Combined Science

Forces

(motion)

ANSWERS

Forces & motion facts

Fold page here

1) What is the difference between distance and displacement?	**1)** Distance is a scalar, while displacement is a vector.
2) What are typical values for walking, running and cycling speeds?	**2)** Walking speed – 1.5 m/s, running speed – 3 m/s, cycling speed – 6 m/s
3) What is the speed of sound?	**3)** 330 m/s
4) What is the equation for speed?	**4)** Speed = distance ÷ time ($v = s \div t$)
5) What is the difference between speed and velocity.	**5)** The velocity of an object is its speed in a given direction. Velocity is a vector.
6) How can we calculate the speed of an object from a distance-time graph.	**6)** The speed of an object can be calculated from the gradient of a distance-time graph.
7) What is the equation for acceleration?	**7)** $a = \Delta v \div t$
8) How can we calculate the acceleration of an object from a velocity-time graph?	**8)** The acceleration can be calculated from the gradient of a velocity-time graph.
9) How can we calculate the distance travelled from a velocity-time graph?	**9)** The distance travelled can be calculated from the area under a velocity-time graph.
10) What do the symbols in the equation $v^2 - u^2 = 2 \times a \times s$ all stand for?	**10)** v – final velocity (m/s), u – initial velocity (m/s), a – acceleration (m/s^2), s – distance travelled (m)
11) What happens to the force of air resistance as an object travels faster?	**11)** The air resistance increases.
12) If an object is falling, why does it reach a terminal velocity?	**12)** As an object falls, it accelerates and its velocity increases. This means the air resistance increases. When the air resistance is equal to the weight of the object, the forces are balanced. The resultant force will then be zero and the object will no longer accelerate and move at its terminal velocity.
13) What does Newton's first law say?	**13)** If the resultant force is zero then an object either remains stationary or remains moving at the same speed in the same direction.
14) What does Newton's second law say?	**14)** The acceleration of an object is proportional to the resultant force on the object, and inversely proportional to the mass of the object ($F = m \times a$)
15) What does Newton's third law say?	**15)** When two objects interact, the forces they exert on each other are equal and opposite.
16) What is the stopping distance of a vehicle?	**16)** It is the sum of the distance the vehicle travels during the driver's reaction time (thinking distance) and the distance it travels under the braking force (braking distance). Stopping distance = thinking distance + braking distance.
17) What is a typical reaction time for a person?	**17)** 0.2 to 0.9s.
18) What can affect a driver's reaction time?	**18)** Tiredness, drugs and alcohol.
19) What can affect the braking distance of a vehicle?	**19)** Adverse road and weather conditions (wet/icy roads) and poor condition of the vehicle (worn tyres/brakes)
20) What happens when force is applied to the brakes of a vehicle?	**20)** Work done by the friction force between the brakes and the wheel reduces the kinetic energy of the vehicle and the temperature of the brakes increases.
21) What happens if the braking force is larger?	**21)** The greater the braking force the great the deceleration of the vehicle. Large decelerations may lead to brakes overheating and/or loss of control.
22) What is the equation for momentum?	**22)** $p = m \times v$
23) What is the conservation of momentum?	**23)** In a closed system, the total momentum before an event is equal to the total momentum after an event.

Speed

Speed is a measure of how far an object has moved in a certain time. Speed is a **scalar**, while velocity is a **vector**.

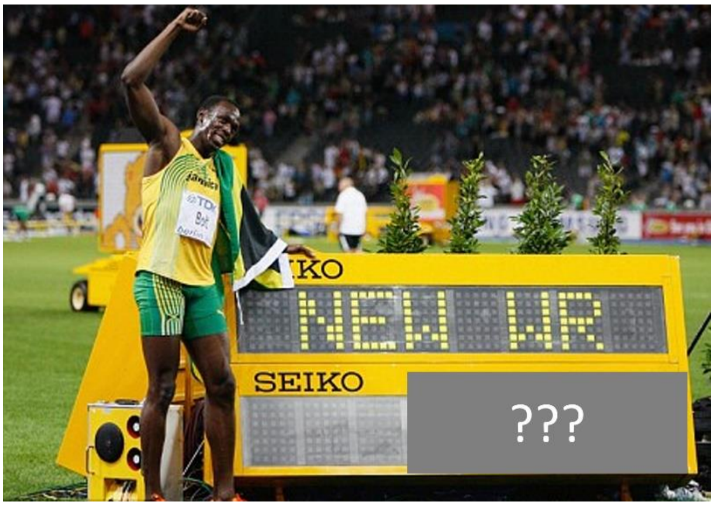
They both can be calculated using the equation:

$$v = s \div t$$

where **v** is the velocity or speed (in m/s)

s is the distance (in m)

t is the time (is s)



Example question: Usain Bolt ran his 100m world record at an average speed of 10.44 m/s. How long did it take for him to finish the race?

Step 1: Write the equation. Rearrange if necessary.

$t = s \div v$

Step 2: Write down the variables

$s = 100 \text{ m}$

$v = 10.44 \text{ m/s}$

Step 3: Calculate the answer

$t = 100 \div 10.44 = 9.58 \text{ s}$

The average person **walks** at a speed of 1.5 m/s, **runs** at a speed of 3 m/s and **cycles** at a speed of 6 m/s. The speed of **sound** in air is 330 m/s.

Speed can also be measured in units of kilometres per hour (km/h) or miles per hours (mph).

Basic Q1 Work out the **speed** of a car travelling on a straight track for:

a) 100 m in 10 s	10 m/s	e) 1000 m in 200 s	5 m/s
b) 320 m in 16 s	20 m/s	f) 300 m in 20 s	15 m/s
c) 1500 m in 180 s	8.3 m/s	g) 50 m in 4 s	12.5 m/s
d) 700 m in 35 s	20 m/s	h) 450 m in 22 s	20.5 m/s

Medium Q2 **How far** does a bus move if it's travelling at:

a) 10 m/s for 30 s	300 m	e) 15 m/s for 28 s	420 m
b) 15 m/s for 20 s	300 m	f) 20 m/s for 20 s	400 m
c) 12 m/s for 180 s	2160 m	g) 100 m/s for 300 s	30 000 m (30 km)
d) 5 m/s for 70 s	350 m	h) 180 m/s for 20 s	3600 m

Q3 **How long** does it take a car to travel:

a) 10 m at 20 m/s	0.5 s	e) 180 m at 6 m/s	30 s
b) 50 m at 10 m/s	5 s	f) 40 m at 12 m/s	3.3 s
c) 55 m at 30 m/s	1.8 s	g) 200 m at 8 m/s	25 s
d) 90 m at 20 m/s	4.5 s	h) 2,000 m at 16 m/s	125 s

Hard

To go from km to m → × 1000

Q4 A plane travels 15 km in 3 mins.

a) Convert 15 km into m. 15 000 m
b) Convert 3 mins into seconds. 180 s
c) How fast is the plane travelling? 83.3 m/s

Q5 A runner runs at 3 m/s for 5 minutes. How far have they run? 900 m

Q6 A bird flies at a speed of 7 m/s for 3 minutes. How far has it travelled? 1260 m

Q7 A car travels 15 metres in 2 seconds.

a) Calculate its speed. 7.5 m/s
b) How long would it take the car to travel 2km? 267 s

Q8 A bus travels 50 km in 2 hours. Calculate its speed in

a) km/h 25 km/h b) m/s 6.9 m/s

Q9 A car travels 100 km in 90 minutes. Calculate its speed. 18.5 m/s

Q10 A train travels at 30 m/s for 2 minutes. How far has it travelled? 3600 m

Q11 A car travels at 30 km/hour. How far, in metres, will the car cover in 90 seconds? 45 000 m

Q12 A cyclist travels 20 km in one hour. What is the average speed? 5.6 m/s

Conversion questions

There are 1,600m in one mile. Convert 30 mph into metres/second.

