With 2019 NCEA Exam included

Part One

2020 Version

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

Definition of motion

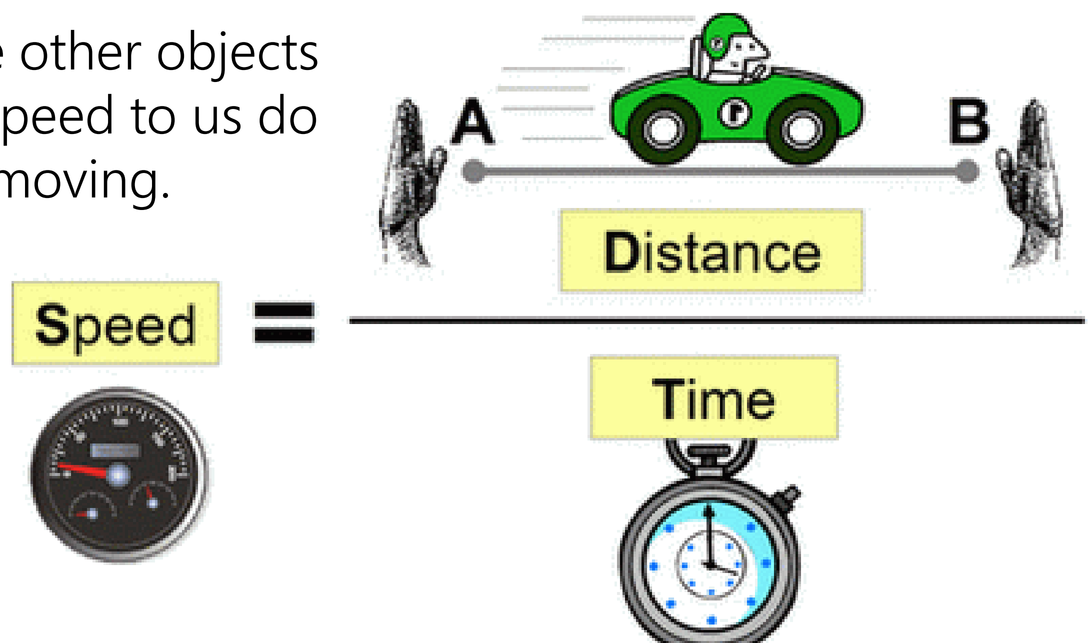
Objects that move from one point of space to another over time are said to have **motion**. Examples include a tortoise slowly moving across the ground or a bullet moving fast after it has been fired from a gun. Objects that remain at the same point of space over a period of time are called **stationary**.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

Speed

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

Constant speed occurs when the object travels the same amount of distance at each even time period. When we travel on an object moving at a constant speed, we do not feel movement for example travelling in an airplane.

Only when we observe other objects moving at a different speed to us do we notice that we are moving.



Measuring Motion in Science

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

Converting measurements

Quantities are often measured in different **scales** depending upon what is most appropriate for the original size. In Science (and Mathematics) we use common **prefixes** to indicate the scale used.
We sometimes want to convert scales from one to another to compare data or to place the measurements into equations.

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

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

To convert from metres to kilometres **divide** by 1000

To convert from kilometres to metres **multiply** by 1000

Time is measured in "imperial units" 1 hour has 60 minutes and 1 minute has 60 seconds **therefore** 1 hour has 3600 seconds

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**.

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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

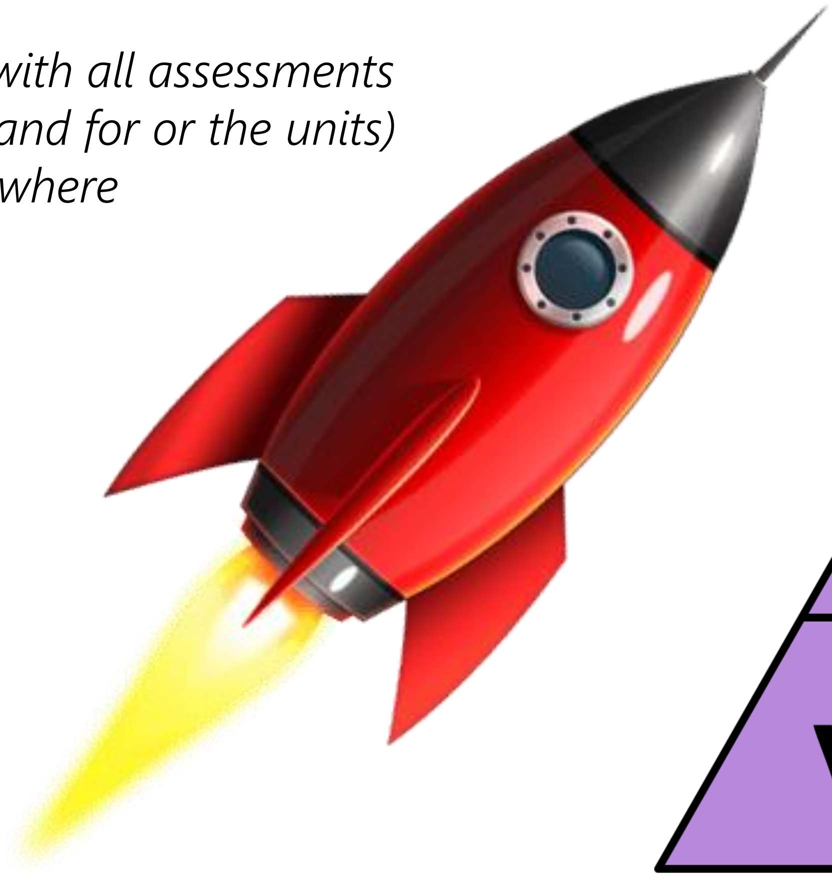
Mean = (113 + 121 + 119) ÷ 3

= **117.7** m

Calculating speed

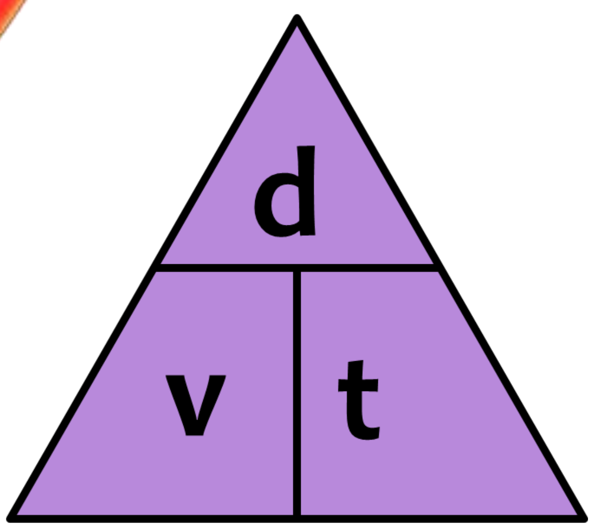
We use this **formula** to calculate speed by placing in the information we have about distance /time into it.
We can also rearrange the formula to calculate distance or time, as long as we know the other two values.
It is important to also use the units after any value in Science.

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.

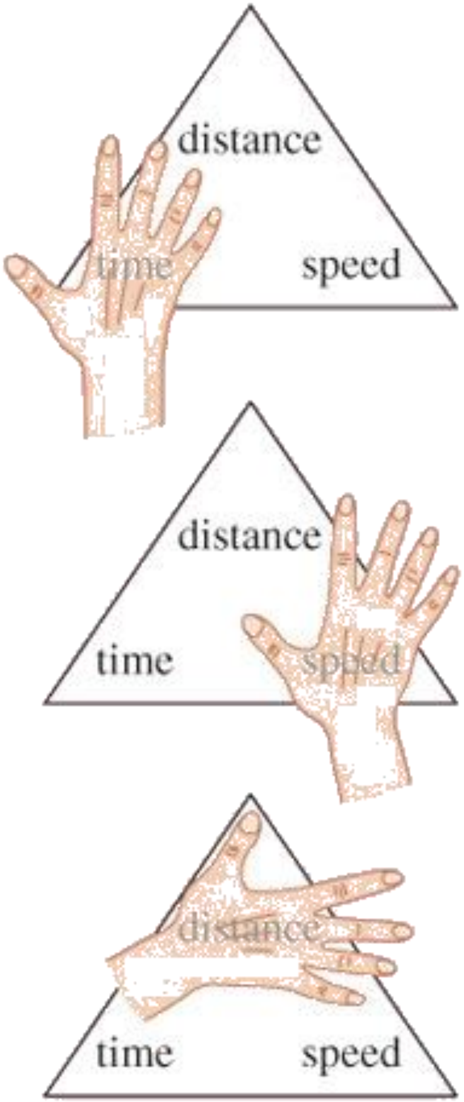


$$v=d/t$$

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

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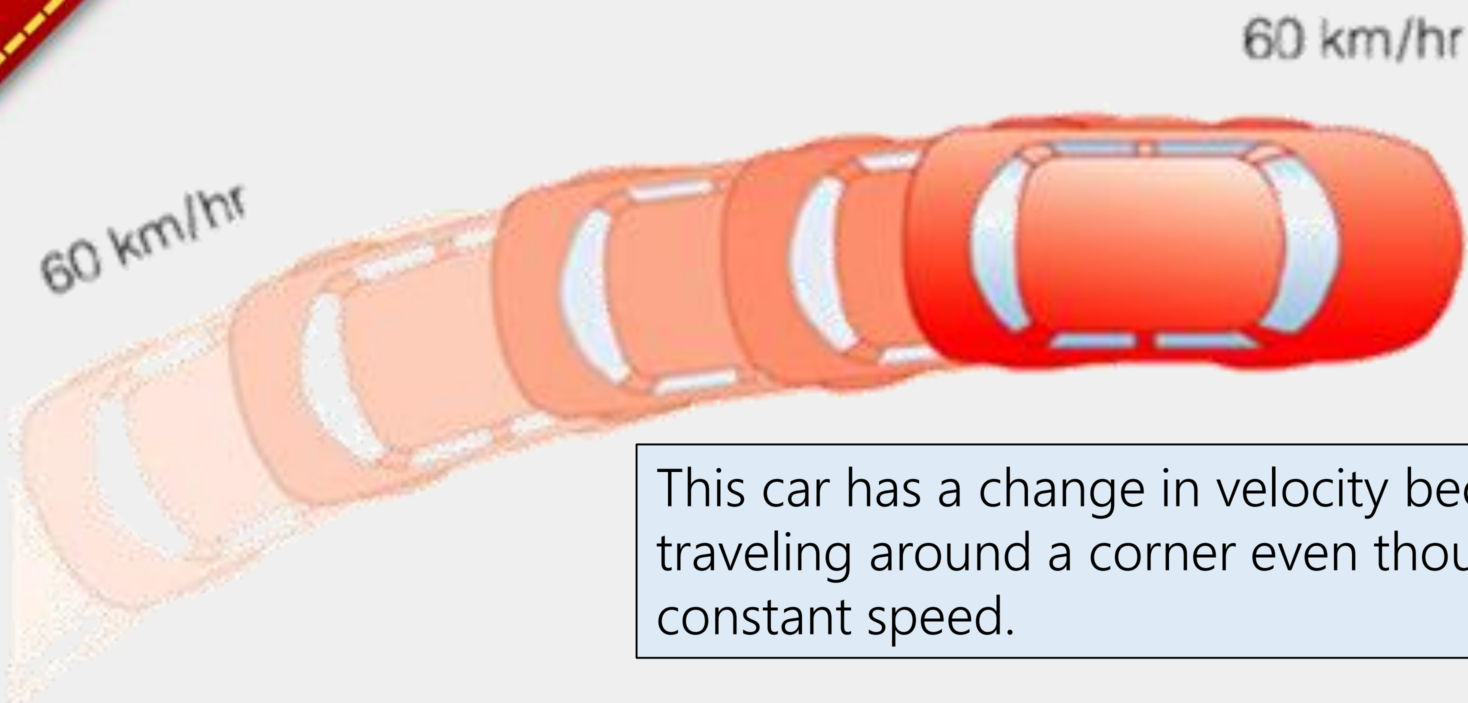
Velocity measures the speed of an object **and** the direction it travels. Two objects can have the same speed but different velocities if they are not travelling the same direction. An object can have a constant speed but its velocity can change if it does not travel in a straight line.

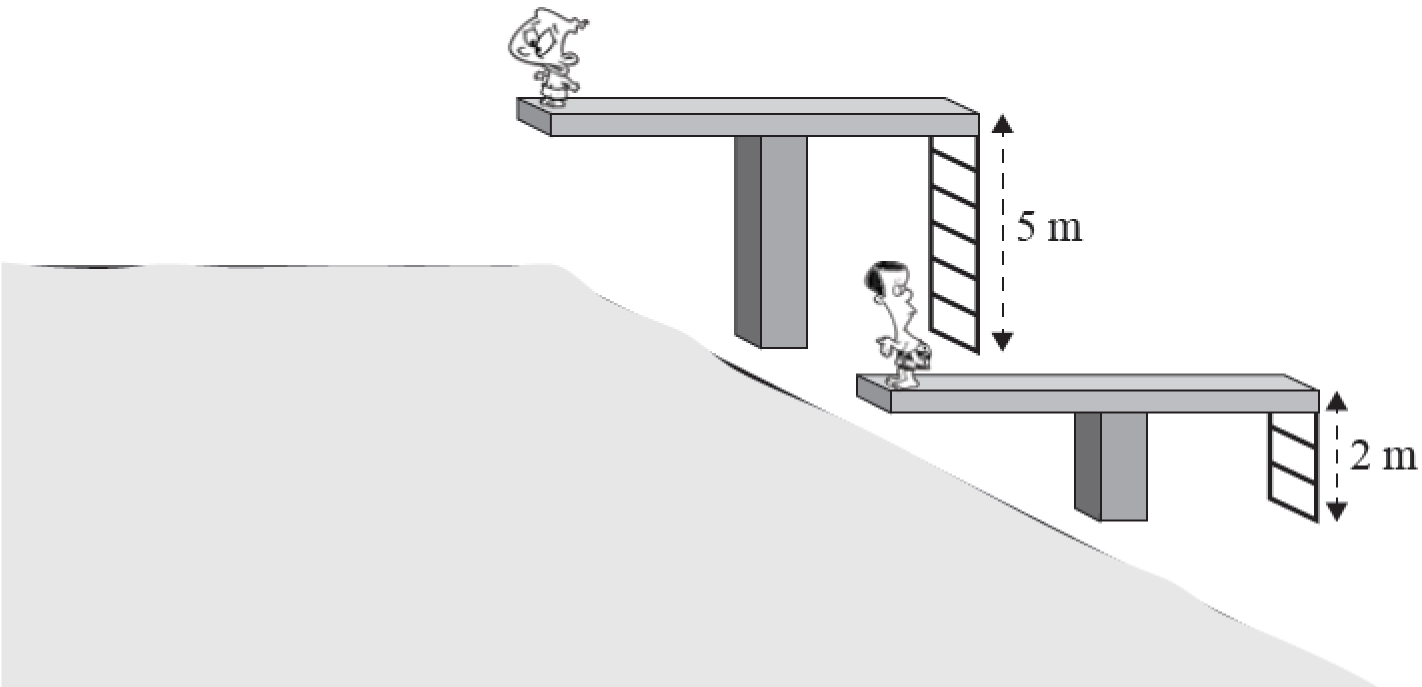


This car has a change in velocity because it is traveling around a corner even though it has constant speed.

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.

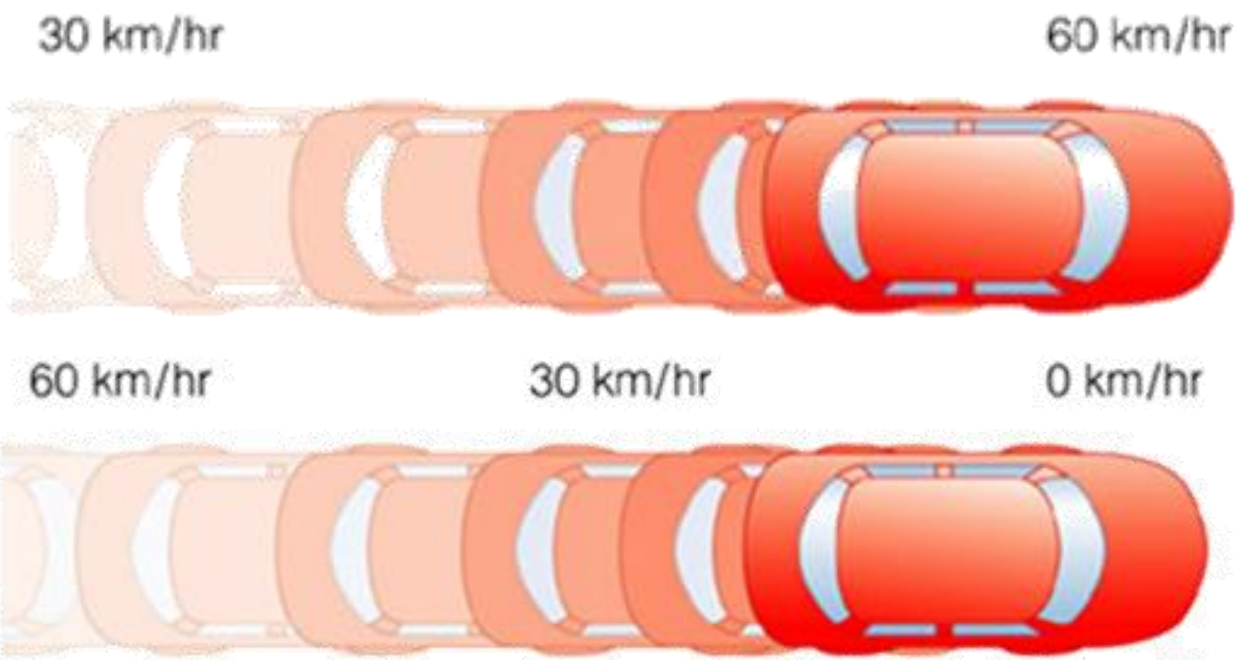
Achieved Question



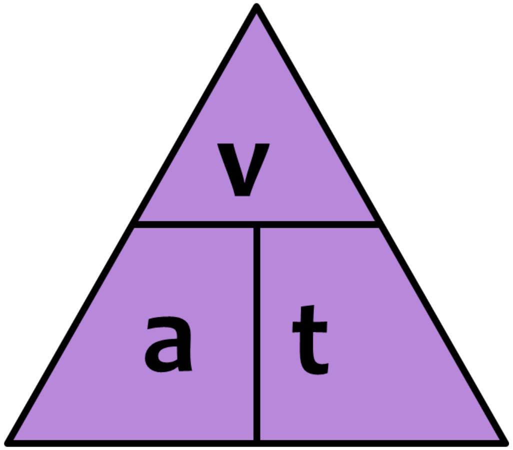
$$v = \frac{d}{t} = \frac{2}{0.60} = 3.3\ \text{m s}^{-1}$$

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)

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

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.

