 Work and Power - The Combine Harvester

Excellence Question

2c. The harvested grain is stored in a shed with a ramp.
(An 85 kg worker climbed to the top of the ramp, a height of 1.2 m. This took 8 seconds. Calculate the **work** done by the worker to get to the top of the ramp and therefore the **power** exerted. Include units.



F = 85 kg x 10 = 850 N

$W = Fd$ = 850 N × 1.2 m = 1020 J

$P = W / t$ = 1020 J / 8 s = 127.5 W

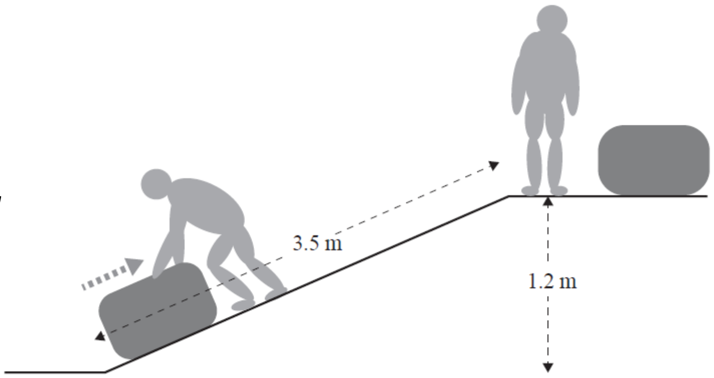
NCEA 2016 Work and Power - The Combine Harvester (part 2)

Excellence Question

2d. The worker dragged a 25 kg bag of grain up the 3.5 m ramp to reach the height of 1.2 m. It took longer to drag the bag up the ramp than to lift the bag straight up to the top of the ramp.

(i) Explain why the **force** needed to drag the bag of grain up the ramp to the top is less than the force needed to lift the bag straight up (vertically). Ignore friction.

As the height above the ground is the same, **the same work is required** to travel up the ramp as lifting the bike straight up. If the same amount of work is done, the same amount of energy is gained. As $W = F \times d$, if d is increased, the **amount of force required to do the same amount of work will be less**, ie a ramp allows the same amount of work to be done with a smaller force over a greater distance.



(ii) Explain whether the **power** needed to drag the bag of grain to the top of the ramp is more or less than the power needed when the bag is lifted straight up (vertically) to the top of the ramp.
(No calculation is required.)

The energy gained by the bag of grain 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**.

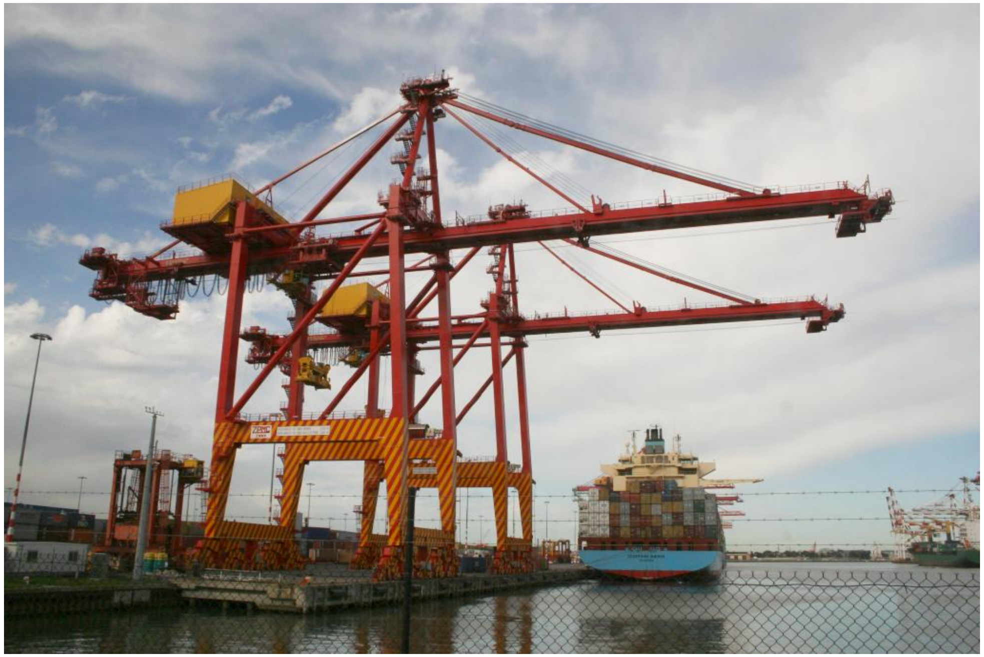
Merit Question

NCEA 2017 Work and Power – The Crane (Part ONE)