Copy the model answer in the space below:

30 miles = 30 x 1600 m = 48 000 m

1 hour = 1 x 60 minutes x 60 s = 3600 s

30 mph = 48 000 m / 3600 s = 13.3 m/s

Task:

1) Usain Bolt sprints at 23 mph. Convert his speed into m/s. 10.2 m/s
2) A car drives at 70 mph on the motorway. Convert the car's speed to m/s.

   31.1 m/s
3) A train travels at 100 mph. Convert the trains speed to m/s. 44.4 m/s
4) An aeroplane travels at 500 mph. Convert the plane's speed to m/s. 222 m/s
5) Bradley Wiggins cycles at a speed of 40 mph. Convert his speed into m/s.

   17.8 m/s
6) During a hurricane, there are winds of 80 mph. What is the speed of the wind in m/s? 35.6 m/s

Q1.

A car has an oil leak. Every 5 seconds an oil drop falls from the bottom of the car onto the road.

(a) What force causes the oil drop to fall towards the road?

Gravitational force/ weight

(1)

(b) The diagram shows the spacing of the oil drops left on the road during part of a journey

Describe the motion of the car as it moves from **A** to **B**.

Accelerating/speeding up

Explain the reason for your answer.

The spacing between the droplets increases

Though time between drops remains the same

So the van is travelling a further distance between each drop

So it must be getting faster

(3)

(c) When the brakes are applied, a braking force slows down and stops the car.

A braking force of 3 kN is used to slow down and stop the car in a distance of 25 m.

Calculate the work done by the brakes to stop the car and give the unit.

3 kN = 3000 N

Work done = force x distance

= 3000 x 25

Work done =75 000 J

(or 75 **<u>k</u>J**)

(3)

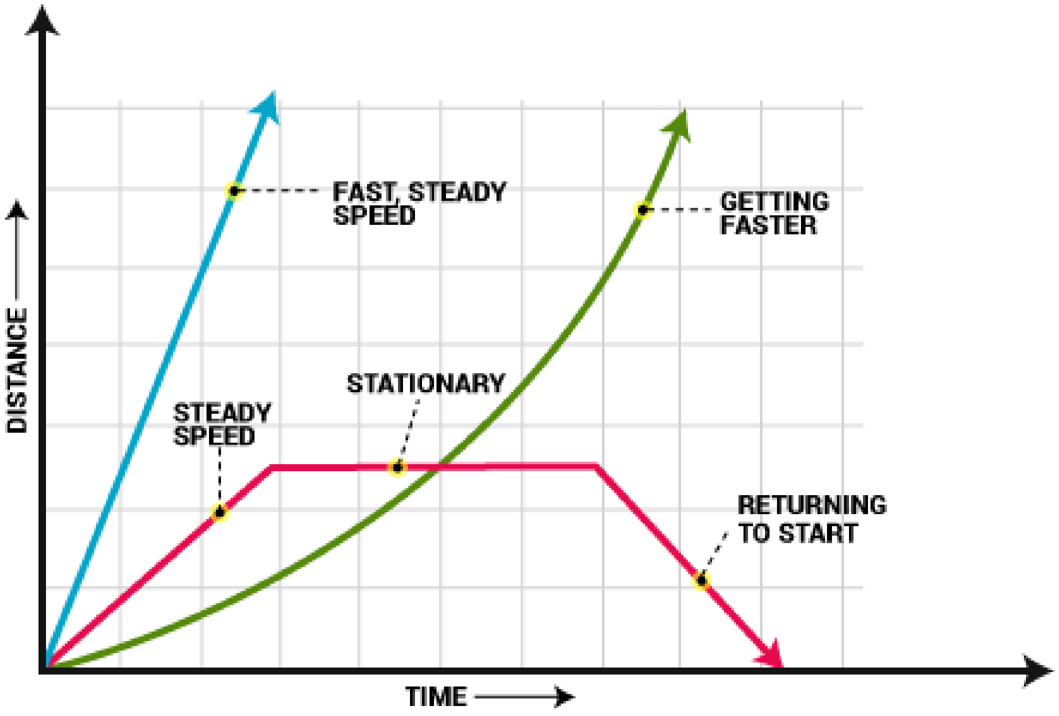
(Total 7 marks)

Distance-time graphs

A **distance-time** graph can be used to see when an object is **stationary** or travelling at a **constant speed**.

The steeper the **slope**, the faster the speed. The gradient (slope) of a distance-time graph shows the speed. This is because of the equation for speed:

$v = s \div t$



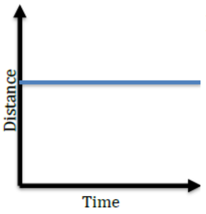
If the distance-time graph is a straight line then the object is moving at a **constant velocity**. A steeper gradient on a straight line means a **faster constant velocity**.

An upwards curve means that the object is **accelerating** and a curve that's levelling off shows an object is **decelerating**.

A flat line shows an object is **stationary** as its not travelling any distance. A line with a negative gradient shows that the object is **travelling back in the reverse direction**.

Basic: For each graph below, match the description of the object's motion.

A.



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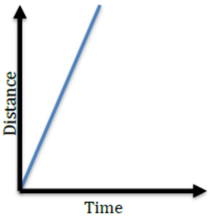
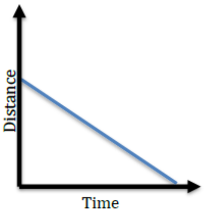
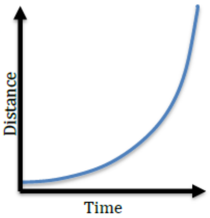


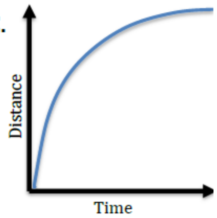
C.



D.



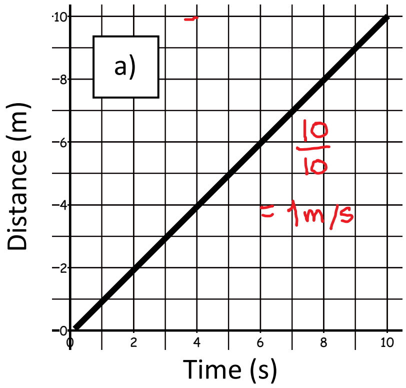
E.



F.

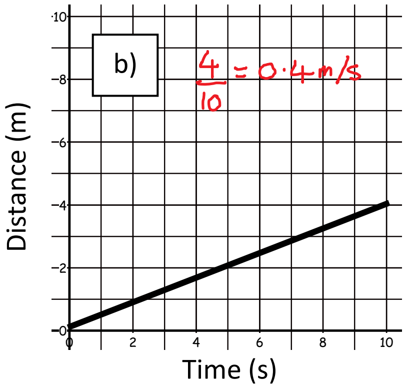
1. D Speeding Up (acceleration)
2. B Constant Speed (high rate of speed)
3. F Constant Speed (low rate of speed)
6. A No Motion (stopped)
7. E Slowing Down (deceleration)
8. C Moving Backwards (constant velocity in reverse)

Medium: Calculate the speeds in each of the distance time graphs.