2014 NCEA Motion – Chairs and footstools

2a: A chair (15.0 kg) and footstool (15.0 kg) are shown beside.
The chair has four legs in contact with the floor, whereas the base of the footstool does not have legs and is entirely in contact with the floor.
(a) It took 6 seconds to push the footstool a distance of 8.0 m across a room.
Calculate the average speed of the footstool as it is pushed.

$$v = \frac{d}{t} = \frac{8}{6} = 1.3\,\mathrm{m\,s^{-1}}$$

(do not accept 1.4 without working)

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

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

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

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

Achieved Question

NCEA 2019 Motion – parachute

Question 3b : The parachutist falls a distance of 450 m during the first 9.49 seconds. Calculate the average speed of the parachutist during this time.

$v = d/\Delta t = 450/9.49 = 47.4$ ms-1

https://medium.com/@rohicks/whuffo-you-jump-out-of-that-plane-14a70d0c4dc6

Background Knowledge

The Earth accelerates around the Sun

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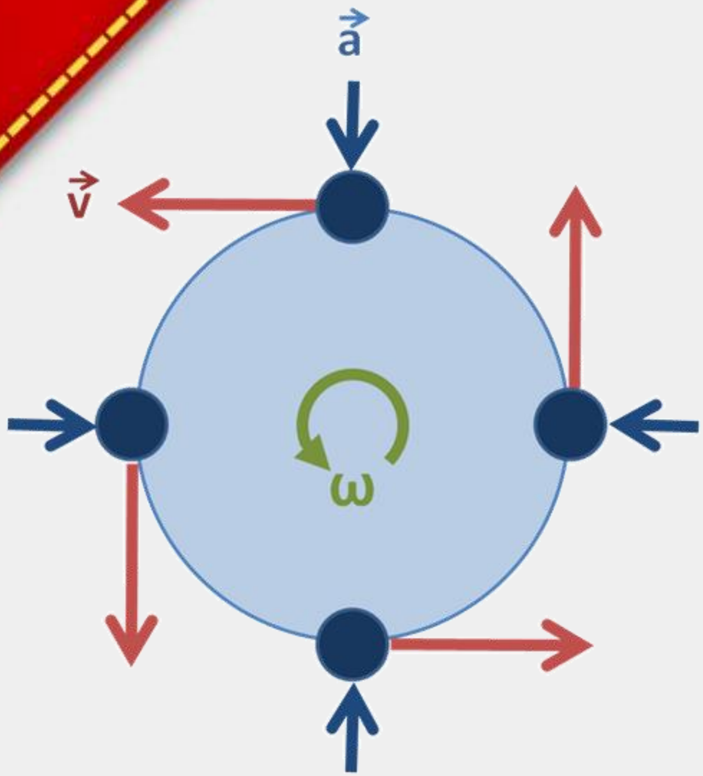
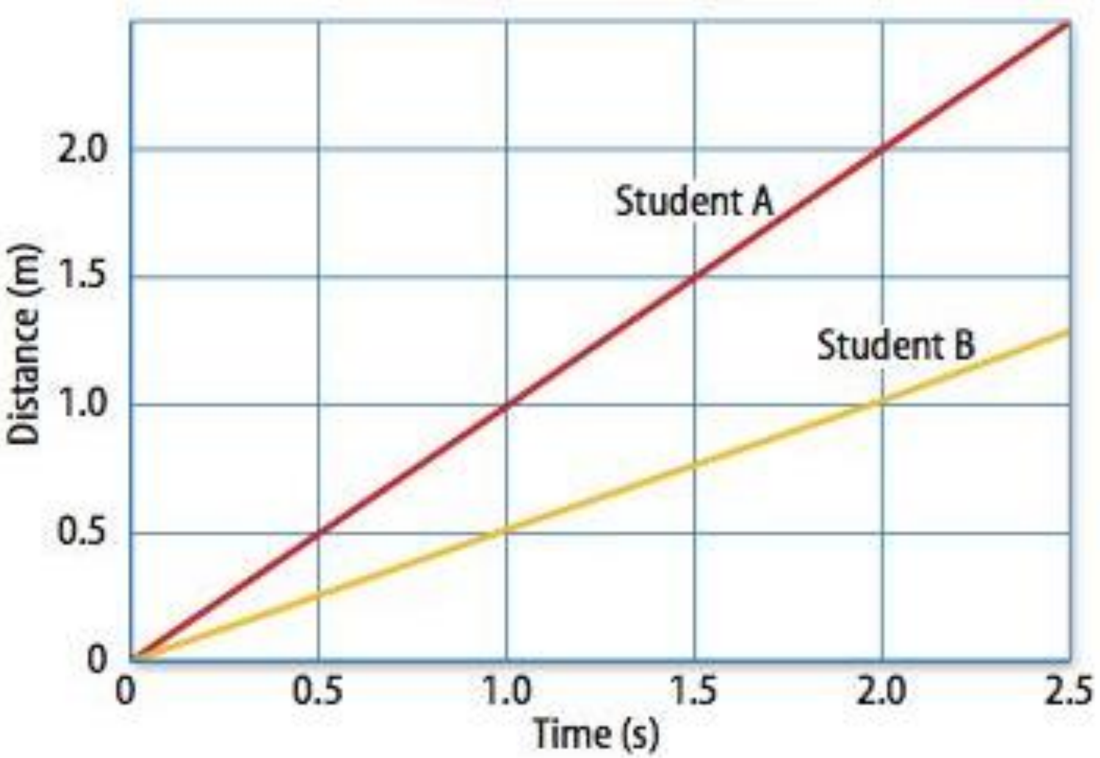


The Earth travels at a constant average speed around the Sun (the speed varies slightly due to the elliptical path) and yet it is accelerating. This is because the direction that the Earth is travelling is constantly changing as it moves around the sun. The gravity force from the sun acts on the Earth 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.

Distance-Time graphs

Distance verses Time graph

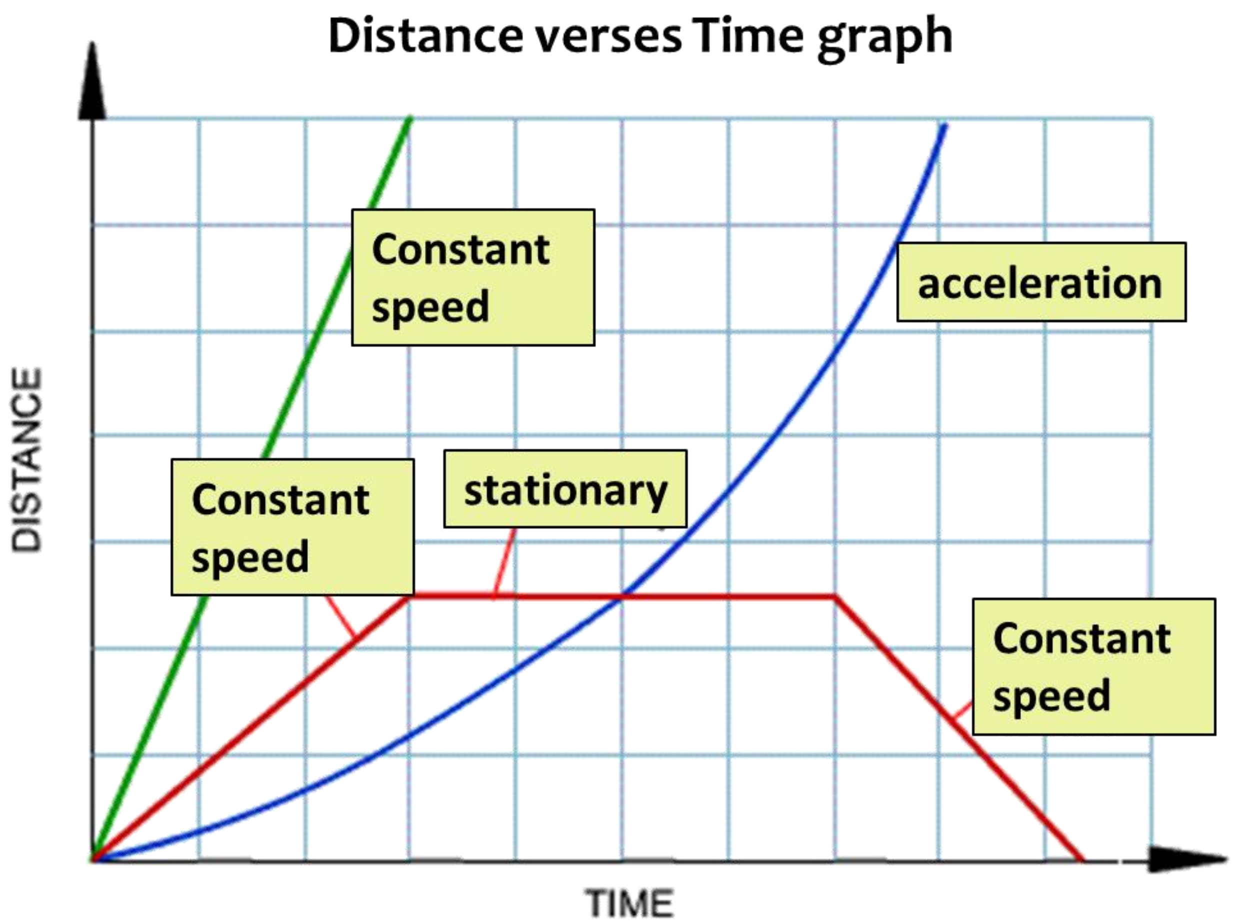


Distance (y axis) and time (x axis) data can be plotted on a line graph to show patterns and compare speeds.

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**.

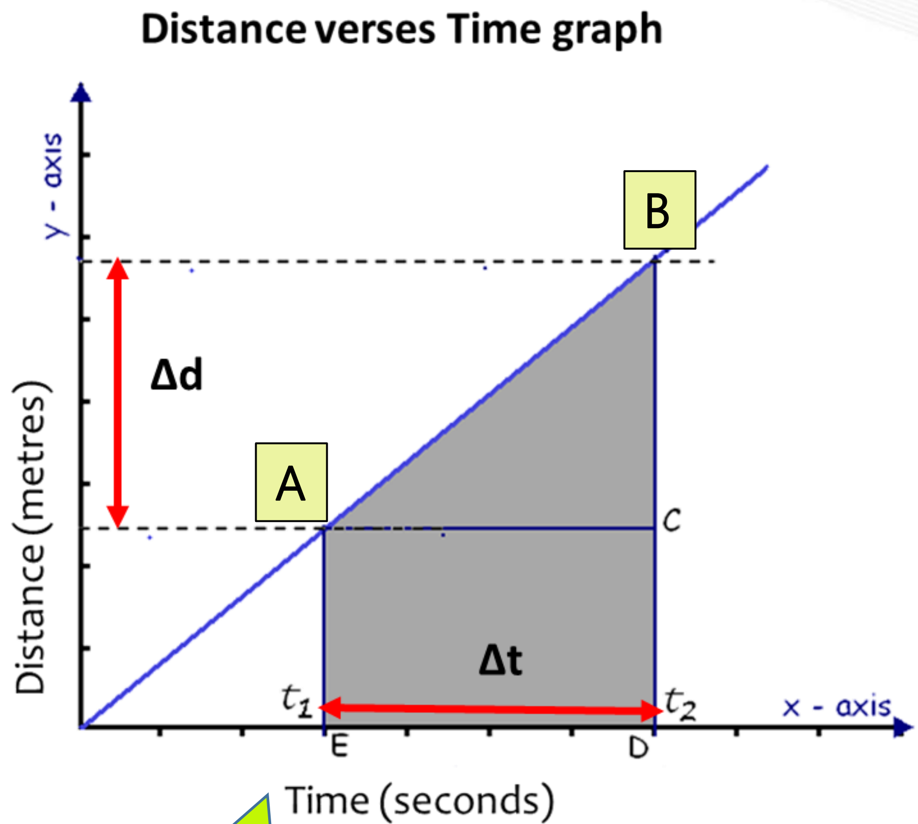
Interpreting Distance-Time graphs

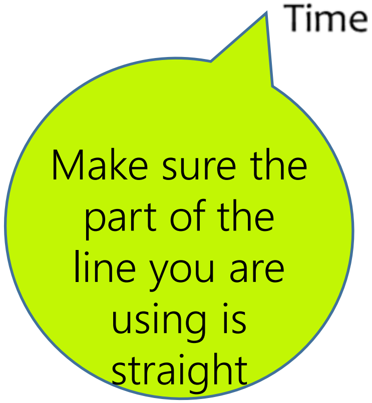


A distance time graph can also show **acceleration** with a curved line (blue) because at each time interval the distance travelled becomes larger and larger. Changes in speed are also shown with a combination of diagonal and horizontal lines (red).

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

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





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

To calculate the value for time find the difference between **t1 and t2** by subtracting the smallest value from the largest value. This will be your Δ time.
Repeat to find distance on the y axis. This will be your Δ distance.

Place both values into your formula to calculate speed (velocity)
v = Δd/ Δt

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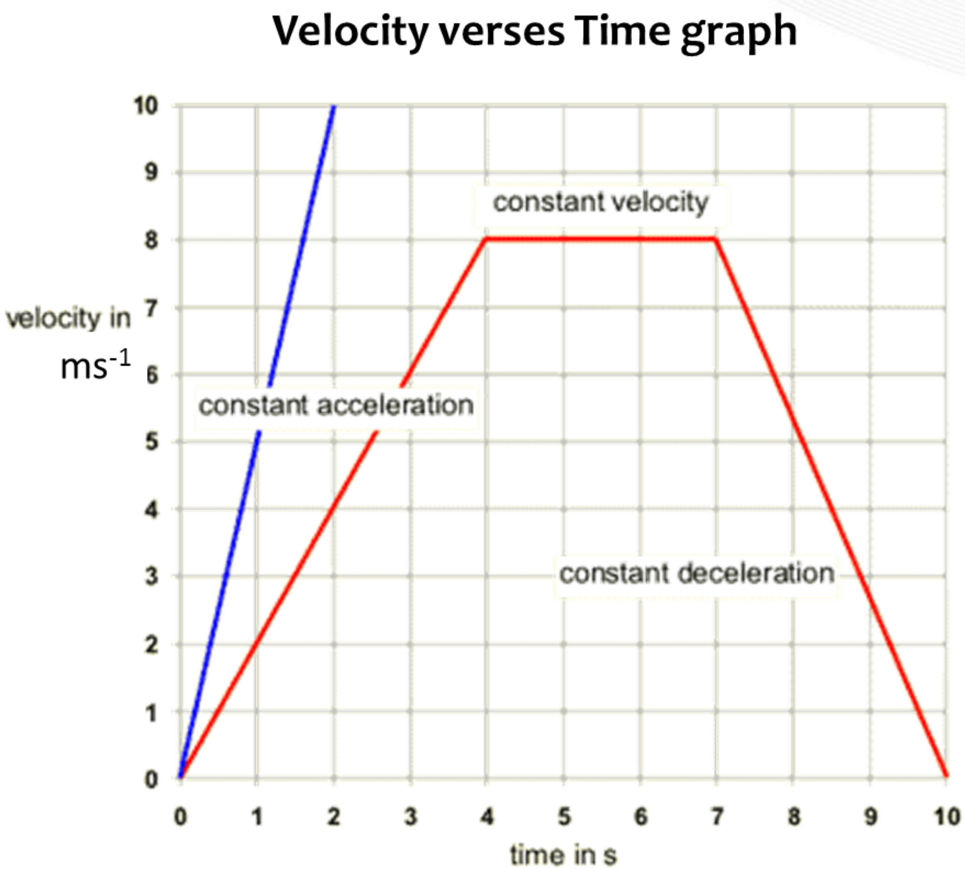
Speed-Time graphs



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

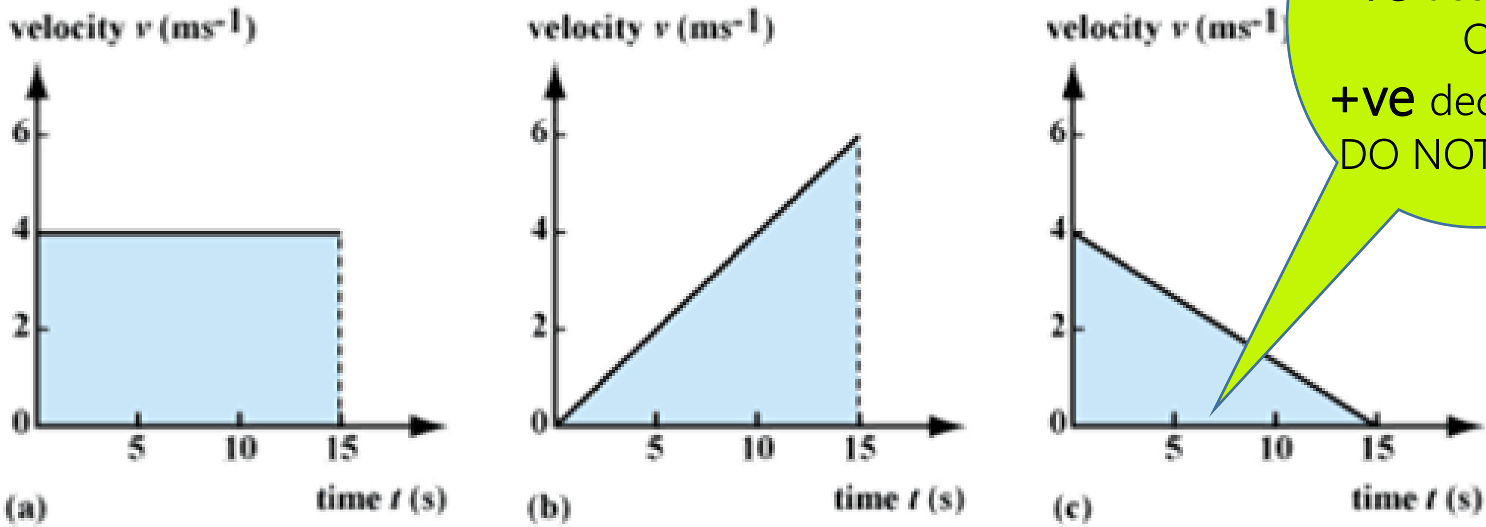
A speed - time graph can show **acceleration**.
The steeper the line (gradient), the faster the acceleration.