Question 3a: The crane shown below lifted a container 30 m in 15 s. The weight of the container is 60 000 N.
(i) Calculate the work done by the crane in lifting the container 30 m.

F = 60 000 N

$W = Fd$ = 60 000 × 30
= 1 800 000 J
= 1800 kJ



Question 3a: (ii) Calculate the power of the crane while lifting the container 30 m in 15 s.

$P = W / t$ = 1 800 000 J / 15 s
= 120 000 W   or 120kW

https://commons.wikimedia.org/wiki/File:Melbourne--swanston-dock-container-crane.jpg

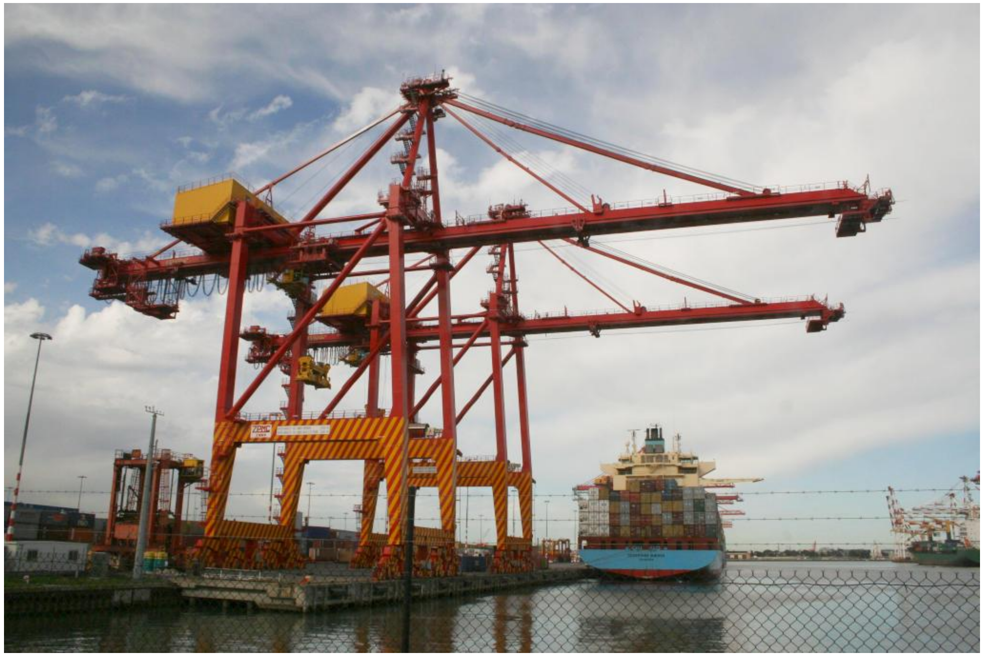
Merit Question

NCEA 2017 Work and Power – The Crane (Part TWO)

Question 3b: Explain what work is being done on the container when it is hanging in the air without moving.

Work is done when a force causes the container (load) to move in a direction of the force. The force is not causing the object to move, so no work is being done.

(No distance travelled in the direction of the force)



https://commons.wikimedia.org/wiki/File:Melbourne--swanston-dock-container-crane.jpg

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. .

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

$W=Fd$

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

$P=W/t$

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

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

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

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.

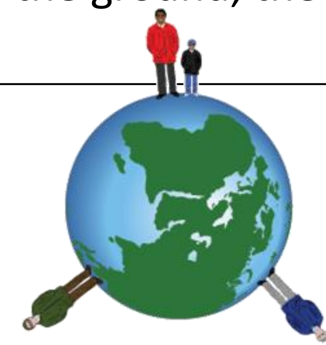
All forms of stored energy are called potential energy – this can not be seen until it is transformed (changed) into active energy. We will be focusing on **gravitational potential energy**, the stored energy objects gain when moved to a height.