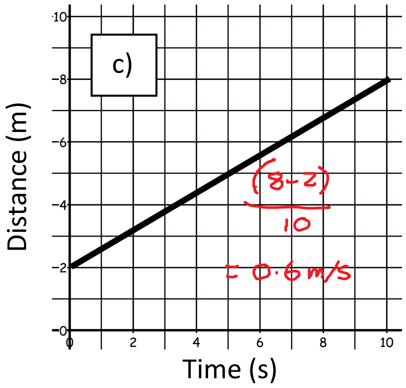


$\frac{10}{10}$

= 1m/s

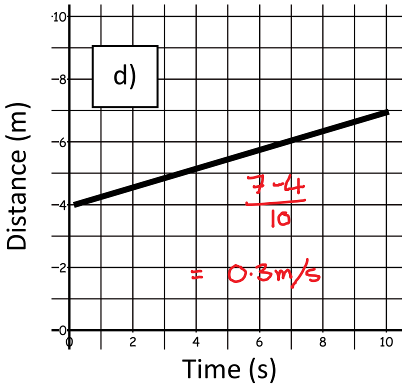


$\frac{4}{10}$ = 0·4m/s



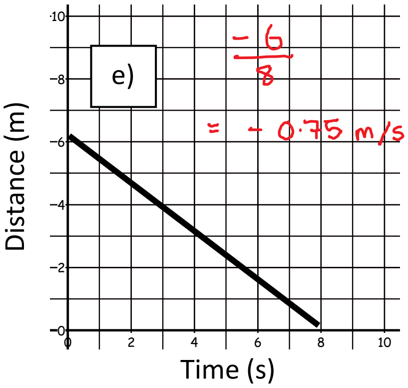
$\frac{(8-2)}{10}$

= 0·6m/s



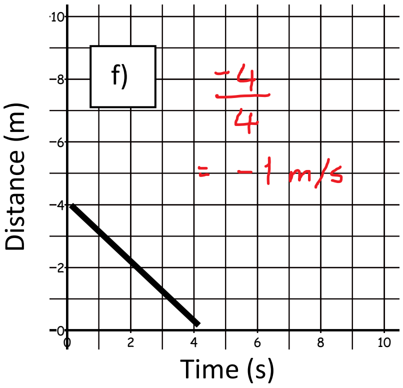
$\frac{7-4}{10}$

= 0·3m/s



$\frac{-6}{8}$

= -0·75 m/s



$\frac{-4}{4}$

= -1 m/s

Hard:

A – B car is travelling at a slow constant speed

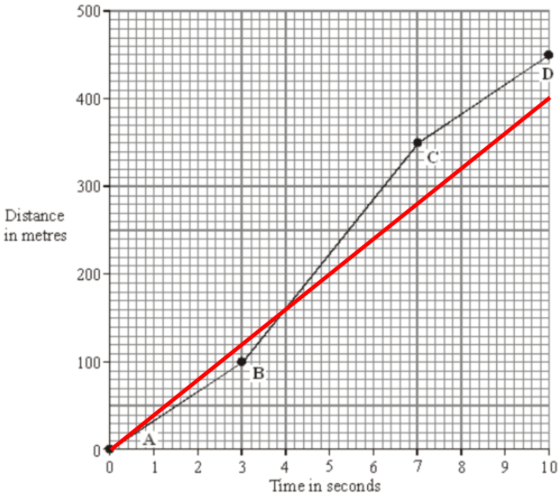
B – C car is travelling at a faster constant speed

C – D car is travelling at a slow constant speed (the same speed as between A and B)

a) Calculate the gradient of the graph between:
   - i) Point A and point B 100 / 3 = 33.3 m/s
   - ii) Point B and point C (350 – 100) / (7 - 3) = 62.5 m/s
   - iii) Point C and point D (450 – 350) / (10 - 7) = 33.3 m/s

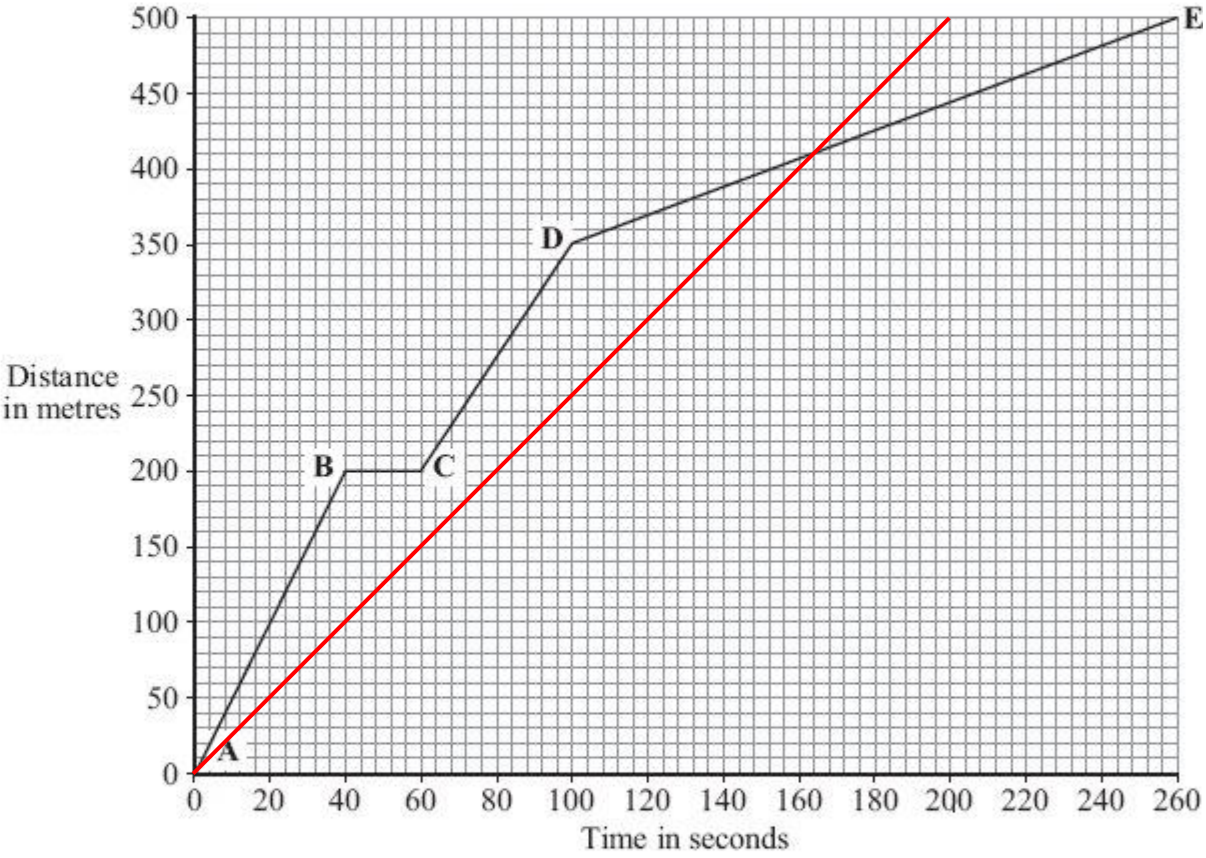
b) Another car travels at a constant velocity of 40m/s. Draw the distance time graph for this car.

c) At what time does the first car overtake the second? 4s



Q1.

Part of a bus route is along a high street.
The distance – time graph shows how far the bus travelled along the high street and how long it took.



(a) The bus travels the **slowest** between points **D** and **E**.

How can you tell this from the graph?

The gradient is the shallowest / the line is the least steep

(b) Between which two points was the bus travelling the **fastest**?

Put a tick (✓) in the box next to your answer.

Points	
A – B	✓
B – C	
C – D	

(1)

(c) There is a bus stop in the high street.
This is marked as point **B** on the graph.

(i) What is the distance between point **A** on the graph and the bus stop?

Distance 200 metres

(1)

(ii) How long did the bus stop at the bus stop?
Show clearly how you work out your answer.

Time for which the line is horizontal: 40 to 60 seconds

Time = 20 seconds

(2)

(d) A cyclist made the same journey along the high street.
The cyclist started at the same time as the bus and completed the journey in 200 seconds. The cyclist travelled the whole distance at a constant speed.

(i) Draw a line on the graph to show the cyclist's journey.

(2)

(ii) After how many seconds did the cyclist overtake the bus?

The cyclist overtook the bus after 164 seconds

(1)

(Total 8 marks)

Acceleration

Acceleration is a measure of how much the **velocity** changes by in a given **time**:

Acceleration = change in velocity ÷ time taken

$$a = \Delta v \div t$$

where **a** is the acceleration (in m/s^2)

Δv is the change in velocity (in m/s)

t is the time (in s).

Note that this equation has be re-written as:

$$a = (v - u) \div t$$

where **v** is the final velocity (in m/s)

u is the initial velocity (in m/s).