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)

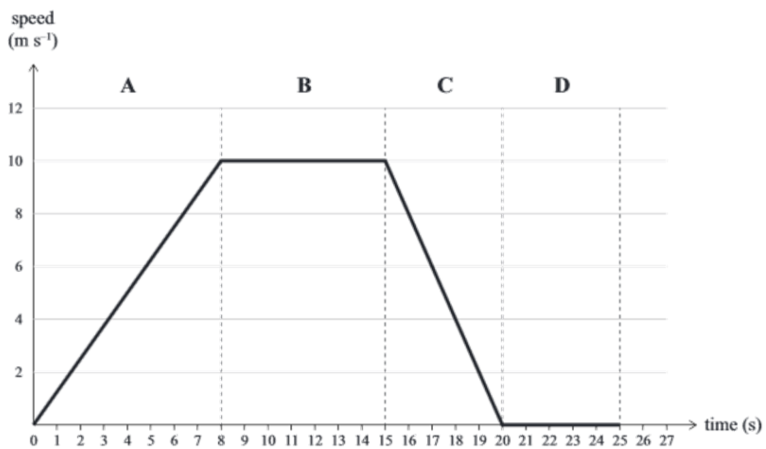
Use the start and finish points of the time and the velocity to work out the total change.
If the time starts from 0 use that as your start point.

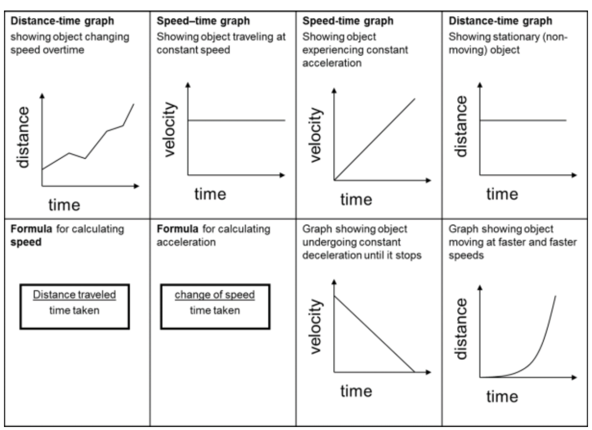
Remember: that Δ means change in.
The **line must be straight** in order to calculate acceleration

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.

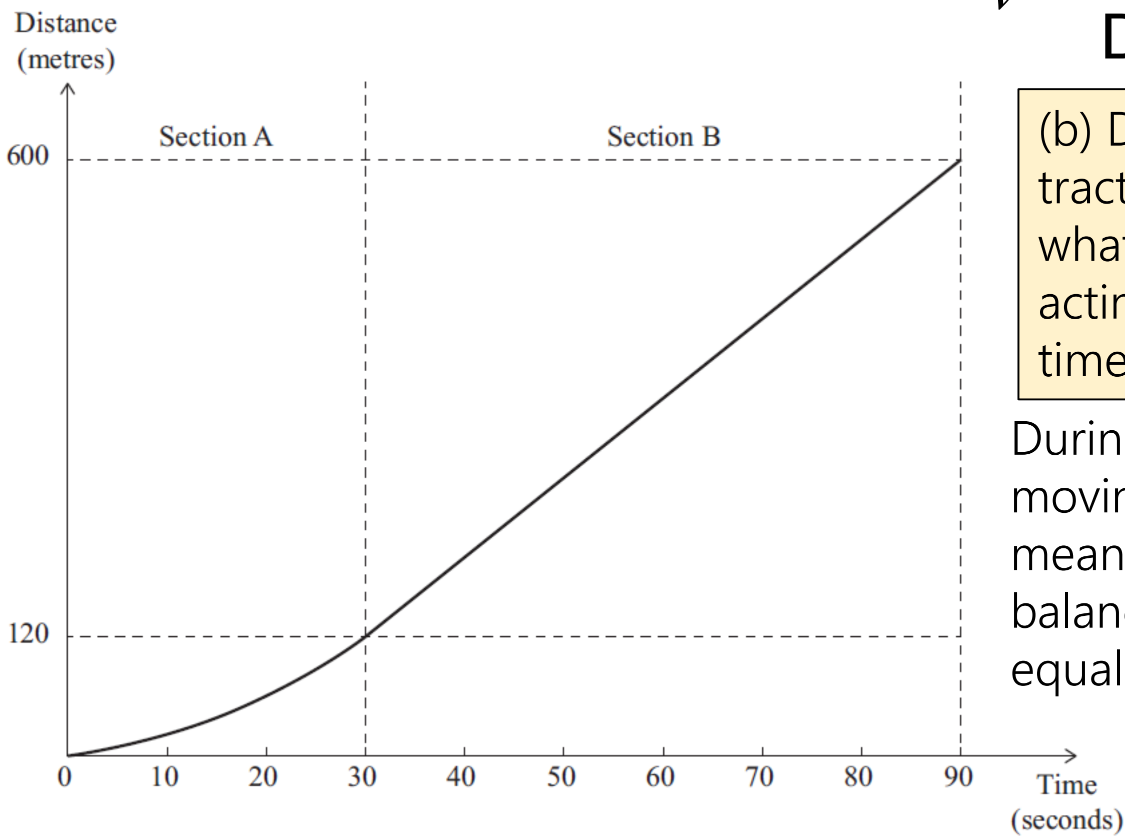
Make sure EVERY section is described and linked to data

Merit Question

NCEA 2012 Distance-time graph - The Tractor

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.

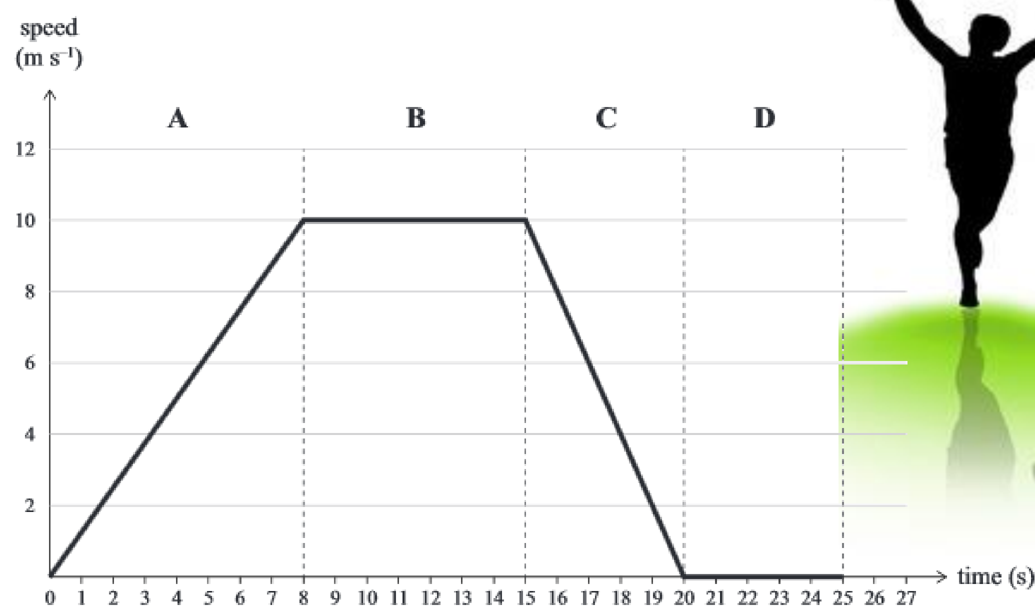
***NOT** forces are equal – but can be forces are equal sizes with **opposite direction**.*

NCEA 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.

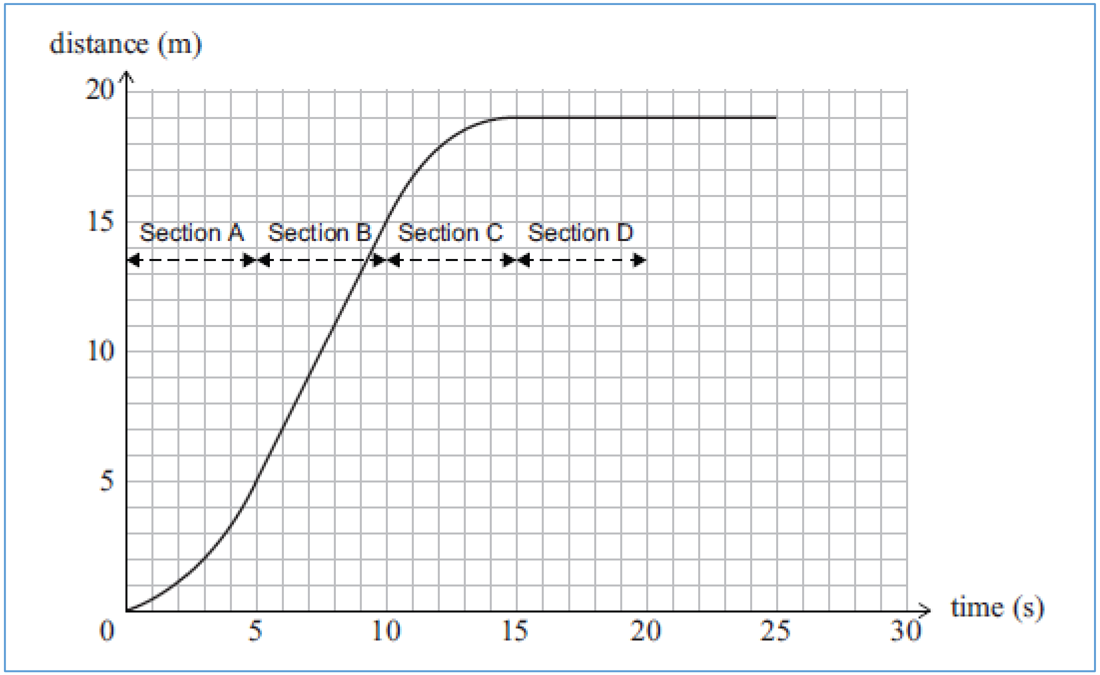


Using Data to back up answers

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.

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

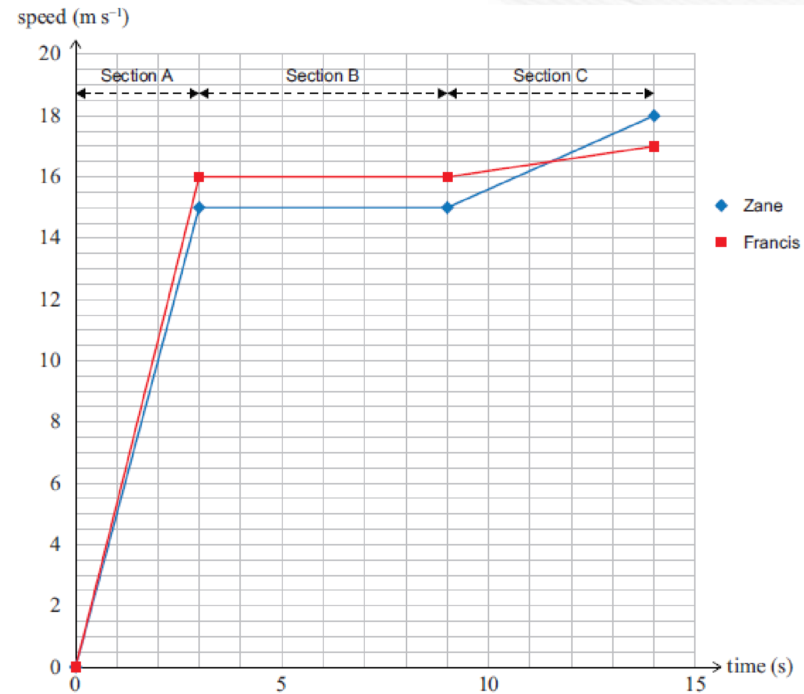
Q3: what is the total distance covered from 5 to 15seconds?

19m – 5m

= 14m in distance covered

NCEA 2014 Speed-time graph – Go-cart Racing

Q4: Two go-carts were racing on a track. A speed / time graph is shown below for each go-cart. Zane's graph is shown in blue, and Francis's in red.



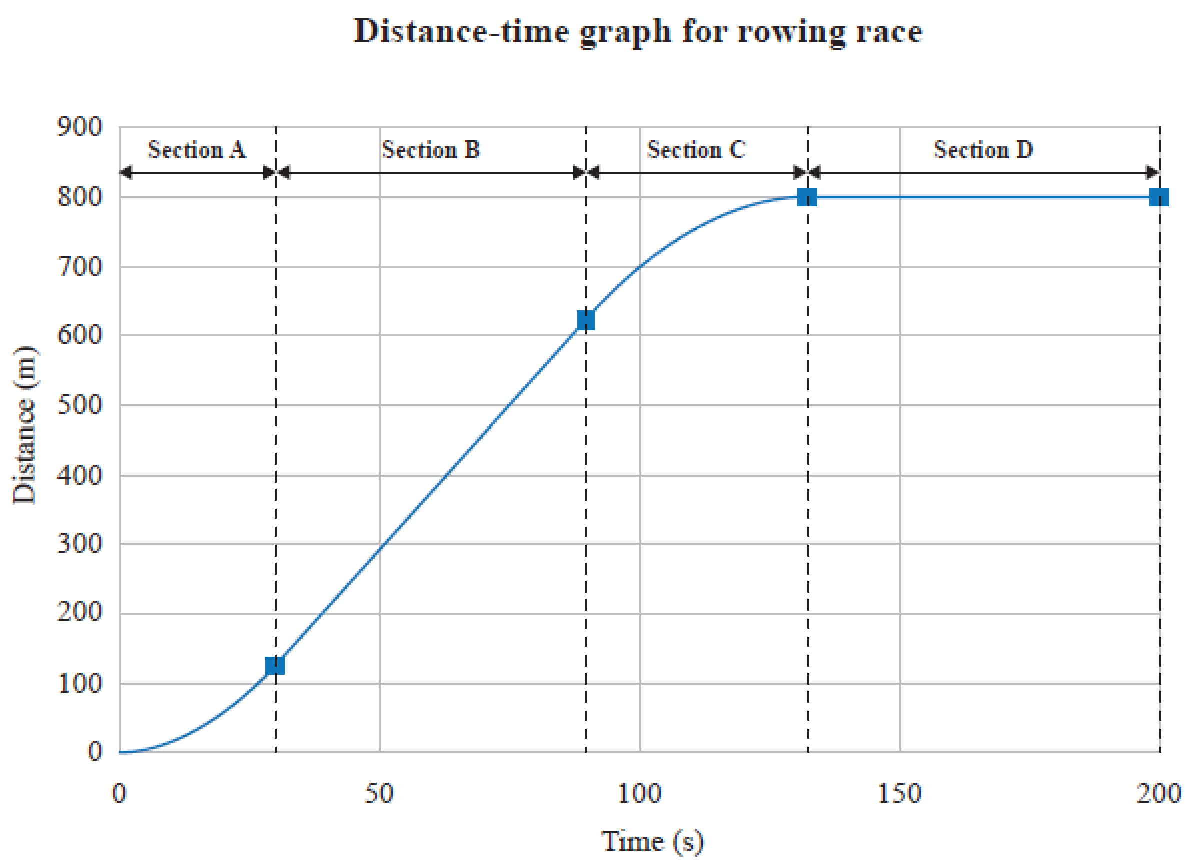
(a) Calculate the acceleration of Zane in the first 3 seconds.

$$a = \frac{\Delta v}{\Delta t} = \frac{(15 - 0)}{(3 - 0)} = 5\text{ m s}^{-2}$$

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

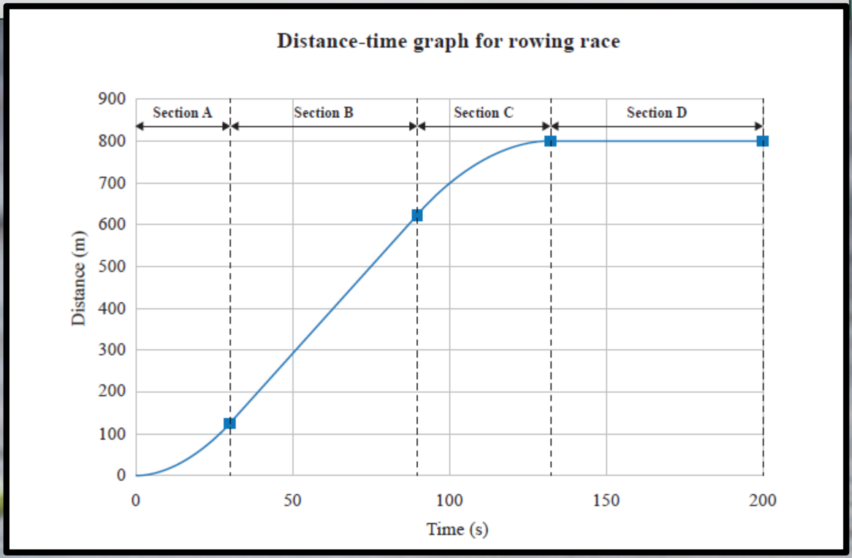
Merit Question

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.