Mechanical kinetic Energy

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

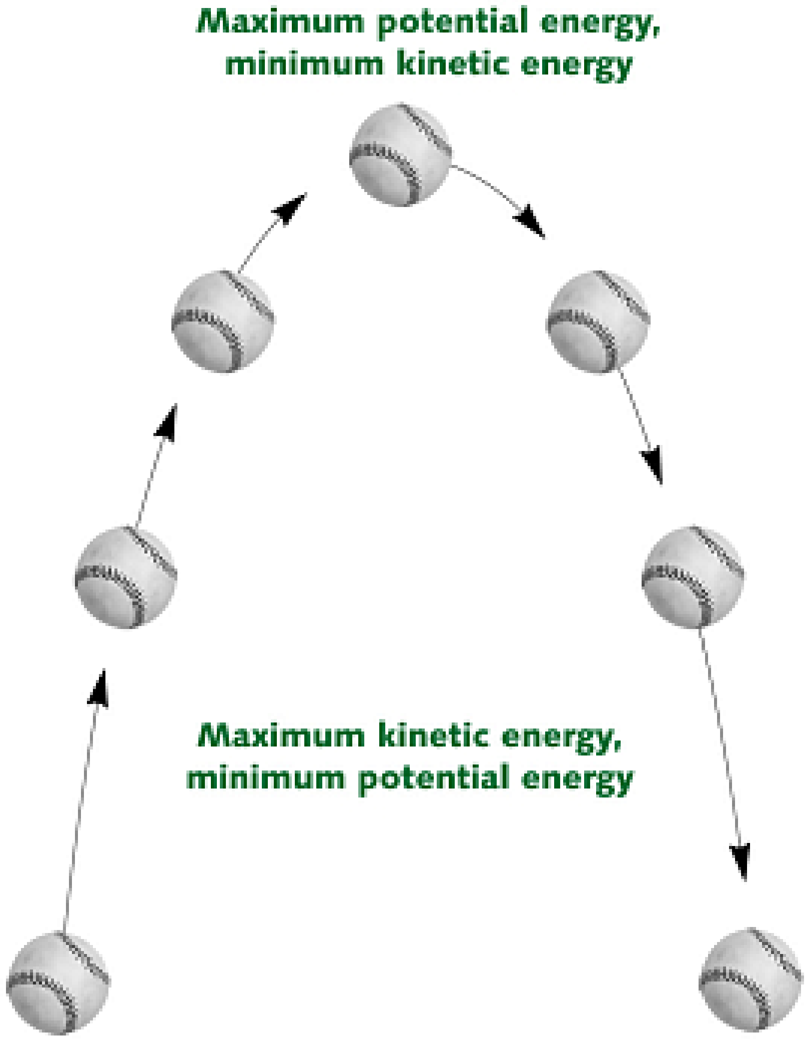
Gravitational potential Energy

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.