Example question: Dina Asher-Smith accelerates from a speed of 2 m/s to 8 m/s in a time of 2 seconds. Calculate her acceleration.

Step 1: Write the equation. Rearrange if necessary.

$a = \Delta v \div t$

Step 2: Write down the variables

$\Delta v = 8 - 2 = 6$ m/s

$t = 2$ s

Step 3: Calculate the answer

$a = 6 \div 2 = 3$ m/s^2

Task: Complete in your exercise book

Basic **Q1** Calculate the acceleration when:

a) Δv = 20 m/s, t = 5 s 4 m/s ^{2} **b)** Δv = 50 m/s, t = 25 s 2 m/s ^{2} **c)** Δv = 15 m/s, t = 3 s 5 m/s ^{2}
d) Δv = 40 m/s, t = 10 s 4 m/s ^{2} **e)** Δv = 80 m/s, t = 4 s 20 m/s ^{2} **f)** Δv = 50 m/s, t = 2.5 s 20 m/s ^{2}
g) Δv = 70 m/s, t = 35 s 2 m/s ^{2} **h)** Δv = 80 m/s, t = 4 s 20 m/s ^{2}

Q2 Change in speed = 14 m/s, time taken = 2 seconds. Calculate the acceleration. 7 m/s^2

Q3 A car accelerates from rest up to a speed of 30 m/s in 12 seconds. Calculate the acceleration. 2.5 m/s^2

Q4 A car travels from rest to 65 m/s in 10 seconds. What is its acceleration? 6.5 m/s^2

Q5 A car travels from rest to 56 m/s in 28 seconds. What is its acceleration? 2 m/s^2

Medium

Q6 A cyclist accelerates from 0 m/s to 8 m/s in 3 seconds.

a) What is his acceleration? 2.7 m/s^2
b) Is this acceleration higher than that of a car which accelerates from 0 to 30 m/s in 8 seconds? No.

Q7 A cyclist in the Tour de France accelerates down a hill from 22 m/s to a speed of 37 m/s. This acceleration takes him 2 seconds.

a) What is the change in velocity? 37 – 22 = 15 m/s
b) Calculate the acceleration. 7.5 m/s^2

Q8 A car is travelling at a steady speed of 28 m/s and its velocity changes to 38 m/s in 20 seconds. What is its acceleration? 0.5 m/s^2

Q9 A lizard accelerates from 2 m/s to 10 m/s in 4 seconds. What is the lizard's average acceleration? 2 m/s^2

Q10 Re-arrange the equation for acceleration to give equations for change in velocity and time taken

Δv = a x t t = Δv / a

Q11 Complete the following table.

Acceleration (m/s^2)	Starting speed (m/s)	Final speed (m/s)	Time taken (s)
(6 – 2) / 2 = 2	2	6	2
2	5	25	(25 – 5) / 2 = 10
10	4	4 + (10 x 2) = 24	2
8	5	5 + (8 x 10) = 85	10
4	8 – (4 x 2) = 0	8	2

Q12 If a Ferrari, with an initial velocity of 10 m/s accelerates at a rate of 50 m/s^2 for 3 seconds, what will its final velocity be? 10 + (50 x 3) = 160 m/s

Q13 A car starts from stationary and then increases its speed to 50m/s in 50s

a. Calculate its acceleration 1 m/s^2
b. It then slows its speed by 20% in 10s calculate the deceleration 20% of 50 m/s = 10 m/s. 10 / 10 = 1 m/s^2

Q14 In a motorcycle test the speed from rest was recorded as intervals in the table below

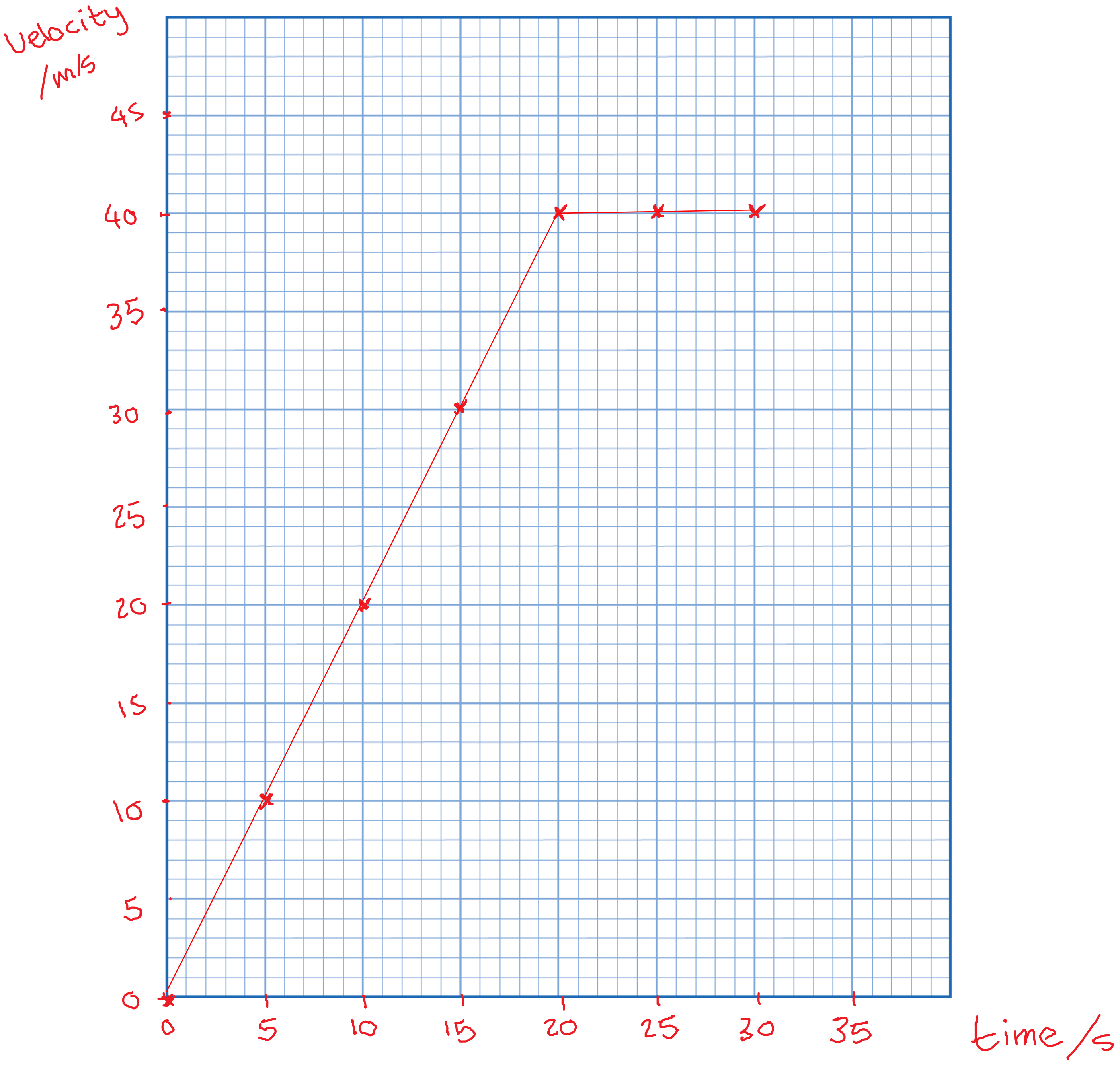
Time in s	0	5	10	15	20	25	30
velocity in m/s	0	10	20	30	40	40	40

a. Plot a velocity time graph of these results

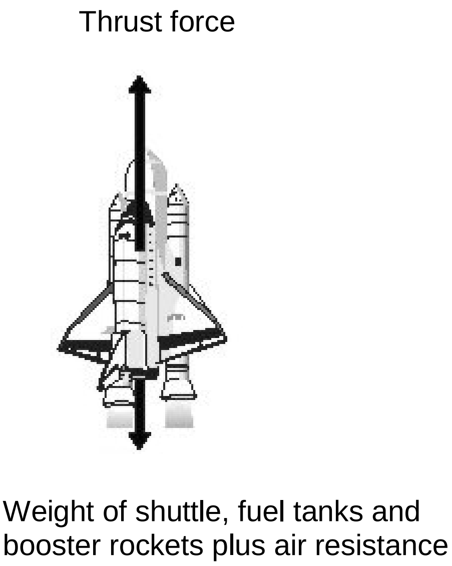
b. Calculate the initial acceleration of the motorcycle 40 / 20 = 2 m/s^2

c. Calculate how far the motorcycle moved in the first 20s and the following 10s
Area under graph: first 20 s = ½ x 20 x 40 = 400 m, following 10 s = 10 x 40 = 400 m

d. Calculate the velocity of the motorcycle after 1.0km from the start if it had kept the same acceleration as it had during the first 20s 63 m/s



(a) The arrows in the diagram represent the size and direction of the forces on a space shuttle, fuel tank and booster rockets one second after launch. The longer the arrow the bigger the force.