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

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

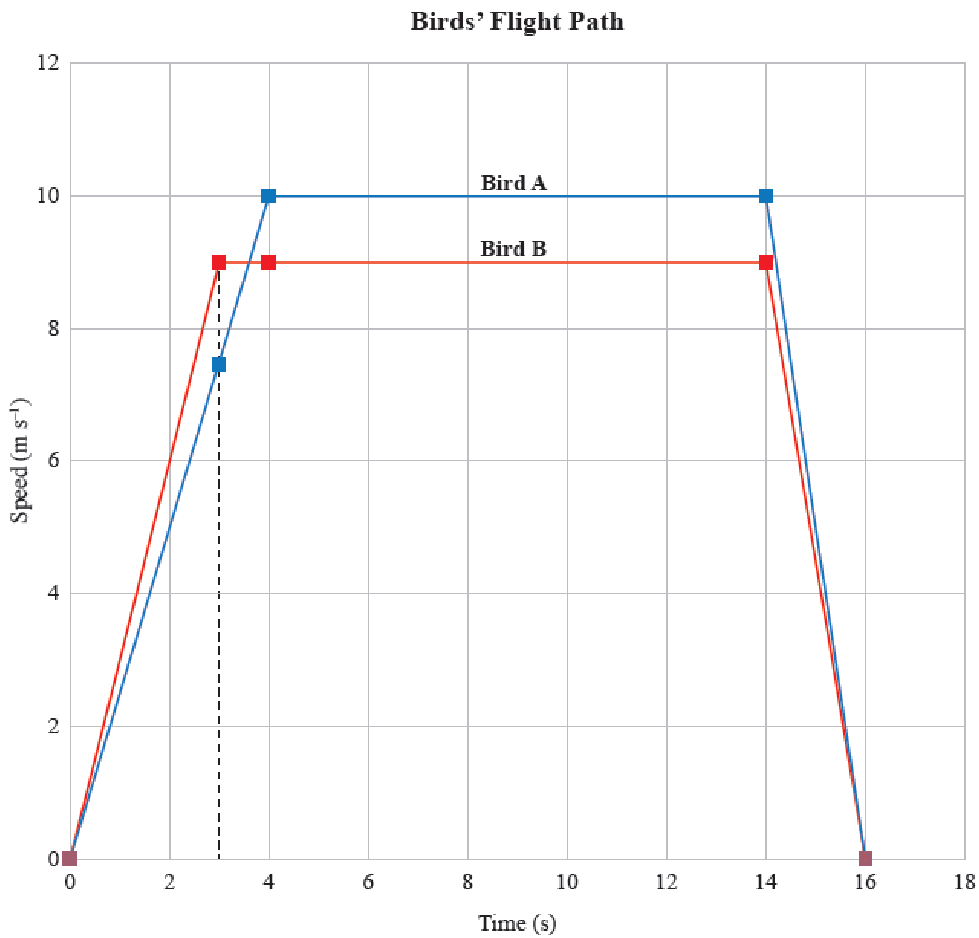
$$W = F \times d = 38.8 \times 125 = 4848\ \text{J}$$



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:

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

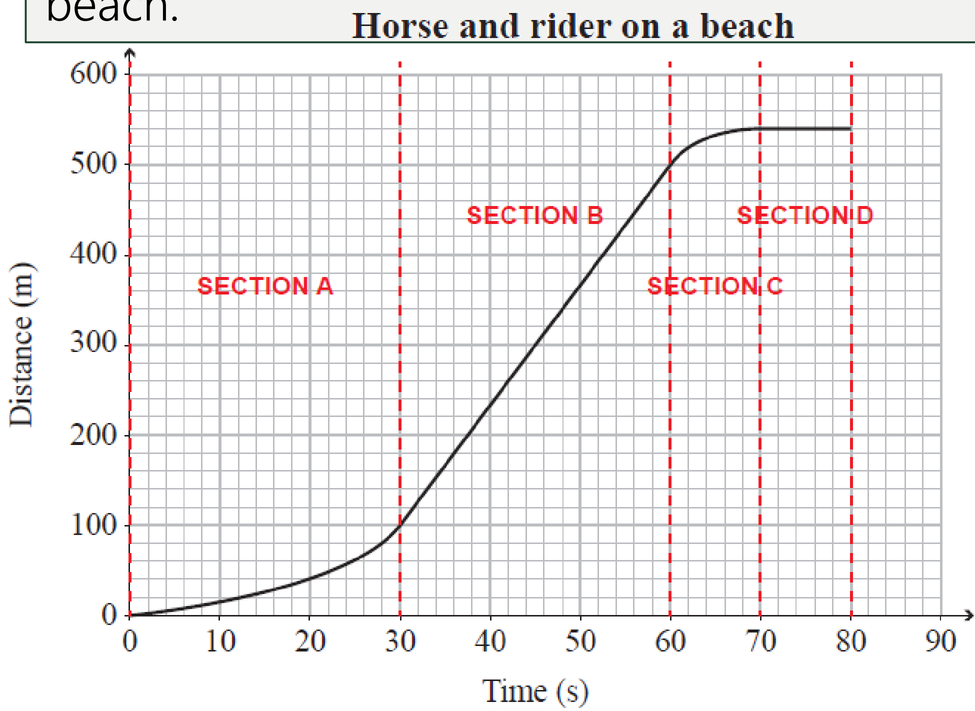
Bird B has an acceleration of:

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

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.

$v = \Delta d / \Delta t$

$= 400/ 30$

$= 13.3\ ms^{-1}$

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

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

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**.

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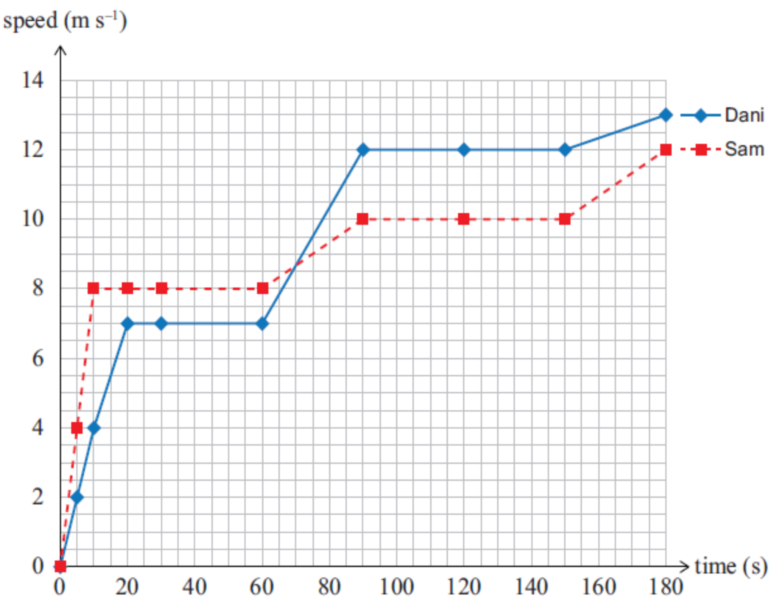

Sam accelerates at 0.8 m s–2 for 10 seconds, reaching a speed of 8 m s–1.
Stays at constant speed of 8 m s–1 for next 50 seconds.
Dani accelerates at 0.35 m s–2 for 20 seconds, reaching a constant speed of 7 m s–1. Stays at constant speed of 7 m s–1 for next 40 seconds.

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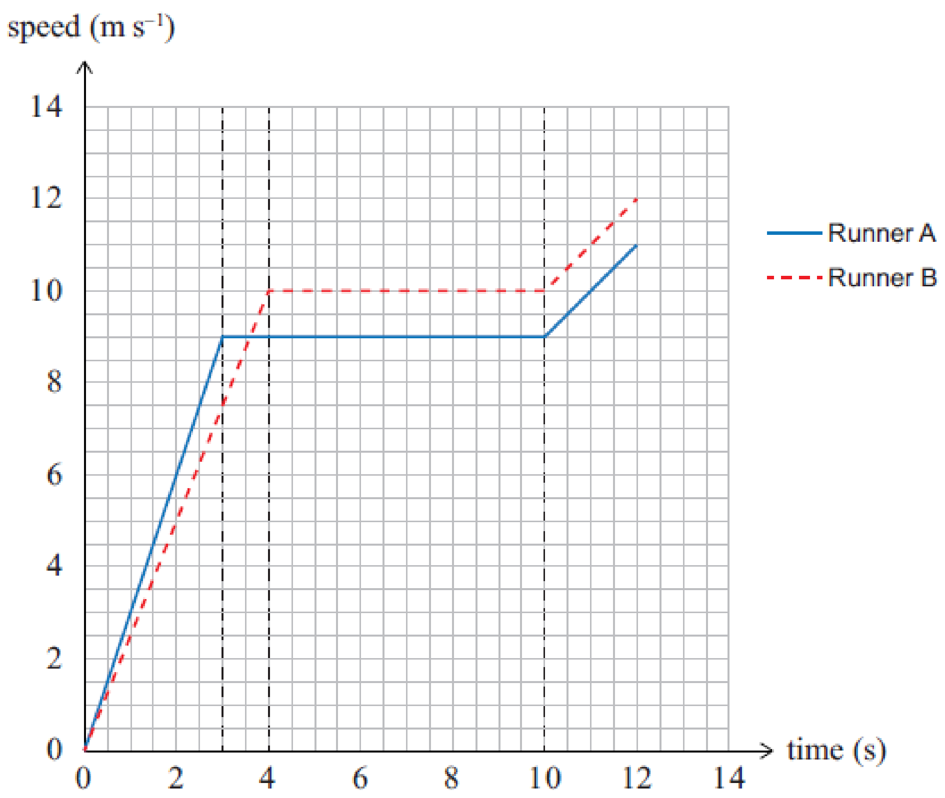
Question 1a: Two horses, ridden by Dani and Sam, are racing against each other. The speed-time graph of their two horses is shown below.
Use the information in the graph to compare the speed AND acceleration of Dani and Sam in the **first 60 seconds**.

Merit Question

NCEA 2018 speed-time graphs – Running Race (Part ONE)

Question 1a: The speed-time graph shows the motion of two runners in a 100 m race. From the graph, which runner has the greater acceleration in the first 3 seconds? Explain your answer. Calculations are not required.



Runner A has the greater acceleration during the first 3 seconds.
The gradient / slope of a speed-time graph equals the acceleration of the object. The steeper the slope, the greater the acceleration. Runner A has a steeper slope than Runner B in the first 3 seconds.

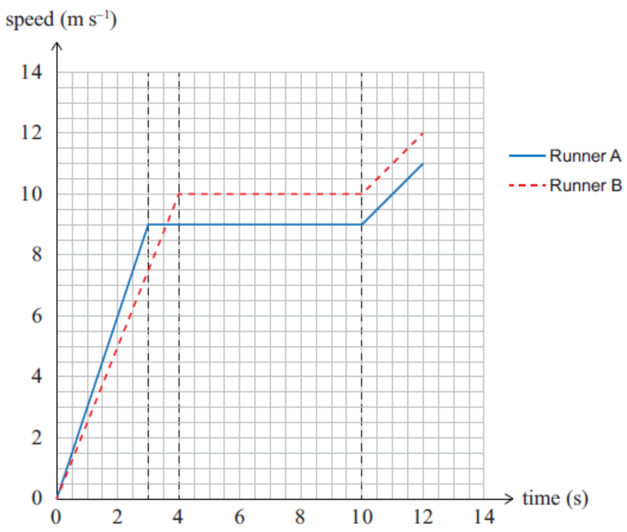
Question 1b: Using the graph, calculate Runner A's acceleration during the first 3 seconds.

$$a = \frac{\Delta v}{\Delta t} = \frac{9.0 - 0.0}{3.0 - 0.0} = 3.0 \text{ m s}^{-2}$$

Merit Question

NCEA 2018 speed-time graphs – Running Race (Part TWO)

Question 1c (i) : Use the information in the graph to compare the speed AND acceleration of Runner A and Runner B in the first 10 seconds.



Runner A accelerates at 3 m s–2 for 3 seconds, reaching a speed of 9 m s–1. Stays at constant speed of 9 m s–1 for next 7 seconds.
Runner B accelerates at 2.5 m s–2 for 4 seconds, reaching a constant speed of 10 m s–1. Stays at constant speed of 10 m s–1 for next 6 seconds.

	Speed	Acceleration
A	First 3 s: v= 4.5 m s^{-1} **The rest:** $\mathbf{v = 9\ m\ s^{-1}}$	**First 3 s:** $\mathbf{a = 3.0\ m\ s^{-2}}$ The rest: $a = 0$ m s^{-2}
B	First 4 s: $v = 5$ m s^{-1} **The rest:** $\mathbf{v = 10\ m\ s^{-1}}$	**First 4 s:** $\mathbf{a = 2.5\ m\ s^{-2}}$ The rest: $a = 0$ m s^{-2}

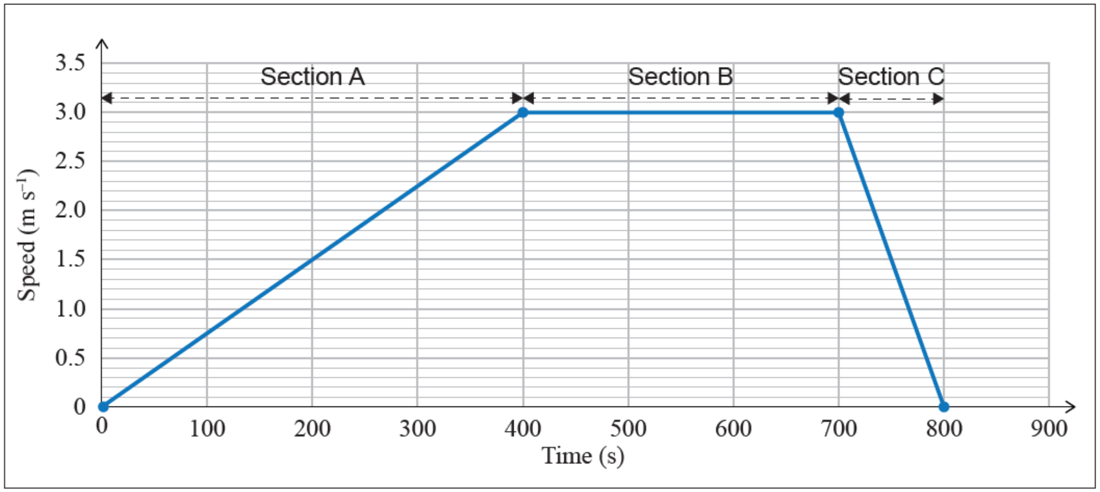
Comparison: Runner A has a greater acceleration during first 3 seconds, but does not accelerate for as long as Runner B. Between 4 and 10 seconds, neither accelerated, they both had a constant speed.
Runner B had a higher constant speed during this time.

Achieved Question

NCEA 2019 speed-time graph – Boat Journey

Question 1a: A boat travels across a lake to the start of a walking track. The graph below shows the boat's journey.
Describe the motion of the boat during each section of the journey.

Boat Journey



In Section A, the boat speeds up / accelerates for 400 s.
In Section B it has a constant speed of 3 m s^{-1} for 300 s.
In Section C it slows down / decelerating for 100 s.

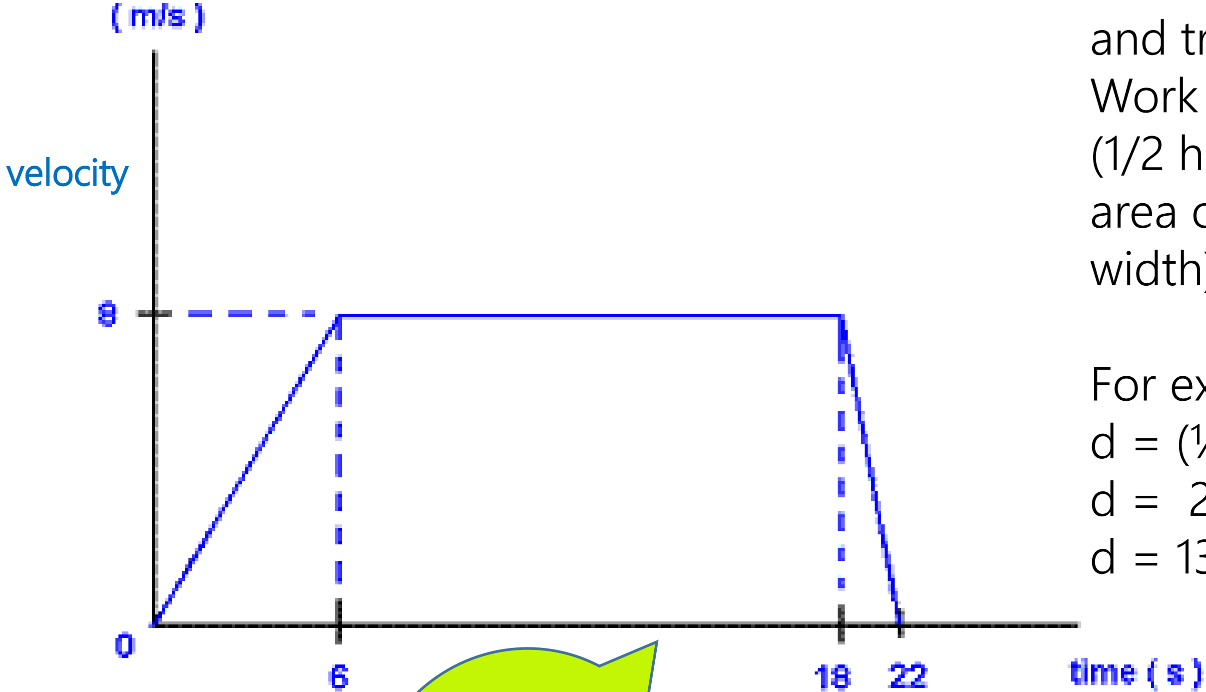
(b) Calculate the acceleration of the boat in the first 400 seconds.

$a = \Delta v / \Delta t \quad = 3.0 / 400$

$= 7.5\times10^{-3}$ m s^{-2} OR 0.0075m s^{-2} OR 7.5 E-3

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

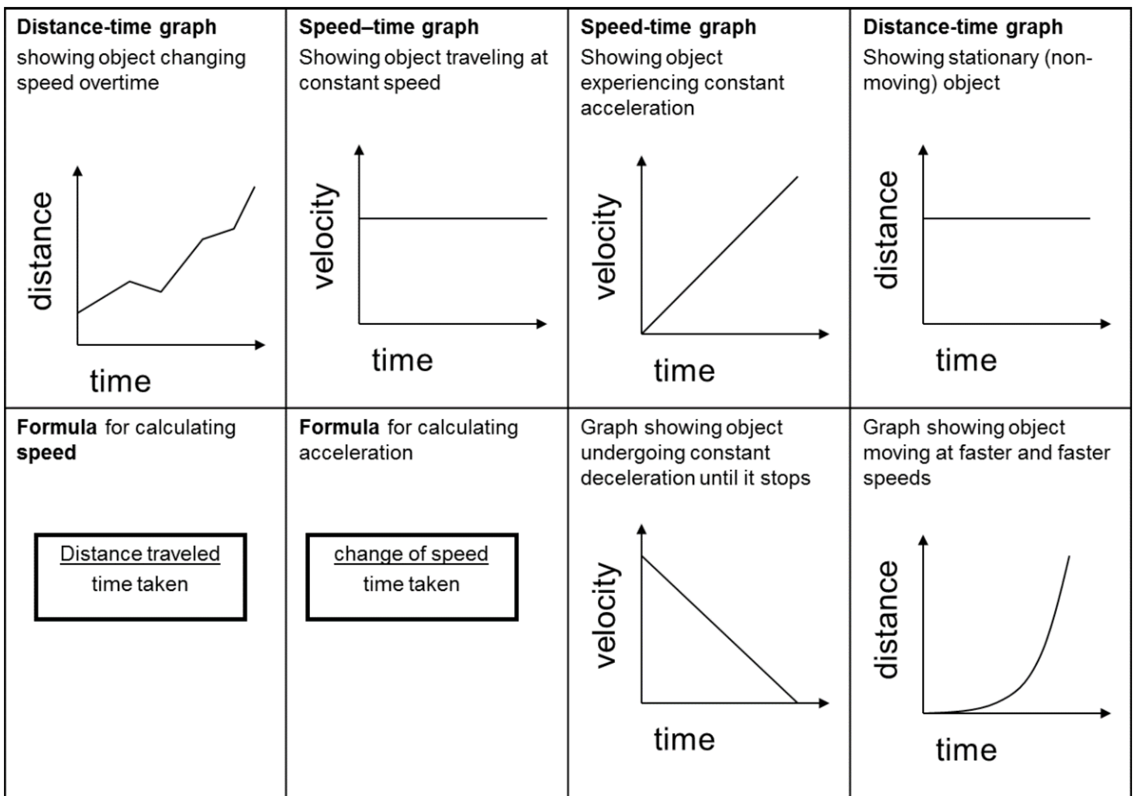
d = 136metres

Remember:
Area for rectangle
Base x height

Remember:
Area for triangle
½ x Base x height

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.