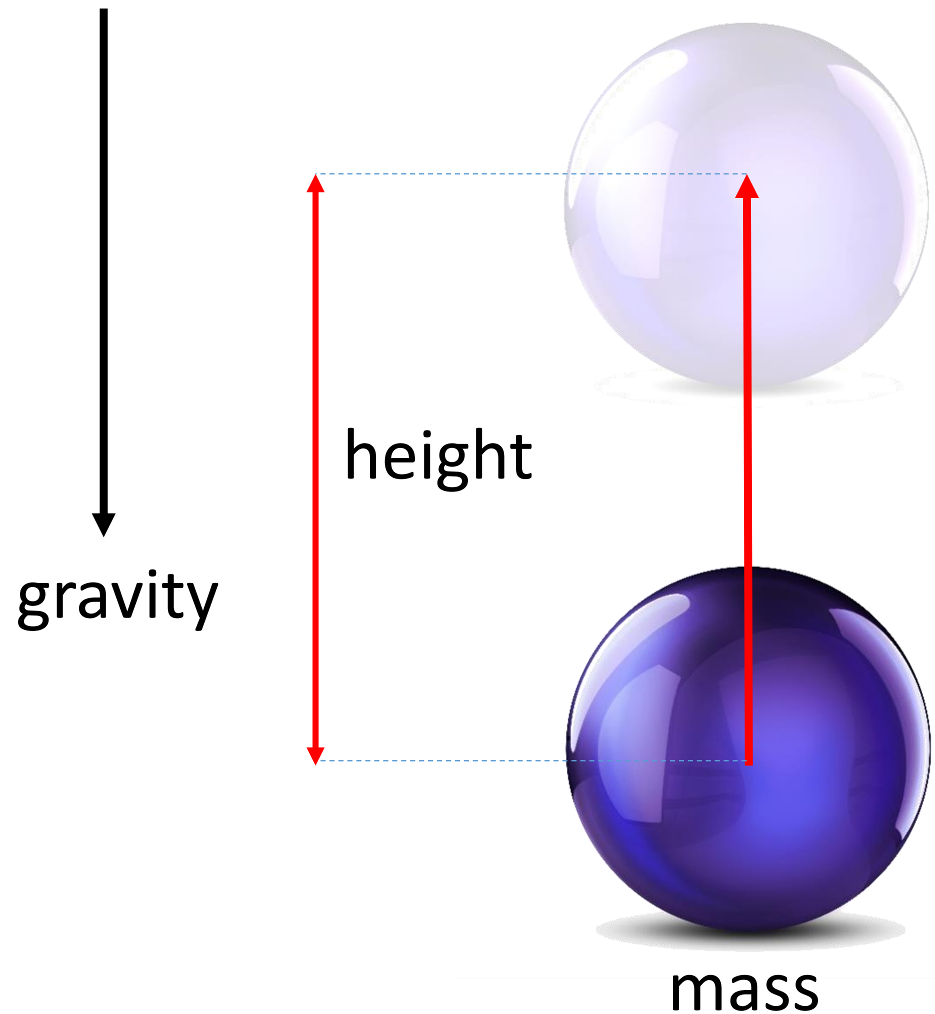
$$\Delta mgh = \Delta \tfrac{1}{2}mv^2$$

Potential energy

Potential energy = mass x gravity x height

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 $\mathbf{F_w = m \times g}$ 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 x 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.

Kinetic energy = 0.5 x mass x velocity^2

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.