(i) Describe the upward motion of the space shuttle one second after launch.

Accelerating

(1)

(ii) By the time it moves out of the Earth's atmosphere, the total weight of the space shuttle, fuel tank and booster rockets has decreased and so has the air resistance.

How does this change the motion of the space shuttle? (Assume the thrust force does not change).

Acceleration increases

(1)

(b) The space shuttle takes 9 minutes to reach its orbital velocity of 8100 m/s.

(i) Write down the equation that links acceleration, change in velocity and time taken.

Acceleration = change in velocity / time taken

(1)

(ii) Calculate, in m/s^2, the average acceleration of the space shuttle during the first 9 minutes of its flight. Show clearly how you work out your answer.

9 minutes = 9 x 60 = 540 seconds

a = 8100 / 540 = 15

average acceleration = 15 m/s^2

(2)

(iii) How is the velocity of an object different from the speed of an object?

Velocity includes direction, speed is just magnitude (velocity is a vector)

(1)

(Total 6 marks)

Velocity-time graphs

Diagonally Up

Constant Acceleration

Horizontal

Constant speed

Diagonally Down

Constant Deceleration

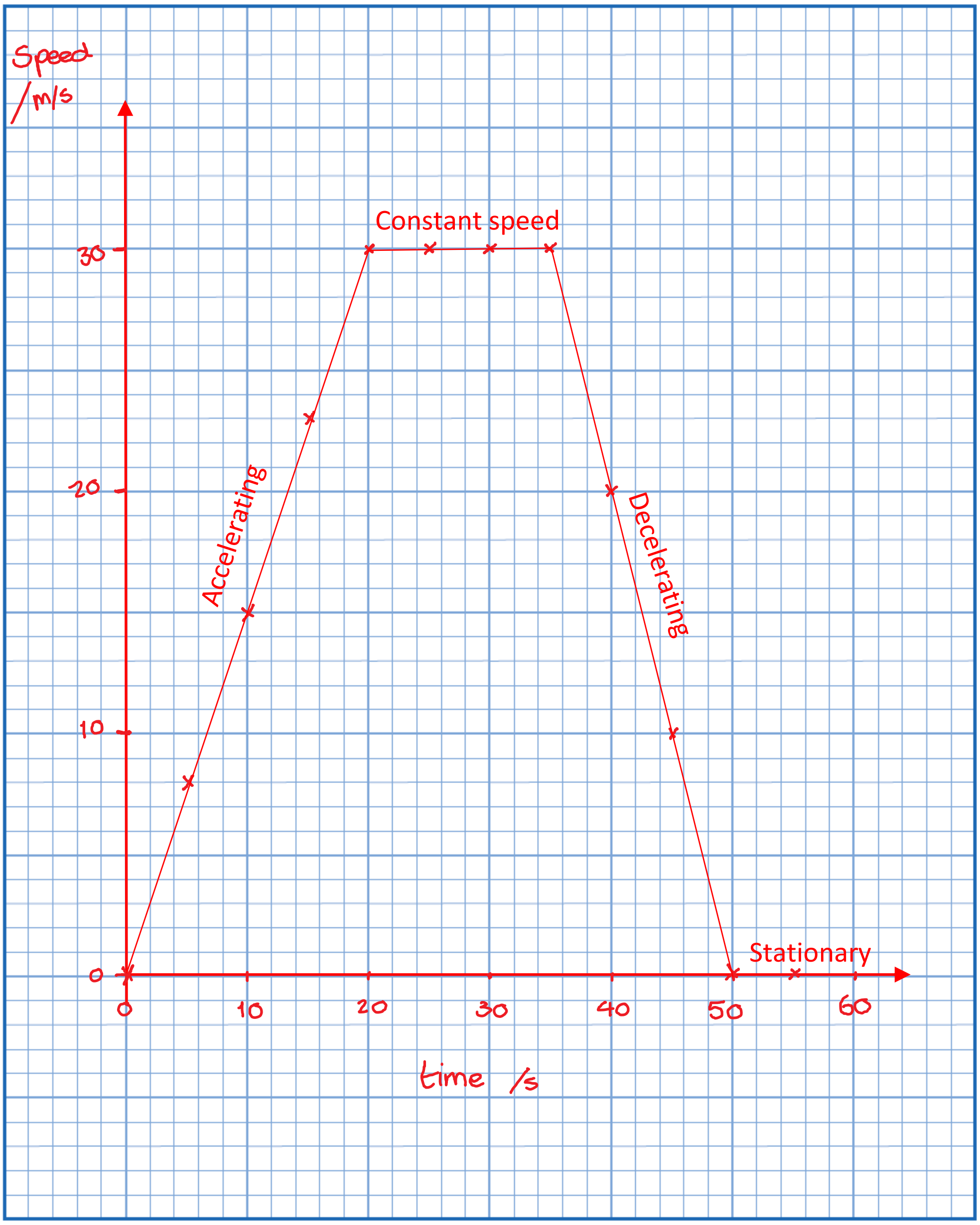
Gradient

This is the acceleration of the object.

Area under the graph

This is the distance travelled by the object.

Time (s)	Speed (m/s)
0	0
5	8
10	15
15	23
20	30
25	30
30	30
35	30
40	20
45	10
50	0
55	0



Task: Plot a velocity-time graph for the above object.

Label where:

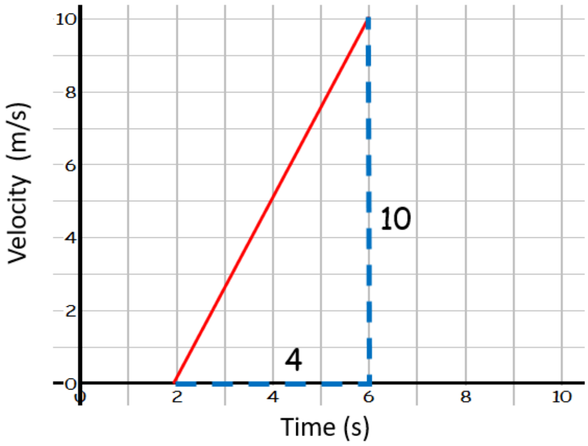
-The object is accelerating.

-The object is travelling at a constant speed.

-The object is decelerating.

-The object is stationary.

Worked Examples

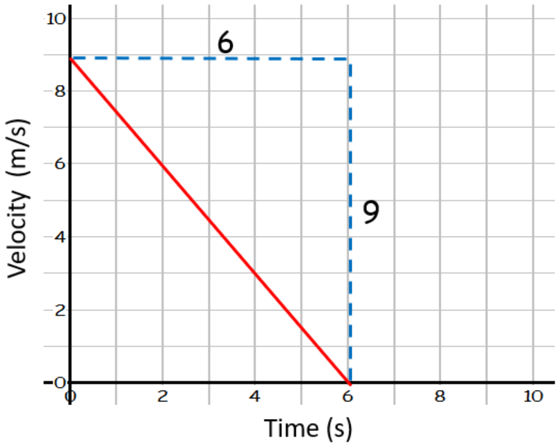


a) Find the acceleration of the object.