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

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)

$d_A = \frac{1}{2} \times 3 \times 16 = 24\text{ m}$

$d_B = 6 \times 16 = 96\text{ m}$

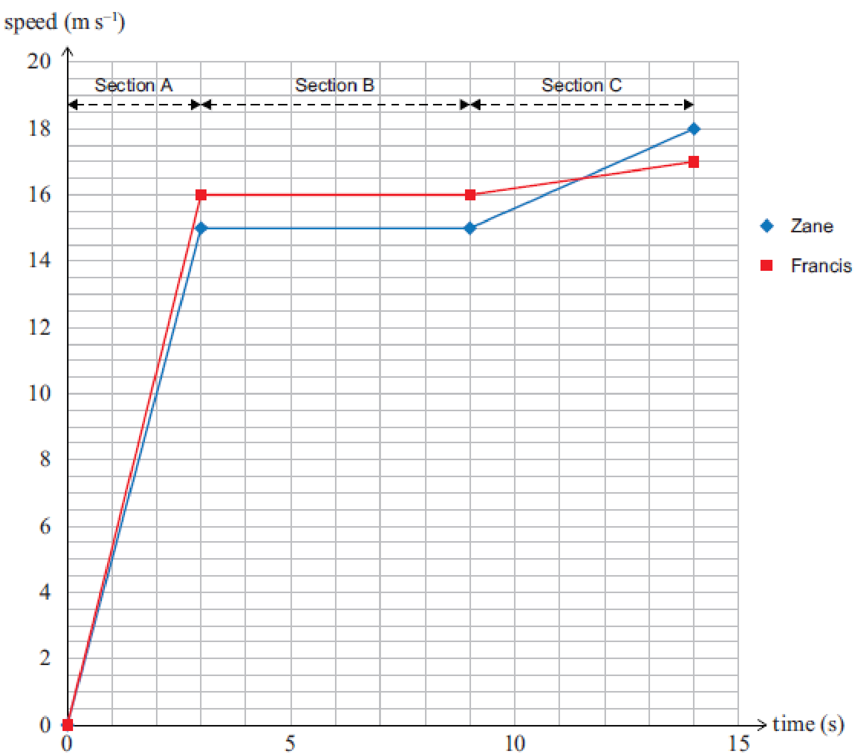
$d_C = \left(\frac{1}{2} \times 1 \times 5\right) + (5 \times 16) = 82.5\text{ m}$

$d_{Total} = 202.5\text{ m}$

NCEA 2014 Distance in a Speed-time graph – Go-cart Racing

4c : Explain which go-cart travelled 200 m around the track first.
In your answer you should: • use the information in the graph • show all working for the calculations • compare the distances travelled by Zane and Francis by the end of 14 s.

Francis travelled the greater distance.



Distance Francis has covered

Area under the graph is:

$$d_A = \frac{1}{2} \times 3 \times 16 = 24\text{ m}$$

$$d_B = 6 \times 16 = 96\text{ m}$$

$$d_C = \left(\frac{1}{2} \times 1 \times 5\right) + (5 \times 16) = 82.5\text{ m}$$

$$d_{Total} = 202.5\text{ m}$$

Distance Zane has covered

Area under the graph is:

$$d_A = \frac{1}{2} \times 3 \times 15 = 22.5\text{ m}$$

$$d_B = 6 \times 15 = 90\text{ m}$$

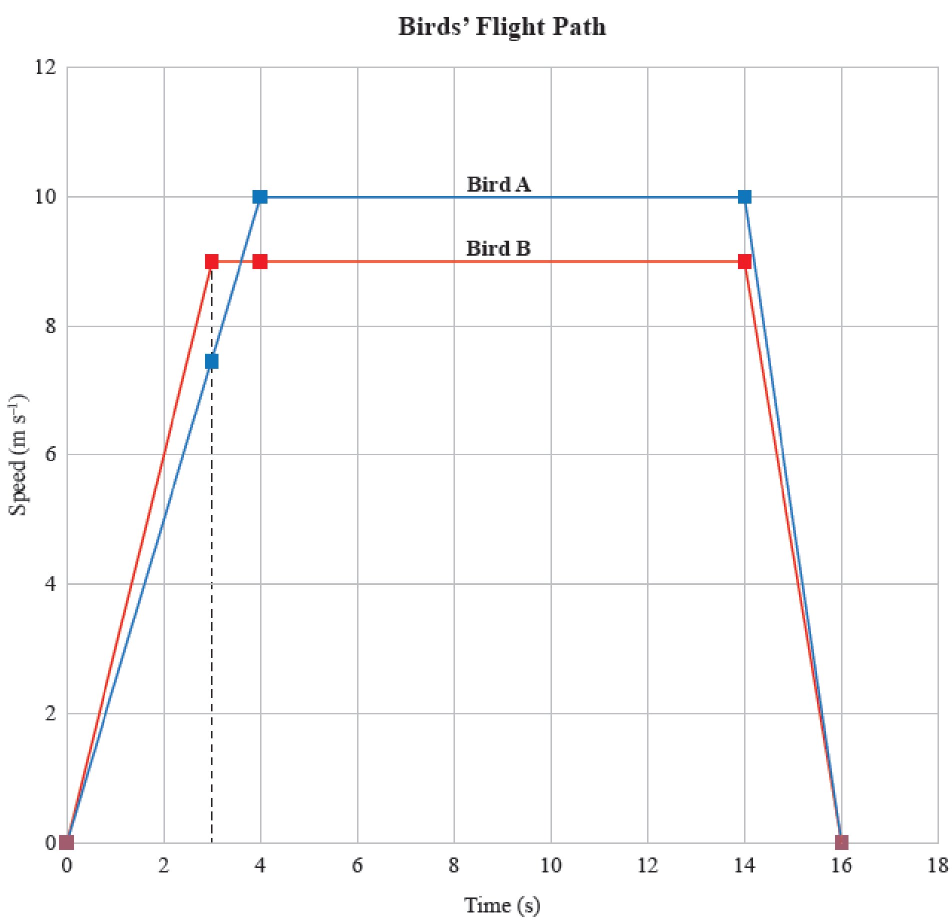
$$d_C = \left(\frac{1}{2} \times 5 \times 3\right) + (5 \times 15) = 82.5\text{ m}$$

$$d_{Total} = 195\text{ m}$$

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:

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

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

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

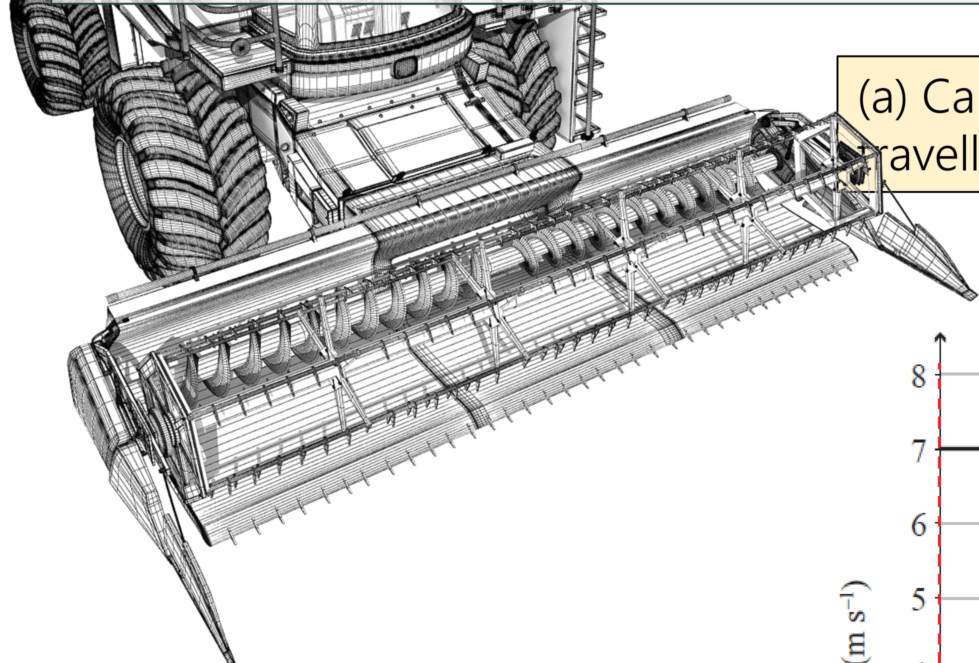
Total distance = 130 m

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

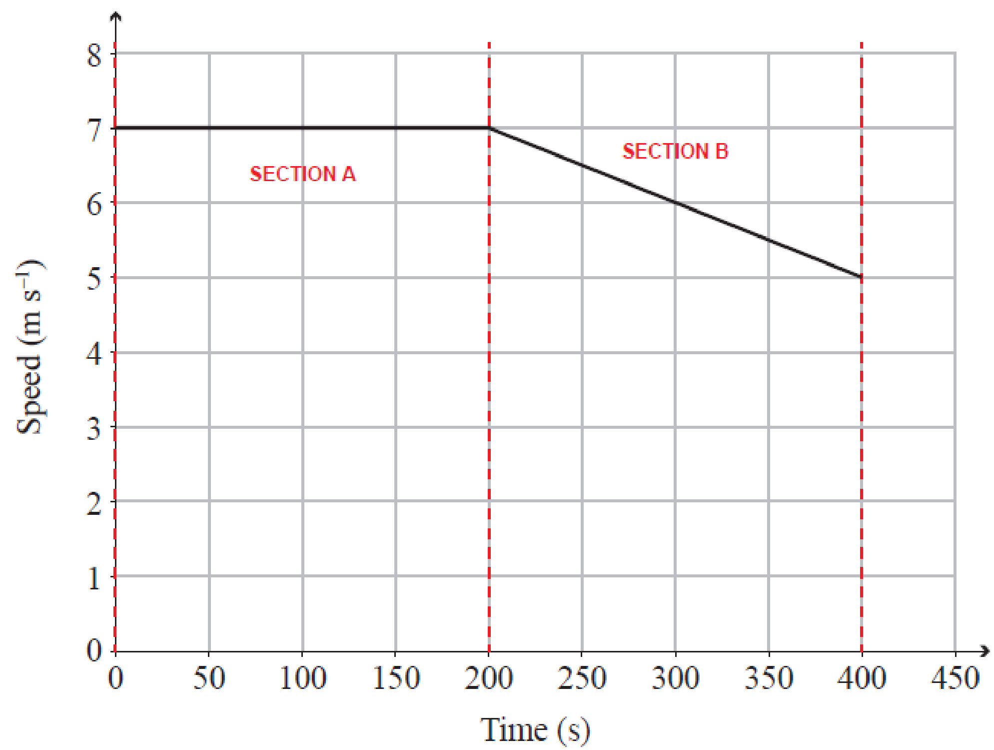
2a. A harvester was working in a paddock. The speed-time graph shows the journey of the harvester.



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

Merit Question

Speed-time graph of a harvester

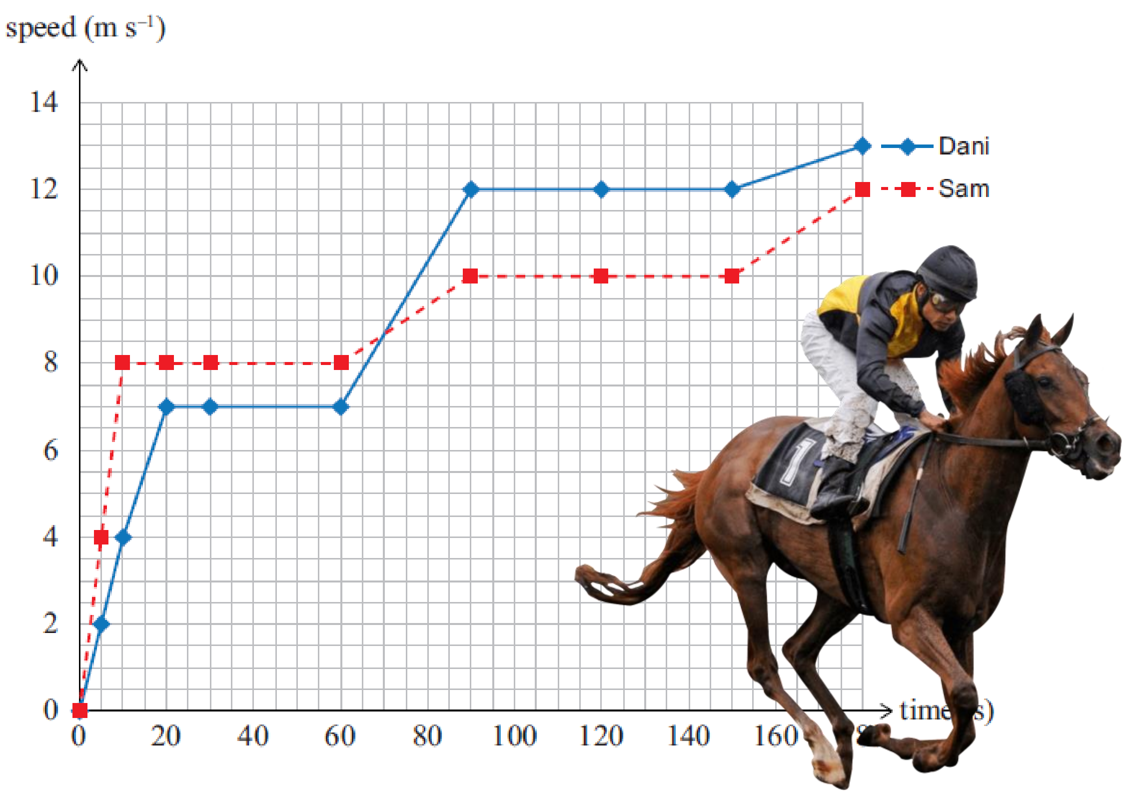


The harvester has travelled:
(section A) 0 – 200 s:
7(h) x 200(b) = 1400 m
Total distance = **1400m**

Excellence Question

NCEA 2017 distance in a speed-time graph – 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)

Excellence Question

NCEA 2018 distance in a speed-time graph – Running Race

Question 1c (ii) : Use the information in the graph and calculations to show which runner, Runner A or Runner B, finished the 100 m first.

Freepik.com

Distance = area under graph.

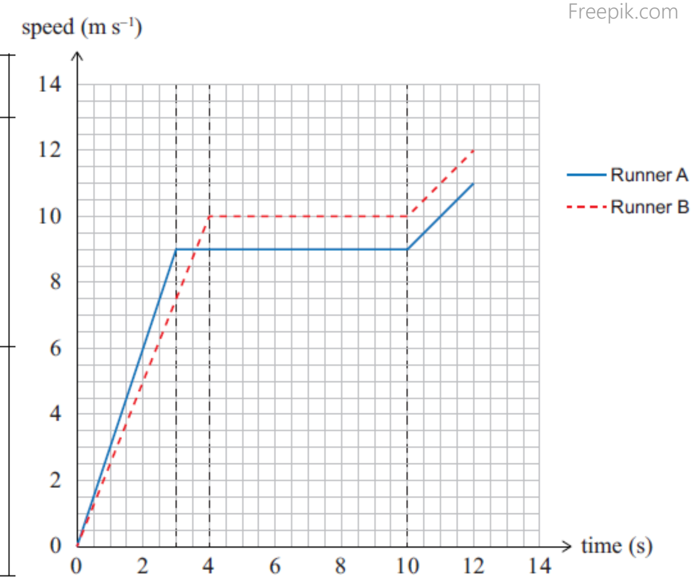
d (Runner A) = (½ x 9 x 3) + (9 x 9) + (1/2 x 2 x 2)

= 13.5 + 63 + 18 + 2
= 96.5m

d(Runner B) = (1/2 x 10 x 4) + (8 x 10) + (1/2 x 2 x 2)

= 20 + 80 + 2
= 102m
Therefore, only Runner B has finished the race.

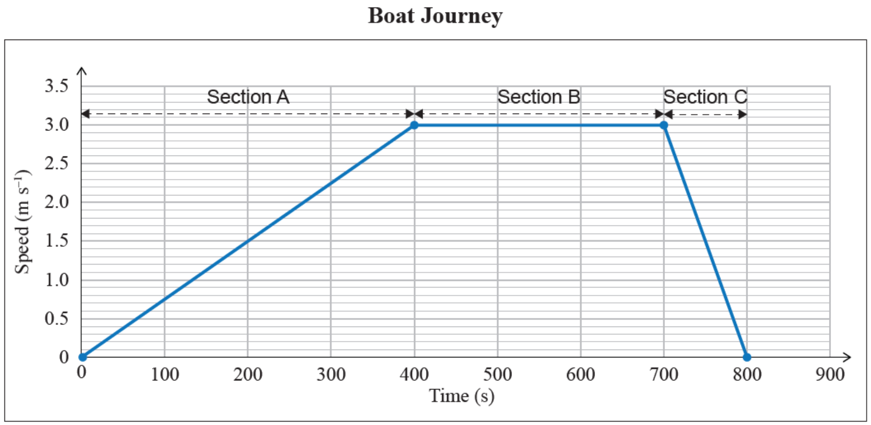
	Speed
A	First 3 s: $v = 4.5$ m s^{-1} **The rest:** $v = 9$ m s^{-1}
B	First 4 s: $v = 5$ m s^{-1} **The rest:** $v = 10$ m s^{-1}



Excellence Question

NCEA 2019 Distance in a speed-time graph – Boat Journey

Question 1d: Show that the total distance travelled by the boat is 1650 m.