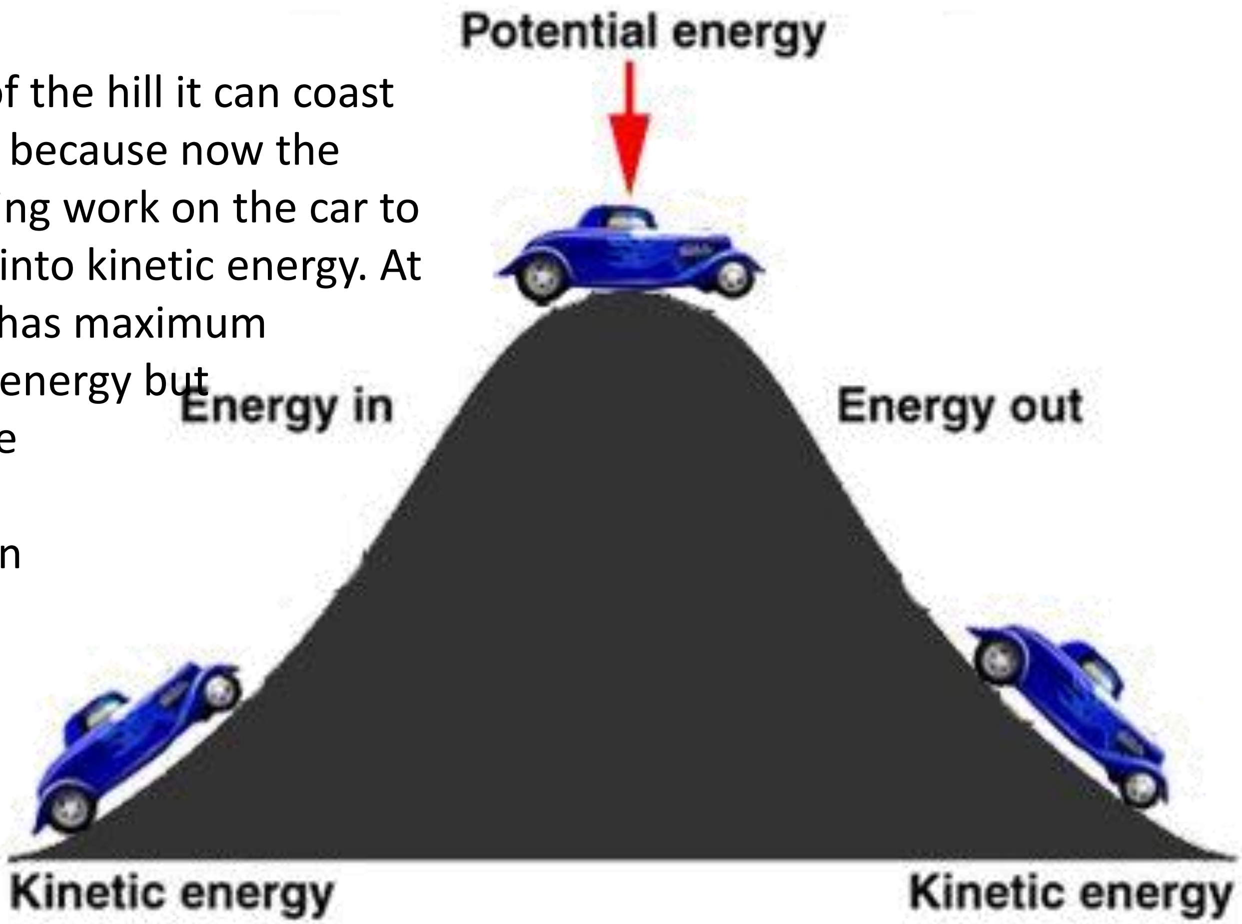
$$E_k=\frac{1}{2}mv^2$$

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.



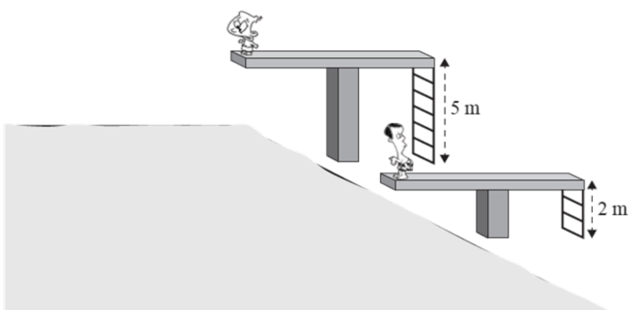
Loss of Energy during transformation

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

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.

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

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

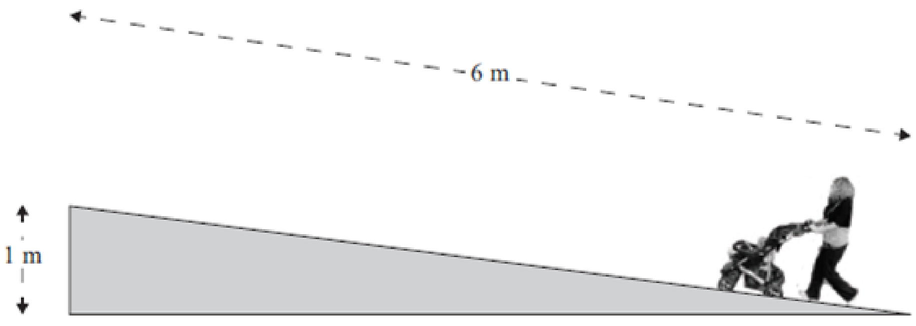
Substitute one type of energy for the other then rearrange equation to find value.

NCEA Work and 'missing' energy – the buggy

Q1: A woman pushes a child in a buggy up a ramp as shown below with a force of 100N. **Calculate the work done** to push the buggy and child up the ramp

$W = F \times d$

$= 100 \times 6 = 600$ J



Q2: The energy gained by the buggy and child (m = 55 kg) at the top of the ramp **does not equal** the work done. Explain why these two values are not equal.