$a = \Delta v \div t$
$= 10 \div 4$
$= 2.5$ m/s^2

b) Find the distance travelled by the object.

Distance travelled = area under line
= area of triangle
= ½ b × h = ½ 4 × 10 = 20 m



a) Find the acceleration of the object.

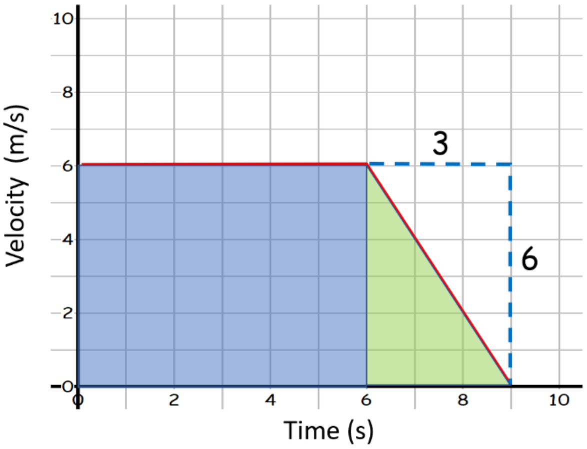
$a = \Delta v \div t$
$= -9 \div 6$
$= -1.5$ m/s^2

b) Find the distance travelled by the object.

Distance travelled = area under line
= area of triangle
= ½ b × h = ½ 6 × 9 = 27 m

Harder worked example

Find the distance travelled by the object.



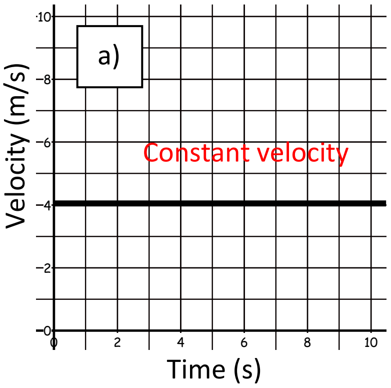
Distance travelled = area under line

= area of square (in blue) + area of triangle (in green)

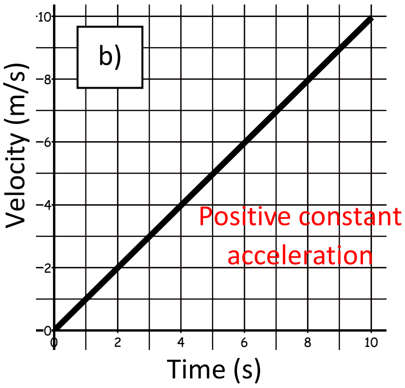
= (6 × 6) + (½ 6 × 3) = 45 m

Basic: Write what each graph shows: constant velocity, stationary, positive constant acceleration, negative constant acceleration, increasing acceleration or decreasing acceleration.

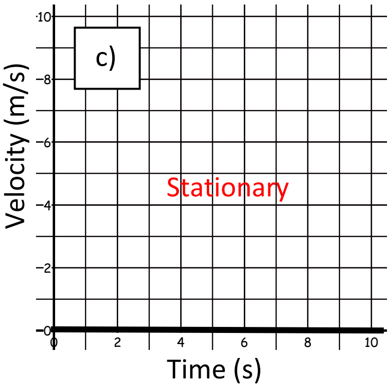
For example; graph a) shows constant velocity (4 m/s).



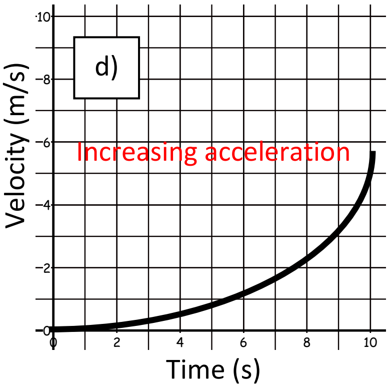
Constant velocity



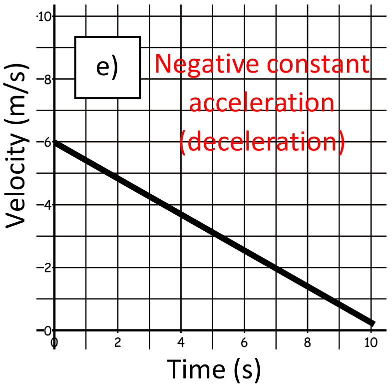
Positive constant acceleration



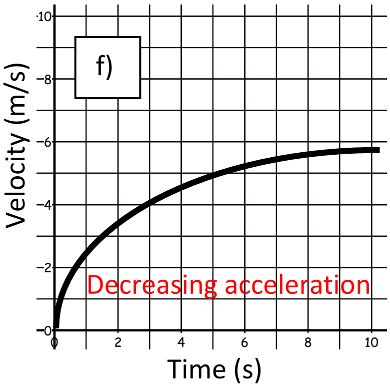
Stationary



Increasing acceleration



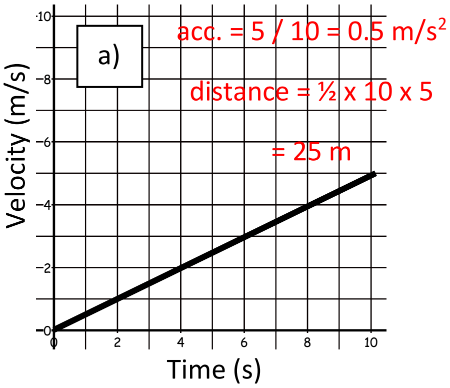
Negative constant acceleration (deceleration)



Decreasing acceleration

Medium: Calculate: 1) The acceleration for each of the graphs below (using the gradient).

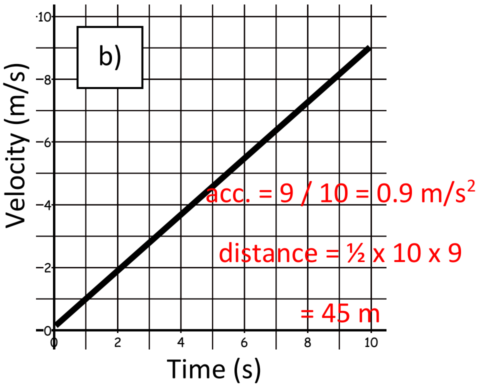
2) The distance travelled for each of the graphs below (using the area under the graph).