Distance travelled = area under the graph.

d = (0 – 400 s) = ½ × 400 × 3 = 600 m

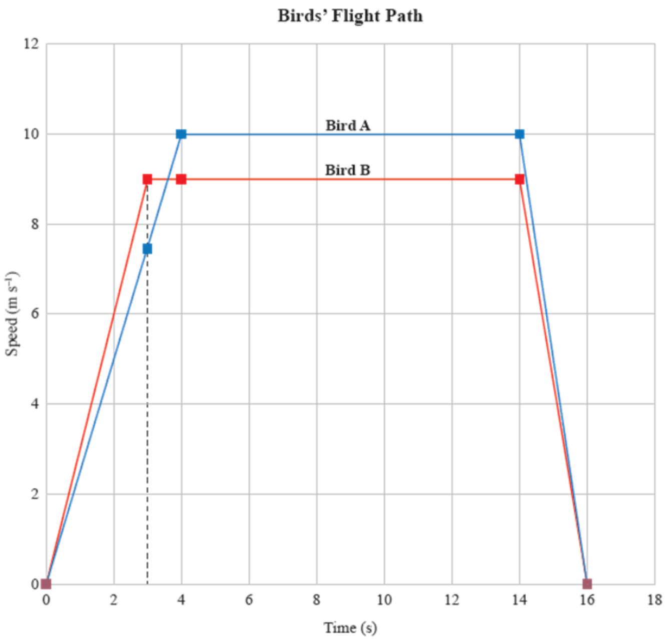
d = (400 – 700 s) = 300 × 3 = 900 m

d = (700-800s) = ½ x 100 x 3 = 150m

Total distance = 600 + 900 + 150 = 1650m

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:

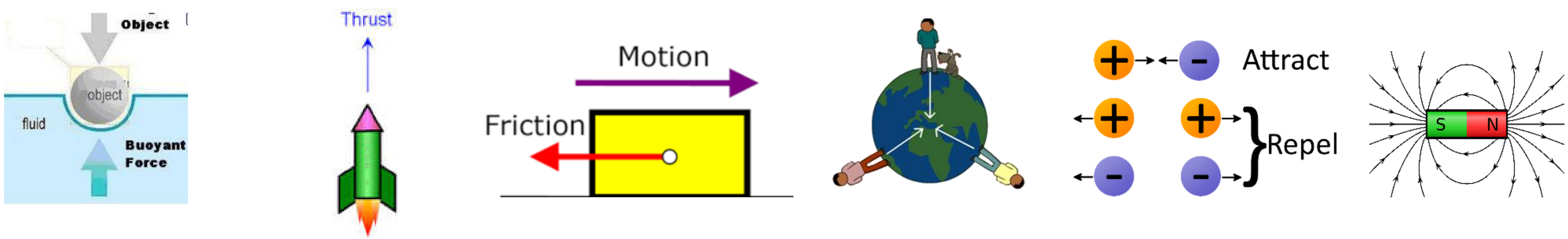
- The shape of an object
- The movement of an object
- The velocity of an object

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

- Forces
  - Contact Forces
    - Buoyancy and surface tension
    - Thrust Force
    - Friction
  - Non-contact Forces
    - Gravitational Forces
    - Electrostatic Forces
    - Magnetic Forces



Pushes, pulls, friction and tension are **contact forces**. Whatever causes the force actually touches the object it acts upon.

Non-contact forces such as electrostatic forces, magnetic forces and gravitational forces act without contact between the object.

Thrust force

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

Acceleration is the state of an object, due to a force applied. It is dependent on the force, and on the mass of an object, but is not a force itself.

Friction force opposes an object that is experiencing thrust force.

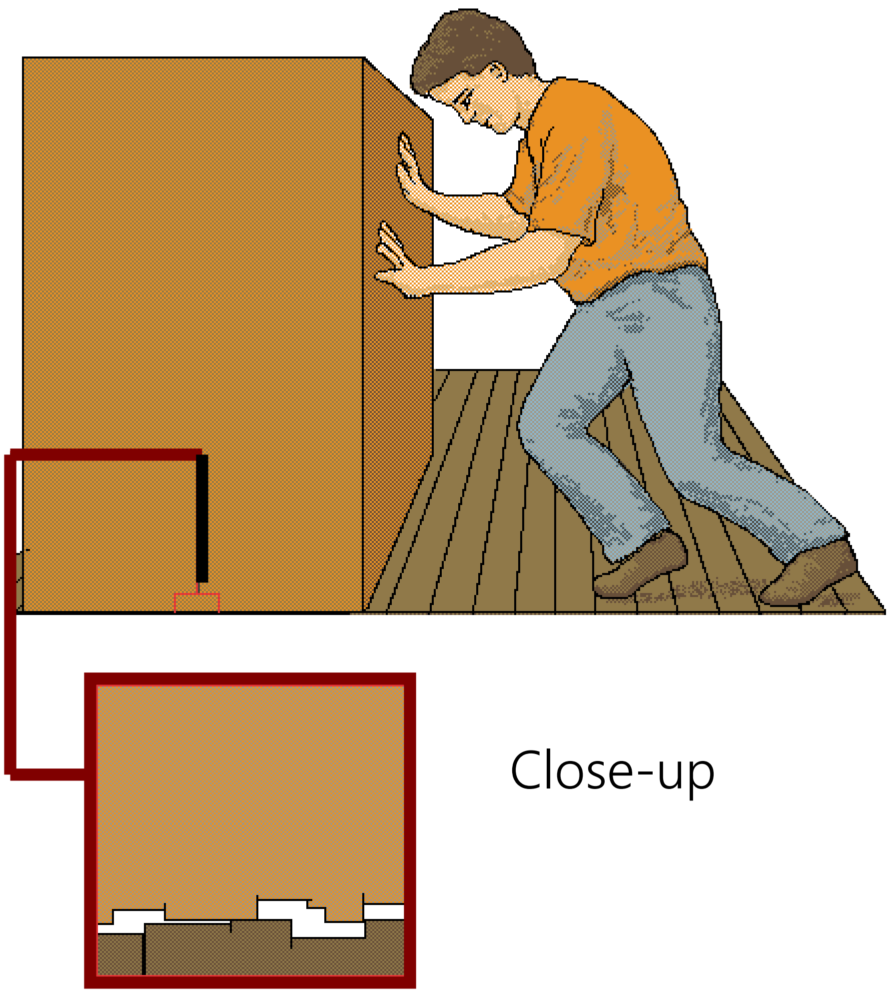
Thrust and friction are “paired forces” that act in opposite directions on an object

Friction often provides opposing force acting on moving bodies

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

When friction occurs, and one surface moves against another, the movement causes Kinetic energy to be changed into heat energy.
Smooth surfaces create less friction than rough surfaces.
Friction that occurs between air or water and a solid body is called resistance.

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



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

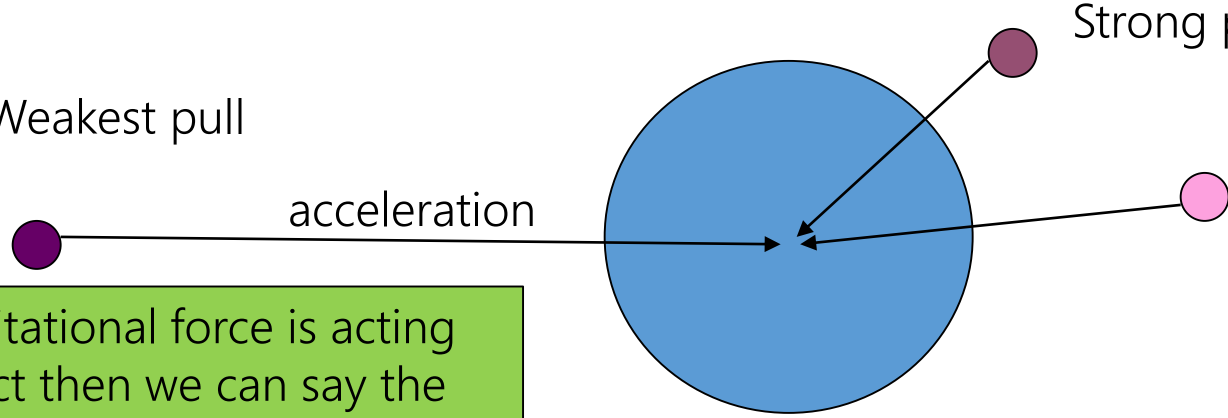
Objects create a gravitational field around them. Gravity gives objects of mass in the field a **weight force**. If the object is not in a gravitation field, it is “weightless”

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

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

>this causes **acceleration** if there is no equal support force

>an object of mass will experience **weight force**

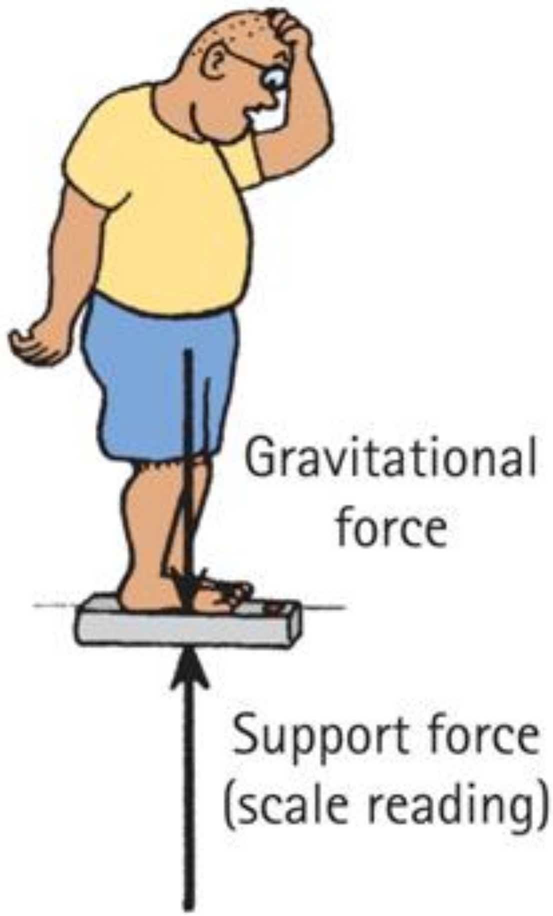


When gravitational force is acting on an object then we can say the object has weight force

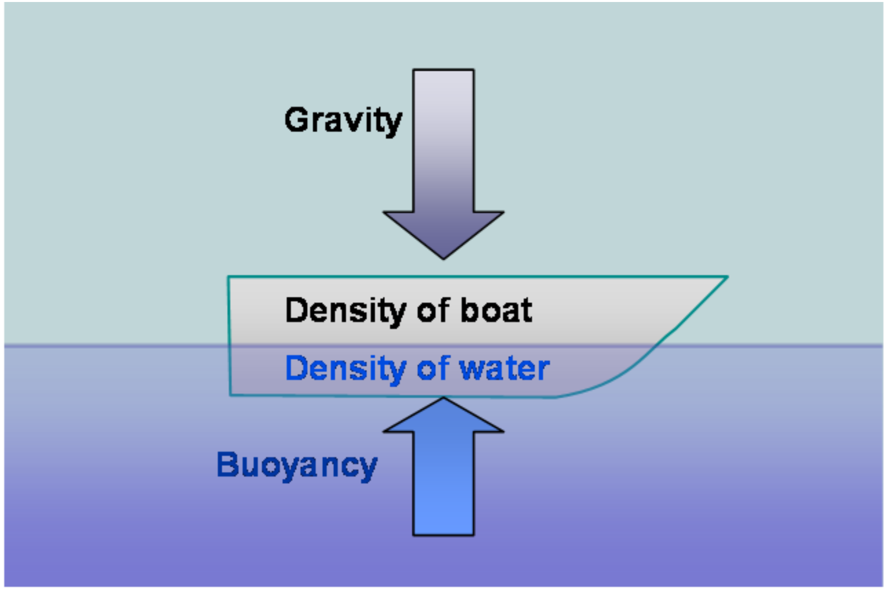
Support forces

Support forces are equal and opposite to an object experiencing weight if the forces are **balanced.**

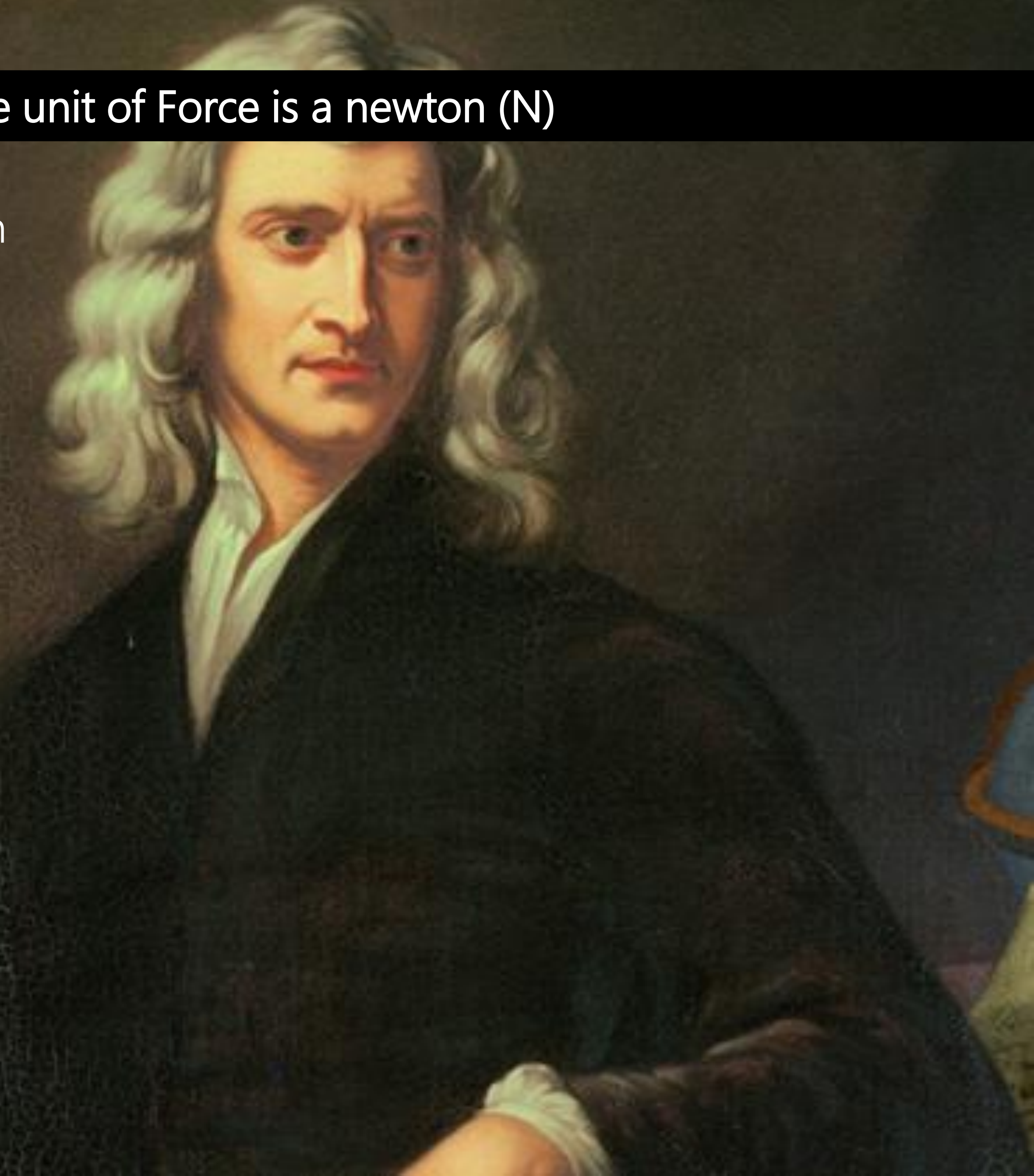
Support force in air is called lift and in water is called buoyancy.



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



The unit of Force is a newton (N)



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 **newtons (N).**

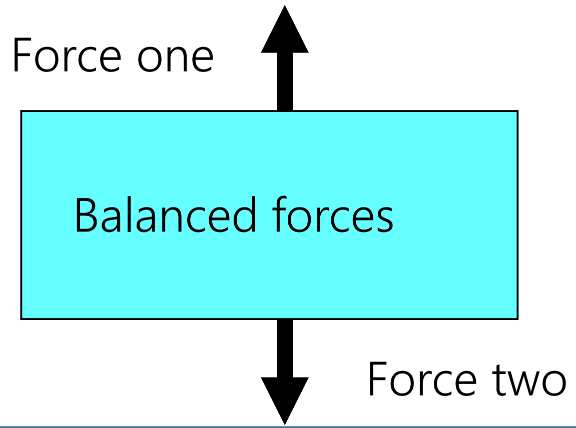
Newton's Laws

First Law

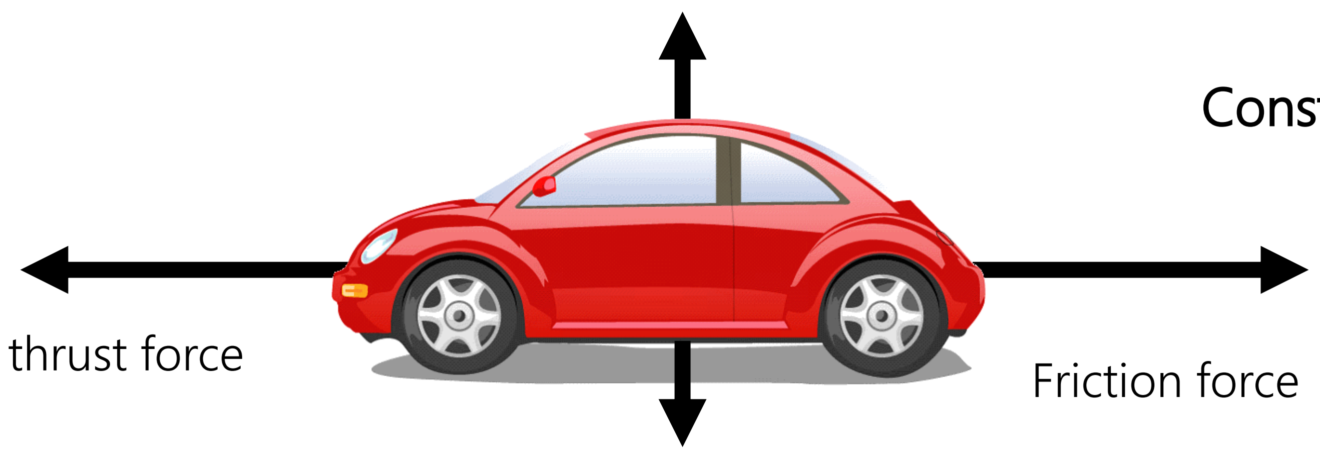
If the forces acting on an object are balanced, then the object will remain stationary or carry on at the same speed in the same direction.