In your answer you should:

- name the type of energy the buggy has, when it reaches the top of the ramp
- calculate the difference between the work done and the energy at the top of the ramp
- explain where the "missing" energy has gone and why this occurs.

Type of energy at top is **gravitational potential energy**

$E_p = mgh = 55 \times 10 \times 1 = 550$ J

Energy difference = 600 – 550 = 50 J

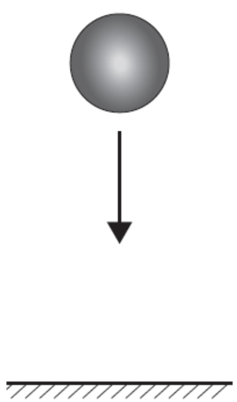
More energy is used to get up the ramp as some of the energy is being **converted into heat** (and sound), due to friction between the wheels and ramp, or the buggy's moving parts.

NCEA 2013 Conservation of Energy - The ball

Merit Question

Question 2a: In a classroom experiment, a ball is dropped onto the floor.
Before the ball is dropped, it is not moving, and has only gravitational potential energy (*E*p). As the ball falls, the gravitational potential energy is converted into kinetic energy (*E*k).
The ball has a mass of 100 grams.
(a) Complete the labels for the diagram below to show the energy changes as the ball is dropped.
Assume that the gravitational potential energy is changed **only** into kinetic energy.

Assume conservation of energy



At the top: $E_p = 0.2$ J $E_k = 0$ J

Halfway: $E_p =$ ________ $E_k =$ ________

Just before it hits the floor: $E_p =$ ________ $E_k =$ ________

Halfway:
$E_p = 0.1$ J $E_k = 0.1$ J
At the bottom:
$E_p = 0$ J $E_k = 0.2$ J

NCEA 2013 Conservation of Energy - The ball (part 2)

Excellence Question

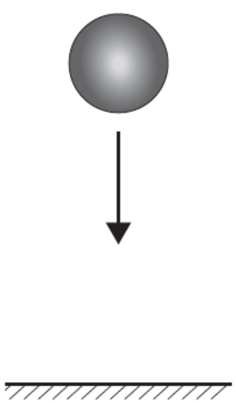
Question 2b: The teacher tells the students that the ball will be travelling at 2 m s^{-1} just before it hits the floor. The students are asked to predict the speed of the ball halfway down from three options:

Option 1: The speed is **less** than 1 m s^{-1}.

Option 2: The speed is **equal** to 1 m s^{-1}.

Option 3: The speed is **greater** than 1 m s^{-1}.

State the correct option, explain your answer, and support your answer using energy calculations. (The ball has a mass of 100 grams.)



Option 3.

At halfway $E_k = 0.1 \text{ J} = ½mv^2 = ½ \times 0.1 \times v^2$

$v^2 = 2$

$v = 1.41 \text{ m s}^{-1}$

Assume conservation of energy and rearrange equation to find velocity

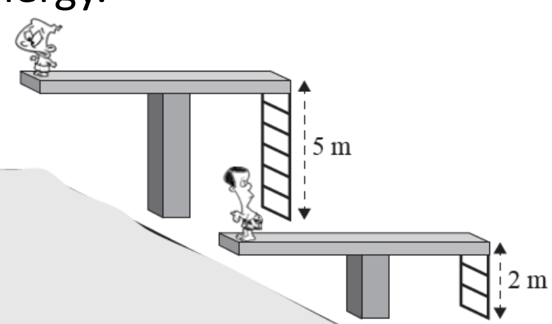
NCEA 2015 Conservation of Energy - the diver

Excellence Question

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.