acc. = 5 / 10 = 0.5 m/s^2

distance = ½ x 10 x 5

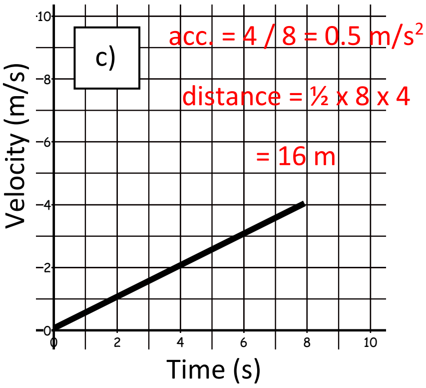
= 25 m



acc. = 9 / 10 = 0.9 m/s^2

distance = ½ x 10 x 9

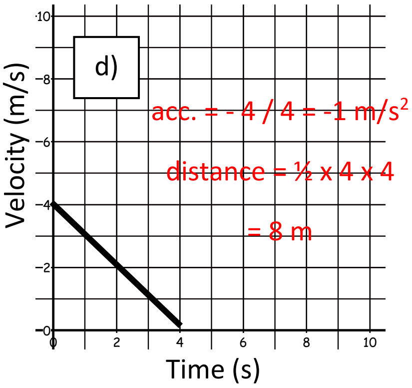
= 45 m



acc. = 4 / 8 = 0.5 m/s^2

distance = ½ x 8 x 4

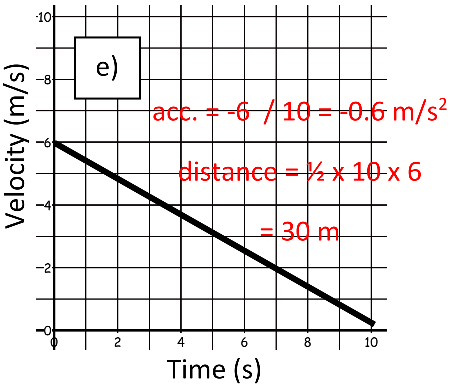
= 16 m



acc. = - 4 / 4 = -1 m/s^2

distance = ½ x 4 x 4

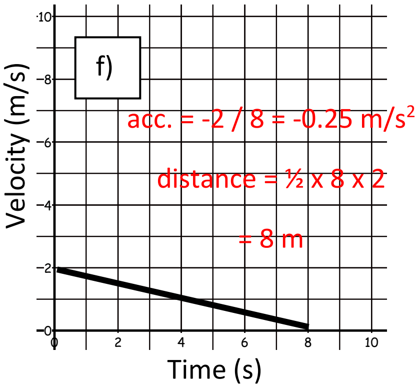
= 8 m



acc. = -6 / 10 = -0.6 m/s^2

distance = ½ x 10 x 6

= 30 m

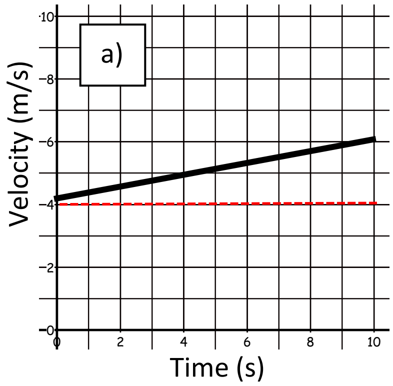


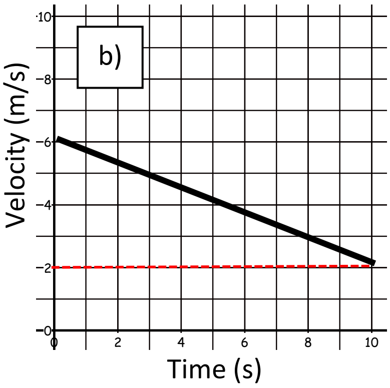
acc. = -2 / 8 = -0.25 m/s^2

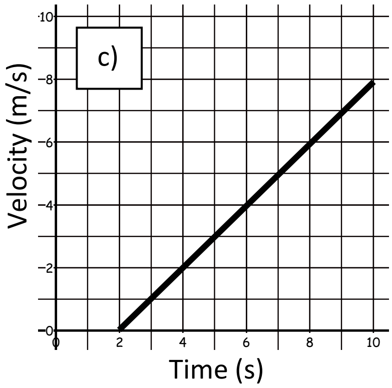
distance = ½ x 8 x 2

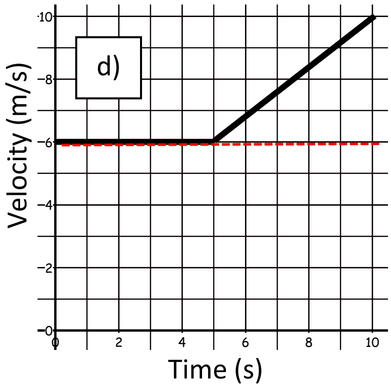
= 8 m

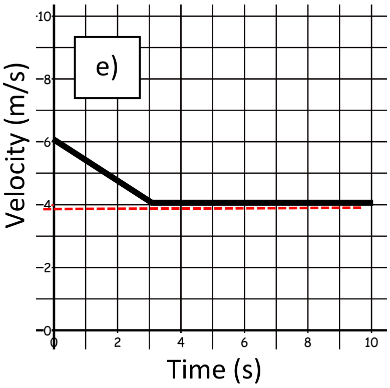
Hard: Calculate the distance travelled for each of the graphs below (you will have to divide the area under the graph into different shapes and add up the areas of each shape to give a total area).

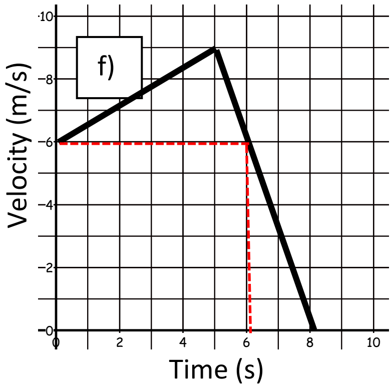












a) (4 x 10) + (½ x 2 x 10) = 50 m
b) (2 x 10) + (½ x 4 x 10) = 40 m
c) ½ x 8 x 8 = 32 m
d) (10 x 6) + (½ x 5 x 4) = 70 m
e) (10 x 4) + (½ x 3 x 2) = 43 m
f) (6 x 6) + (½ x 2 x 6) + (½ x 6 x 3) = 51 m

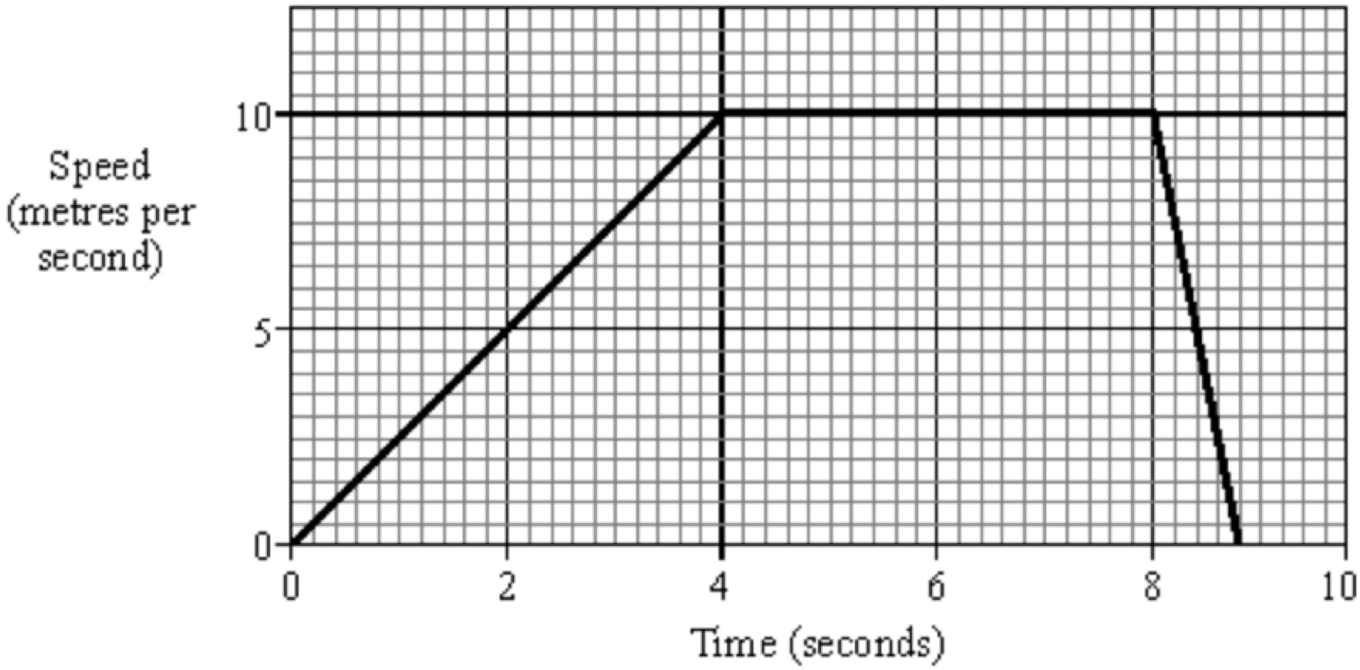
The graph below shows the speed of a runner during an indoor 60 metres race.

a) Calculate the acceleration of the runner during the first four seconds. 10 / 4 = 2.5 m/s^2

b) How far does the runner travel during the first four seconds? ½ x 4 x 10 = 20 m

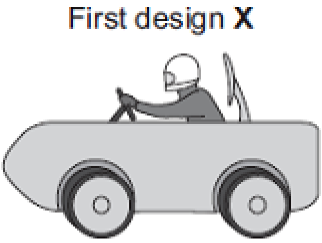
c) How long does the runner take to decelerate after the end of the race? 0.4 s

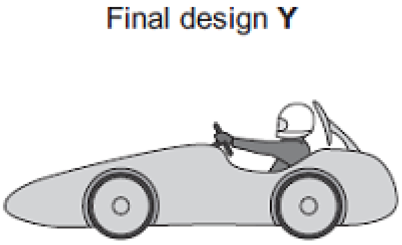
d) What is the total distance travelled by the runner? 60 + (½ x 0.4 x 10) = 62 m



Q1.