Force diagrams show the magnitude and direct of each force

Stationary



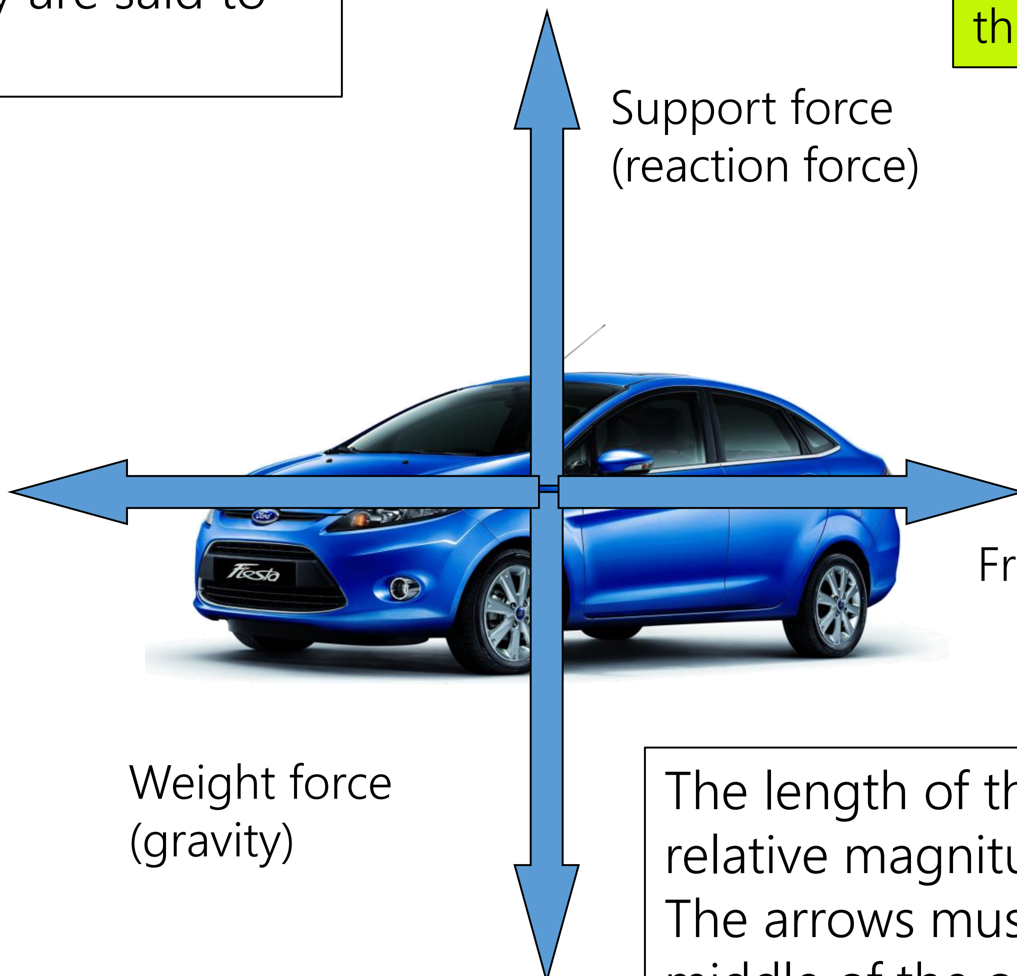
Constant speed



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

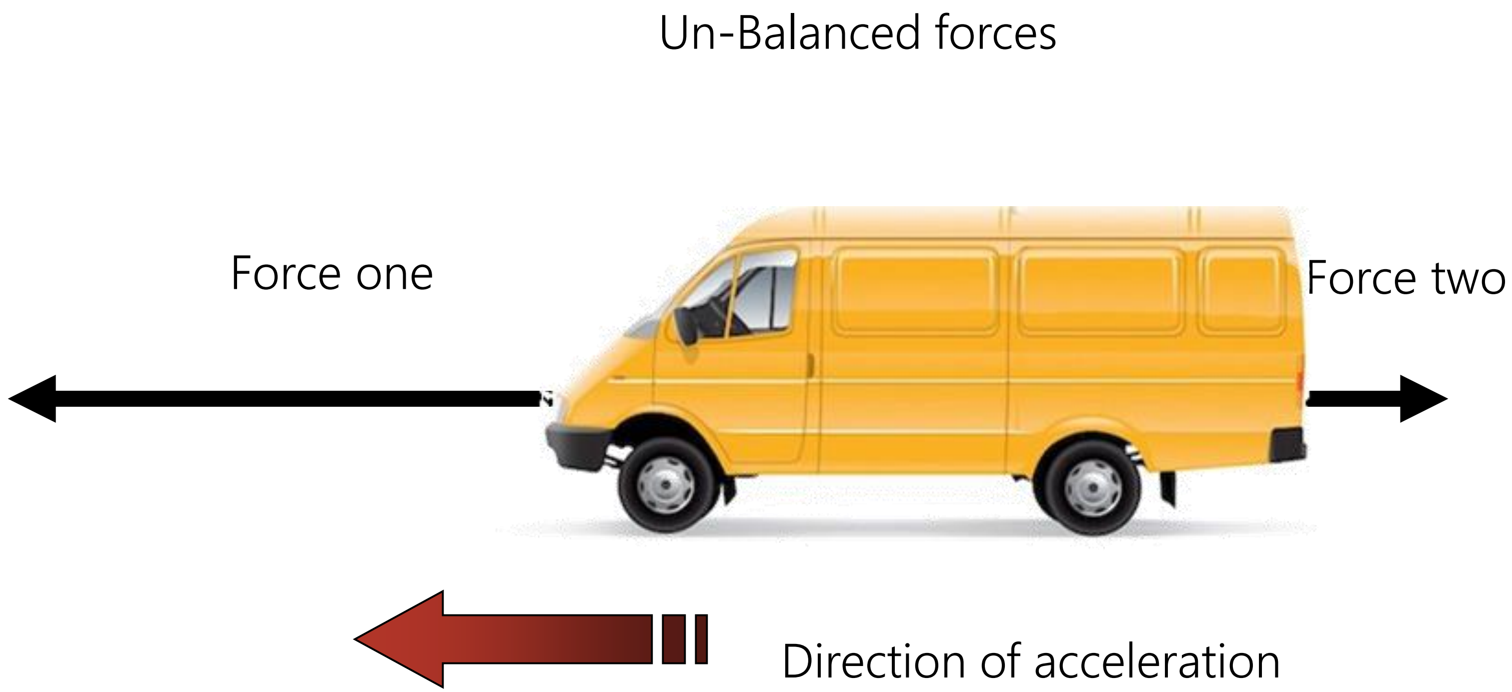
When skydivers reach **terminal velocity,** they are traveling at a constant speed. The forces of gravity accelerating the skydiver towards earth are matched exactly by the force of friction from the air particles pushing against the skydiver. If the person wears an aerodynamic suit or points their body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

Newton's Laws

Second Law

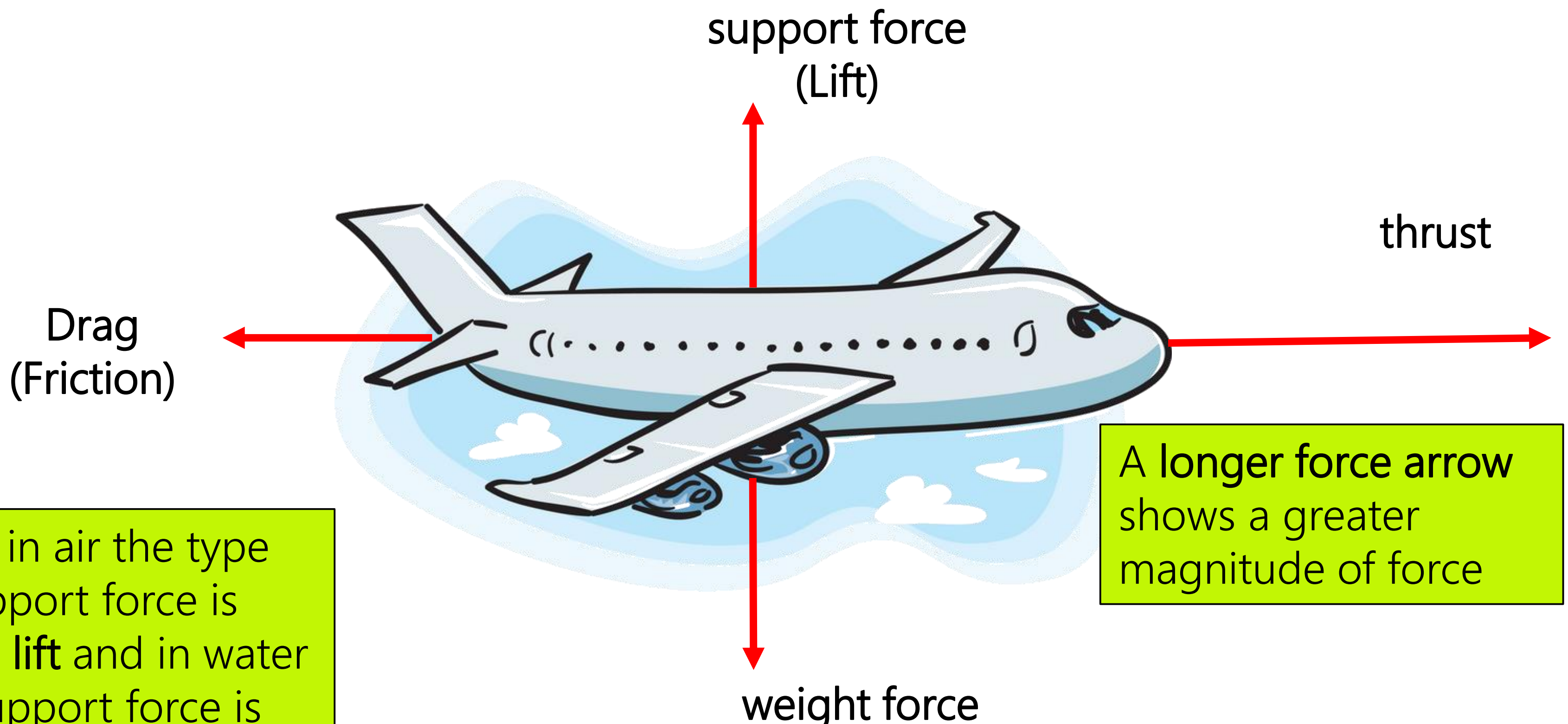
If unbalanced forces act on an object, then the object will accelerate in the direction that the net force acts.

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)



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

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

Net Force

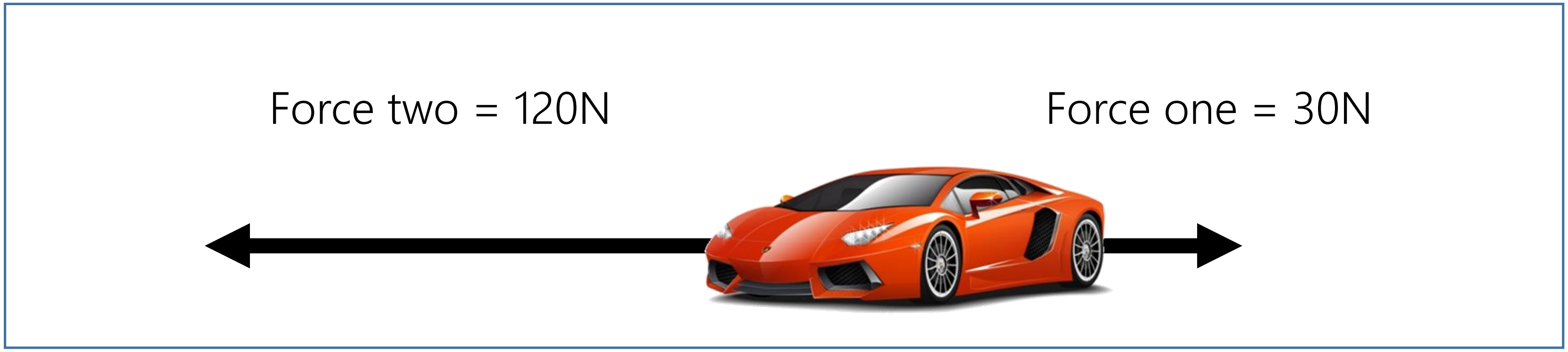
A net force is the resultant force when multiple forces interact. When forces are balanced on an object, the net force is **zero.** If there is zero net force, the object maintains **constant speed or is stationary.**

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.

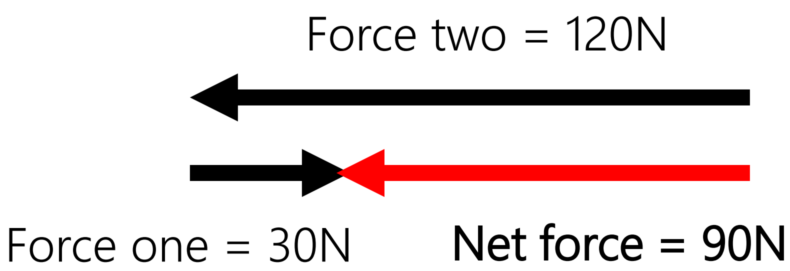
Calculating Net Force

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



NCEA 2013 Force diagrams – The Runner

MERIT question

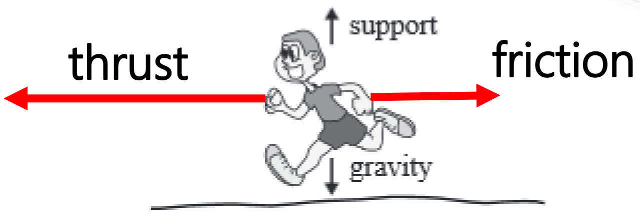
Q 1b: On the diagrams below, draw and label the thrust and friction forces acting on the runner in sections A, B, and C. (see below)
In your answer you should:
•use arrows to show the directions of the thrust and friction forces
•beside each diagram, state if thrust is greater than friction, thrust is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

The gravity and support forces have been done for you

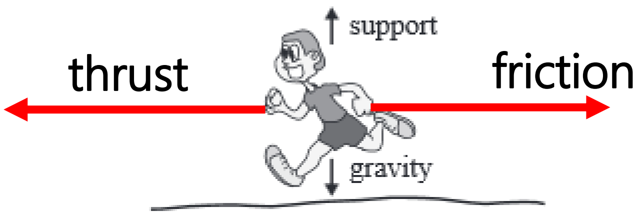
Section A: Accelerating
Section B: Constant speed
Section C: Decelerating

From previous question

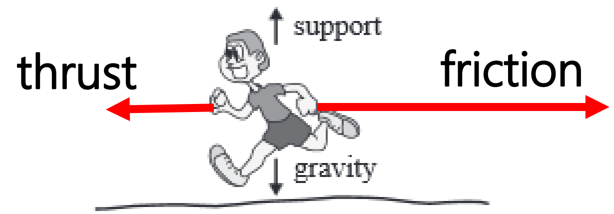
Section A



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.

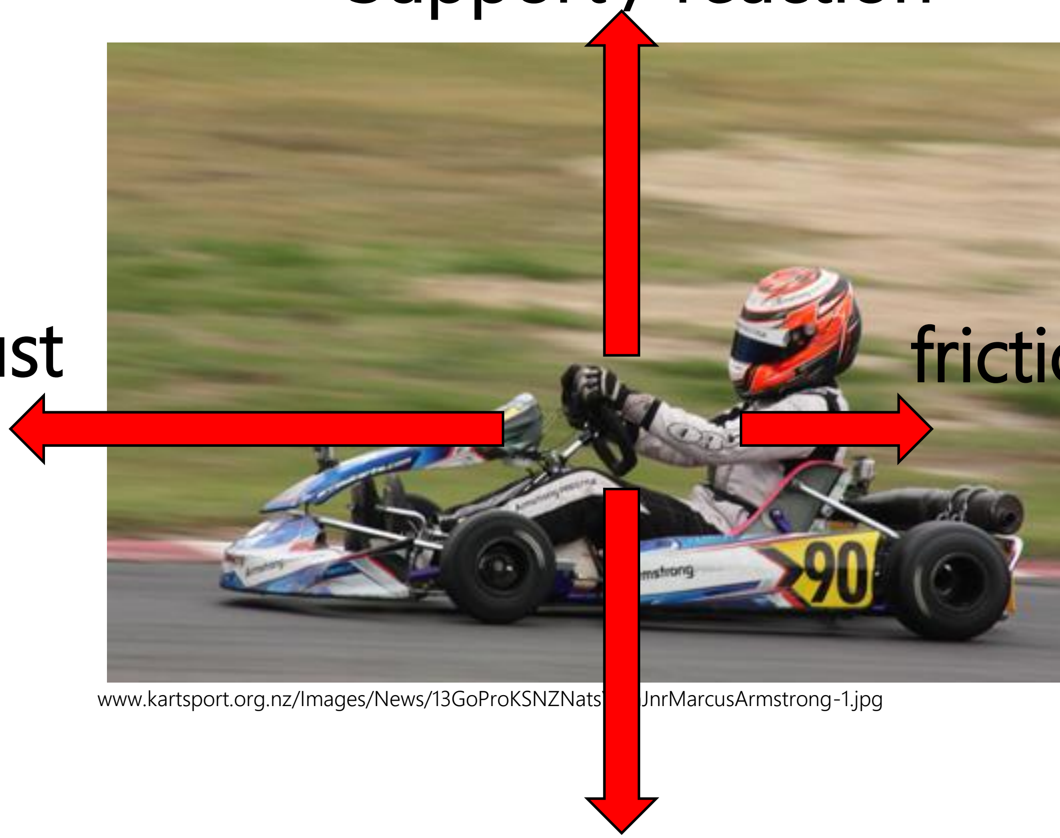
Section A:
The runner is accelerating. This is because there is a net force pointing forwards. This occurs when the thrust force is greater than friction.

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 2014 Net Force – Go-cart Racing (Part ONE)

4b (i) : On the photo below, draw and label ALL the forces acting on Zane's go-cart in **Section B** of the graph. The track is flat and horizontal. Ensure that your labels show the relative sizes of the forces.



www.kartsport.org.nz/Images/News/13GoProKSNZNats/JnrMarcusArmstrong-1.jpg

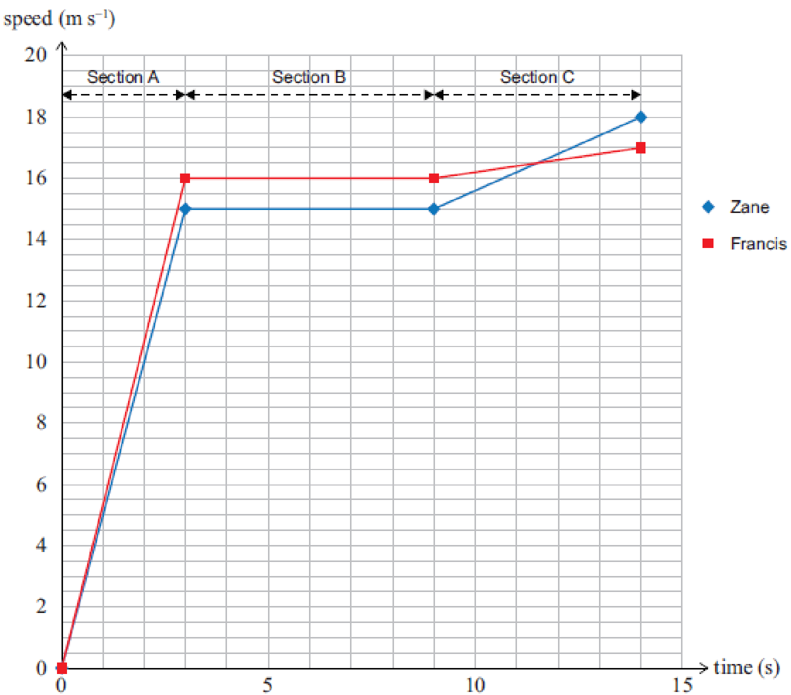
NCEA 2014 Net Force – Go-cart Racing (part TWO)

4b (ii) : Discuss the forces that are acting on Zane's go-cart to explain its motion in Section B of the graph.