Answer 1d: 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.



$$E_k = E_p$$

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

OR

$$v^2 = 2gh$$

$$v = \sqrt{2gh}$$

$$v = \sqrt{2 \times 10 \times 5}$$

$$v = 10 \text{ m s}^{-1}$$

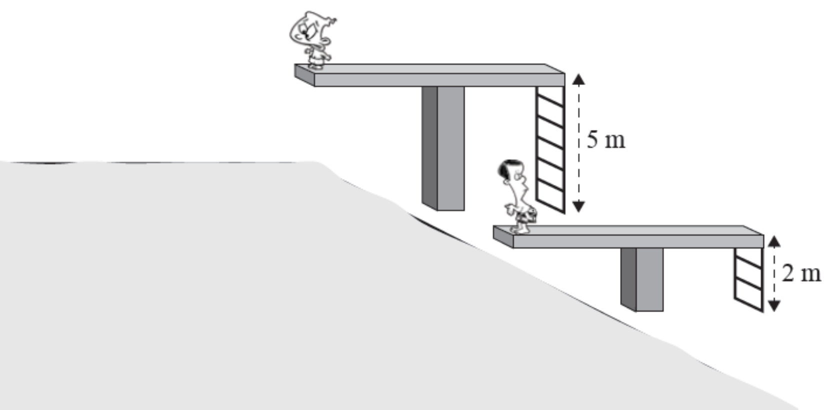
NCEA 2015 'missing' Energy - the diver

Excellence Question

Question 1e: Explain why Ian's actual speed as he is about to hit the water, is slower than that calculated in part (d).

Answer 1e: There are some losses of energy due to friction / air resistance. This means that some of the initial gravitational potential energy is converted into heat and sound as well as kinetic energy. As a consequence, the kinetic energy is less than that calculated (theoretical value), and the boy enters the water at a slower speed. Air resistance / friction occurs as the boy falls, because the boy is pushing past air particles. As the air particles rub against the boy, heat and sound are generated.

Explain that air resistance / friction causes losses of energy AND the energy is converted into heat and / or sound **AND** that, as the kinetic energy (energy of motion) is less, the boy enters the water at a slower speed.



NCEA 'missing' energy – the crane

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.

Answer: 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. **Some kinetic energy is lost as heat energy** due to the frictional force of air resistance.

$E_P = mgh = 150 \times 10 \times 12 = 18\,000$ J

Difference between E_P and E_K: $= 18\,000 - 15\,000 = 3\,000$ J

NCEA 2016 Conservation of Energy - The Rocket

Excellence Question

Question 3c: A small rocket has a mass of 2.60 kg and a weight of 26.0 N. The rocket had gained 1950 J of potential energy at its maximum height. It then fell back to the ground. What was the maximum speed it could reach just before hitting the ground (assuming energy is conserved)?

Answer 3c: $E_p = E_k$

$E_k = 1950$

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

$1950 = \frac{1}{2} \times 2.60 \times v^2$

$v = \sqrt{1950 \times \frac{2}{2.60}}$

$v = 38.7$ m s^{-1} (3sf)

(Sig. figs not required.)

Excellence Question

NCEA 2017 Conservation of Energy – The Crane

Question 3d: The crane was lifting another container and the cable broke. The 6500 kg container fell 15 m to the ground below. The container had 970 000 J of kinetic energy just before it hit the ground.

Calculate the energy the container had before the cable broke.

AND

Explain why there is a difference in the energy of the container when it was hanging from the crane compared to just before it hit the ground.

$E_P = mgh = 6500 \times 10 \times 15 = 975\,000$ J

Difference between E_P and E_K: = 975 000 J – 970 000 J = 5 000 J

At the top, the container has a certain amount of gravitational potential energy and no kinetic energy.

Just before the container hits the ground, the gravitational potential energy has been converted into kinetic energy.There are some losses of energy due to frictional force of air resistance. This means that some of the initial gravitational potential energy is converted into heat and sound as well as kinetic energy. Air resistance / friction occurs as the container falls, because the container is pushing past air particles. As the air particles rub against the container , heat and sound are generated

As a consequence, the kinetic energy is less than that calculated (theoretical value) using the assumption of conservation of energy

http://www.nauticexpo.com/prod/liebherr-international-deutschland/product-30468-323600.html

"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

Background Knowledge

Perpetual Motion

GZ Science Resources

Due to the principal of the conservation of energy an object, in theory, should be able to continuously transform the total amount of potential energy into kinetic energy and back again to maintain perpetual or continuous motion without the input of further energy. In reality small amounts of energy are lost as sound or heat energy and an object will eventually become stationary.