Weight and support are equal and opposite. (evidence can come from b (i))

Thrust and friction are equal and opposite.

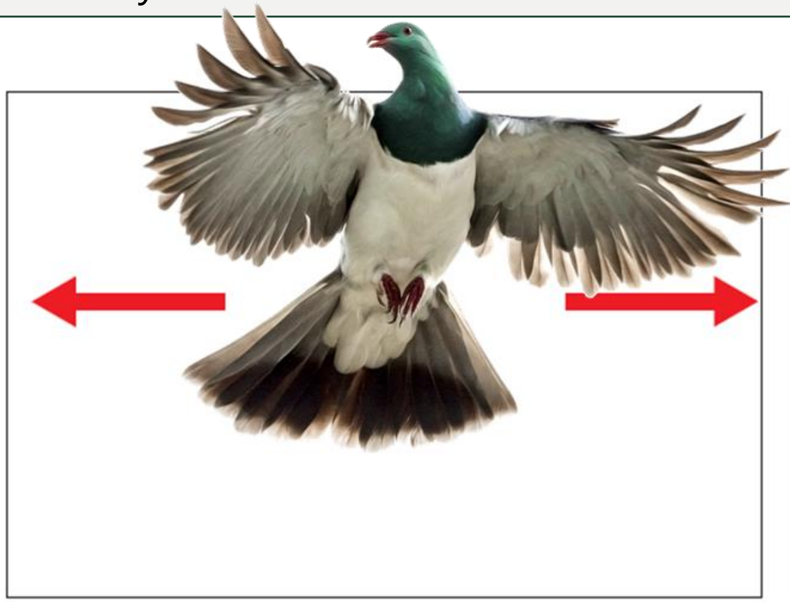
The go-cart is moving with a constant speed, meaning that the acceleration is zero. If acceleration is zero, the net force must also be zero. This means that all the forces acting are balanced. Forces are balanced and therefore $F_{net} = 0$.



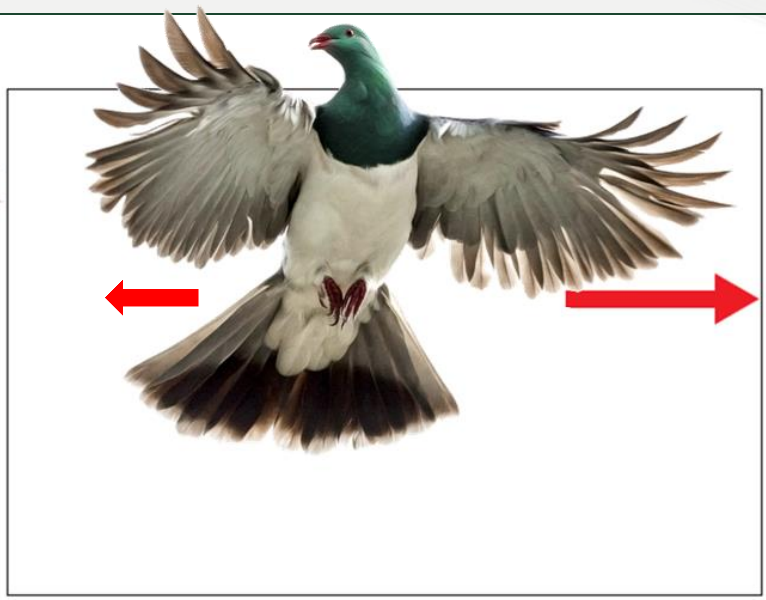
NCEA 2015 Force diagrams – the kererū

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:

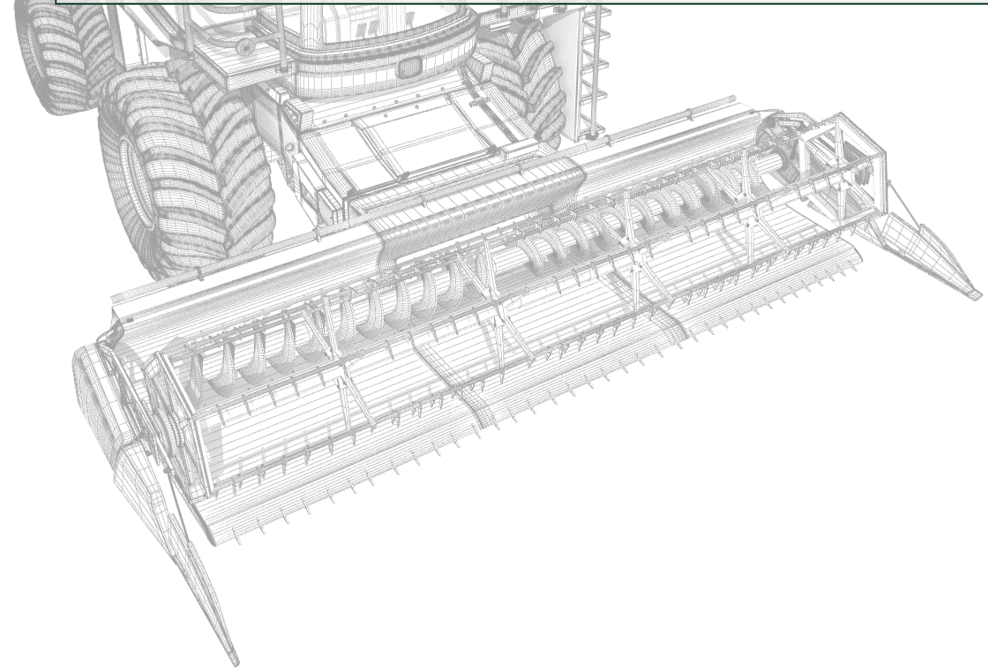
A **net force is the resultant** (overall/total/sum of) **force** on an object (when multiple forces interact). If the forces are pointing in the **same direction**, the **forces add**, giving a larger net force. If the forces are in **opposite direction**, the **forces subtract**, giving a smaller net 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.**

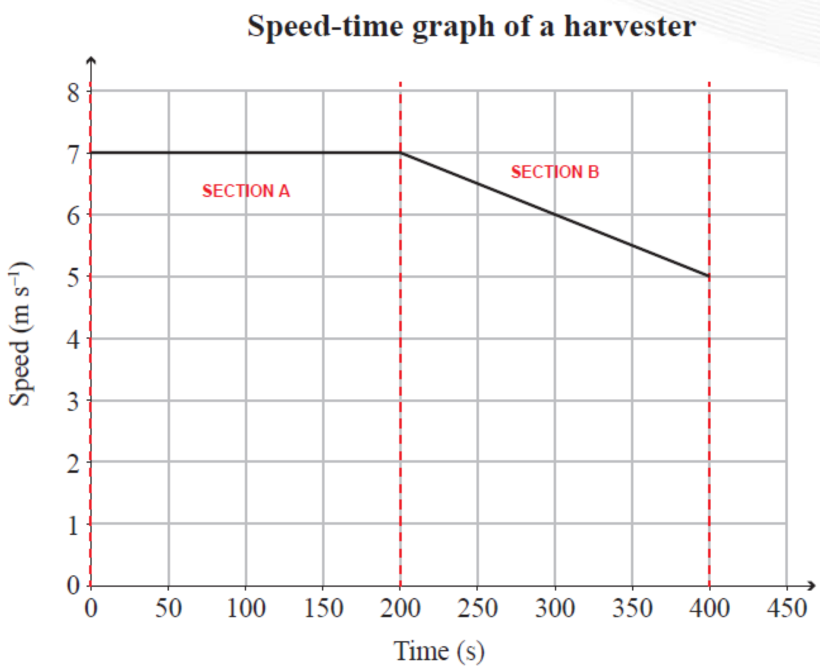
Excellence Question

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:

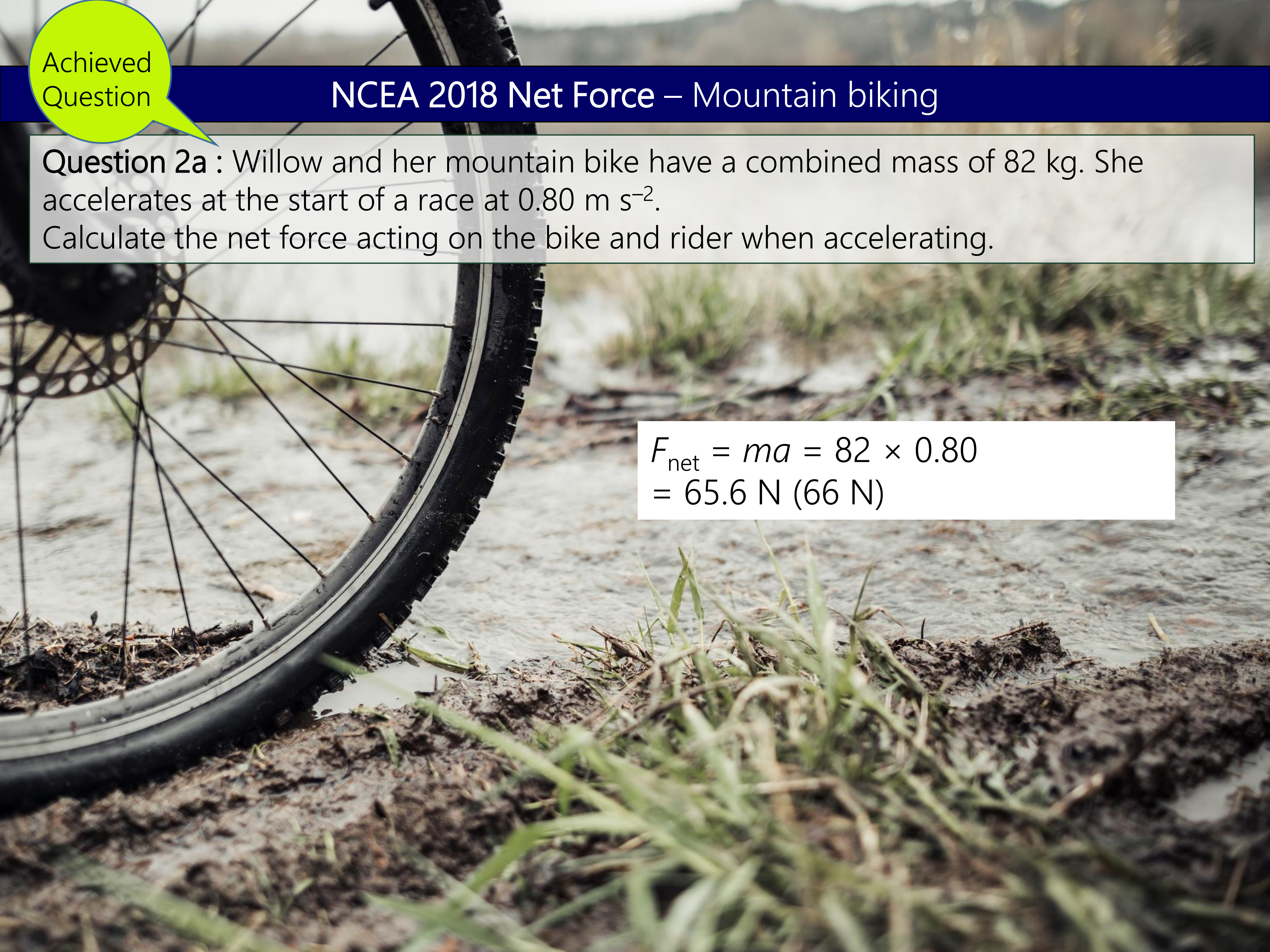
- describe what is meant by net force
- explain the link between the direction of the vertical net force and motion.

Force diagram

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 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.



Achieved Question

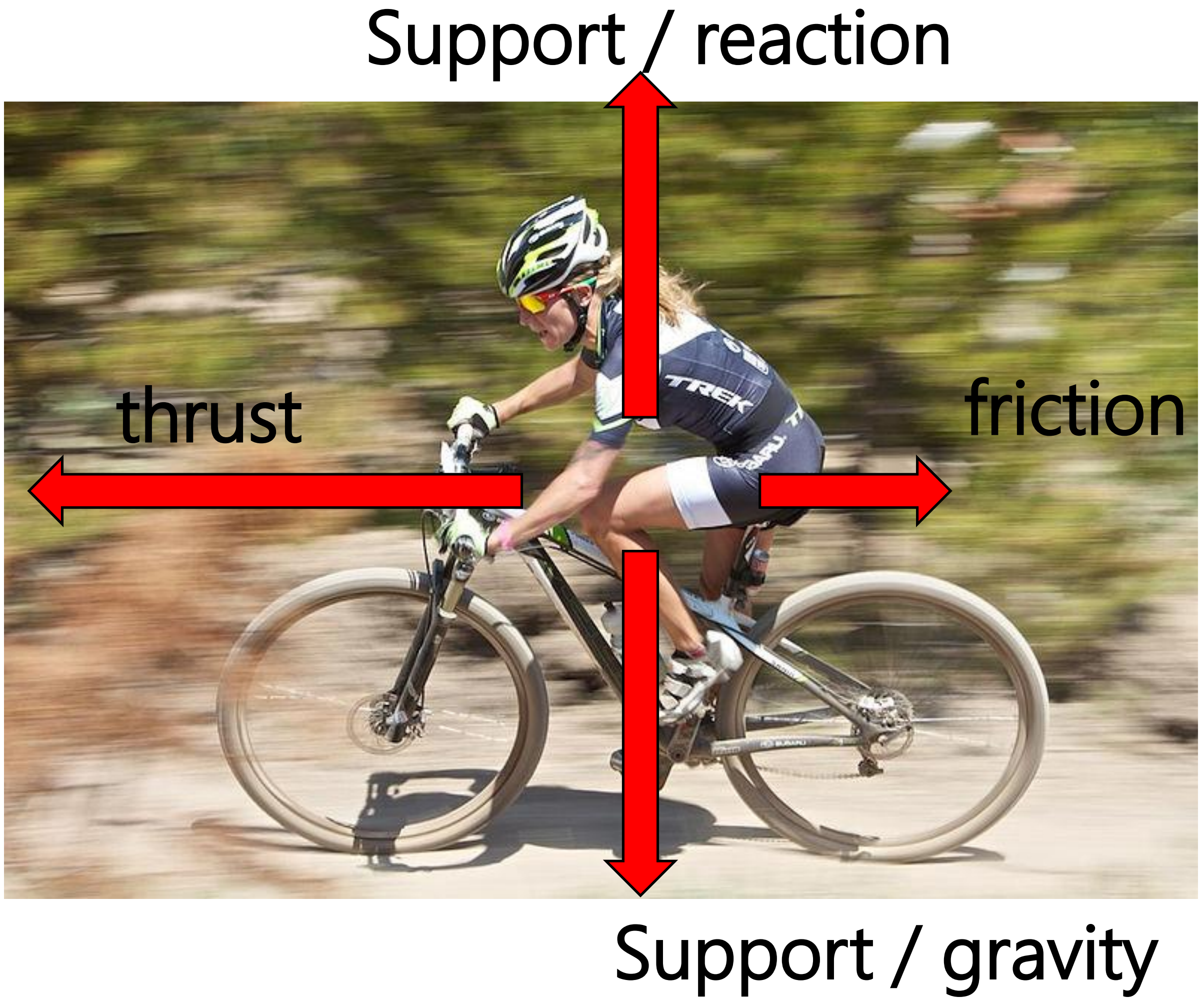
NCEA 2018 Net Force – Mountain biking

Question 2a : Willow and her mountain bike have a combined mass of 82 kg. She accelerates at the start of a race at 0.80 m s^{-2}.
Calculate the net force acting on the bike and rider when accelerating.

F_{net} = *ma* = 82 × 0.80
= 65.6 N (66 N)

NCEA 2018 Net Force – Mountain biking

Question 2b (i) : Draw and label arrows on the diagram below to show ALL the forces acting on Willow and her bike when accelerating.



Question 2b (ii) : Explain the size of the forces involved when Willow and her bike are **accelerating**.

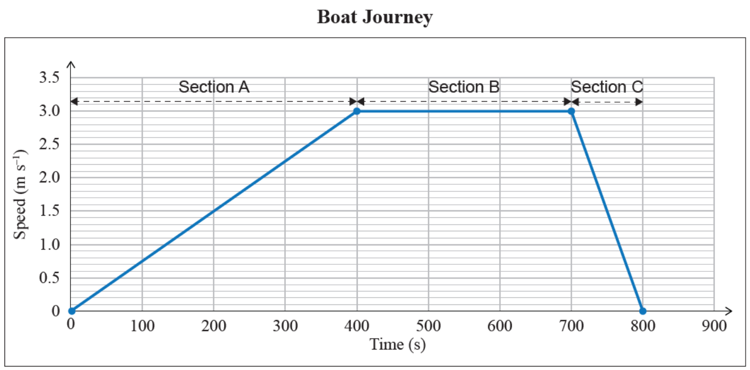
Weight and support are equal and opposite.
Thrust and friction are not equal and opposite.
The bike is accelerating, meaning that the horizontal net force is not zero, as thrust is greater than friction. The bike will accelerate (to the left / speed up).

Excellence Question

NCEA 2019 Net Force – Boat Journey

Question 1c: Explain the acceleration and motion of the boat shown in Section B of the graph by discussing the horizontal forces acting on the boat.

Thrust and friction / drag are equal and opposite. The boat is moving with a constant speed, meaning that the acceleration is zero. If acceleration is zero, the net force must also be zero. This means that all the forces acting are balanced. Forces are balanced and thus *F*net = 0 and therefore there is no acceleration (in Section B)



Excellence Question

NCEA 2019 Net Force – parachute

Question 3c : Explain the vertical motion of the parachutist immediately after jumping out of the plane (before the parachute opens).
In your answer you should:
- describe the vertical motion of the parachutist
- describe the net vertical force, and state whether the force(s) are balanced or unbalanced
- explain how the net vertical force affects the vertical motion.

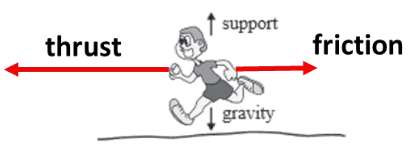
The forces acting on the parachutist are the weight downwards and air resistance upwards. The forces are unbalanced because the weight force is greater than air resistance. Thus the net force is in the direction of the weight force downwards. The net force downwards makes the parachutist accelerate in the direction downwards.

https://medium.com/@rohicks/whuffo-you-jump-out-of-that-plane-14a70d0c4dc6

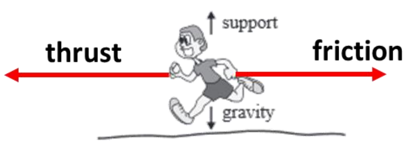
Net Force

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

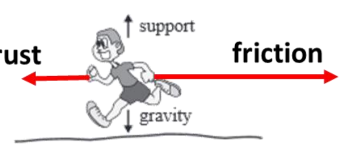


Section B



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 … 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.