(a) Some students have designed and built an electric-powered go-kart. After testing, the students decided to make changes to the design of their go-kart.





The go-kart always had the same mass and used the same motor.

The change in shape from the first design (**X**) to the final design (**Y**) will affect the top speed of the go-kart.

Explain why.

- more streamlined/ decreased surface area

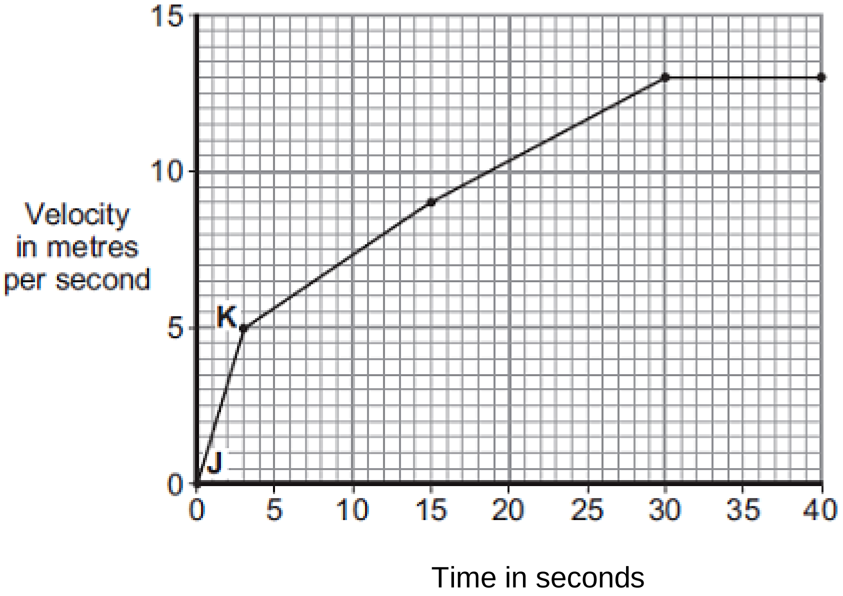
- air resistance is smaller (for the same speed)

- so it reaches a higher speed (before resultant force becomes zero)

(3)

(b) The final design go-kart, **Y**, is entered into a race.

The graph shows how the velocity of the go-kart changes during the first 40 seconds of the race.



(i) Use the graph to calculate the acceleration of the go-kart between points **J** and **K**.

Give your answer to **two** significant figures.

a = Δv / t = 5 / 3

= 1.7 m/s^2

(2)

(ii) Use the graph to calculate the distance the go-kart travels between points **J** and **K**.

distance = area under the graph = ½ x 3 x 5
= 7.5 m

(2)

(iii) What causes most of the resistive forces acting on the go-kart?

Air resistance

(1)
(Total 8 marks)

Acceleration II

$v^2 - u^2 = 2 \times a \times s$

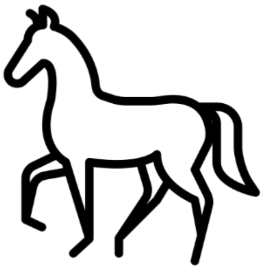
where v = final velocity (in m/s)
u = initial velocity (in m/s)
a = acceleration (in m/s^2)
s = distance (m)

Occasionally some variables in a question can be **hidden**. The following are some examples of hidden variables:

Initially at rest = initial velocity (u) is 0 m/s
Constant velocity = acceleration of 0 m/s^2
Acceleration due to gravity = g of 9.8 m/s^2

Worked example:

A horse starts **at rest.** It **accelerates** at **3m/s^2** over a distance of **40m.** What will its **final velocity** be?



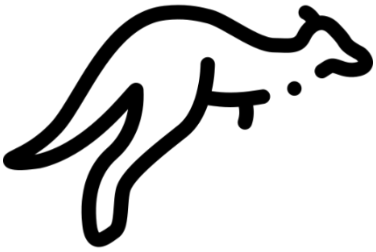
$v^2 – u^2 = 2 x a x s$
$v^2 – 0 = 2 x 3 x 40$
$v^2 = 240$
$v = √240 = 15.5 m/s$

Task: Complete in your exercise book.

1. A sports car starts at rest. It accelerates at 11.25 m/s^2 over a distance of 32m. What will its final velocity be? 26.8 m/s
2. Dr. Edmunds' cat Lola jumps at a mouse that is 1.5m away. Lola starts from rest and accelerates at 12 m/s^2. What will Lola's final velocity be when she reaches the mouse? 6 m/s
3. A sloth starts from rest and accelerates at 0.02 m/s^2 over a distance of 40m before reaching its top speed (final velocity). What will the sloths top speed be? 1.3 m/s
4. A super tanker accelerates 0.1 m/s^2 over a distance of 1.5 km to reach its maximum speed. What will its maximum speed be? 17.3 m/s

Worked example:

A kangaroo is bouncing at 20m/s when it accelerates at 2m/s^2 over a distance of 15m. What will its final velocity be?



$v^2 - u^2 = 2 \text{ x } a \text{ x } s$
$v^2 – 20^2 = 2 \text{ x } 2 \text{ x } 15$
$v^2 - 400 = 60$
$v^2 = 60 + 400$
$v = \surd 460 = 21.4$ m/s

Task: Complete in your exercise book.

1. A helicopter is flying at 35m/s when it accelerates at 4m/s^2 over a distance of 300m. What will its final velocity be? 60.2 m/s
2. A lorry driver is driving at 45m/s when she hits the breaks. The lorry slows down with an acceleration of –5m/s^2 over a distance of 200m before driving on normally. What will its final velocity be? 5 m/s

Harder questions: For these you first need to use $\mathbf{a = \Delta v \div t}$ and then use $\mathbf{v^2 - u^2 = 2 \times a \times s}$

3. a) Usain Bolt starts from rest and reaches a top speed of 12 m/s in 6 seconds. What is his acceleration? 2 m/s^2
   b) Using your answer from part a) and assuming he ran at a constant acceleration, what was his final velocity after he had travelled 10m?
   6.3 m/s
4. a) A space shuttle starts from rest and reaches a speed of 44 m/s after only 8 seconds. What was its acceleration? 5.5 m/s^2
   b) If the shuttle started at 10 m/s and accelerated at the same rate over a distance of 2 km, what would its final velocity be? 149 m/s
5. a) A squirrel is moving at 0.2 m/s. It accelerates to 1.4 m/s in one minute. What was its acceleration? 0.02 m/s^2
   b) If the squirrel kept accelerating at this rate, with what speed would it head-butt the fence after travelling the full length of the 11m garden?
   0.69 m/s

1

Figure 1 shows an electric wheelchair.

Figure 1

(a) The wheelchair moves at a constant speed of 2.4 m/s for 4.5 seconds.

Calculate the distance moved by the wheelchair.

Distance = 2.4 x 4.5

= 10.8 m

(2)

(b) What could be a reason for the speed of the wheelchair decreasing?

Tick **one** box.

It started going downhill. ☐

It started going uphill. ☑

Its store of kinetic energy increased. ☐

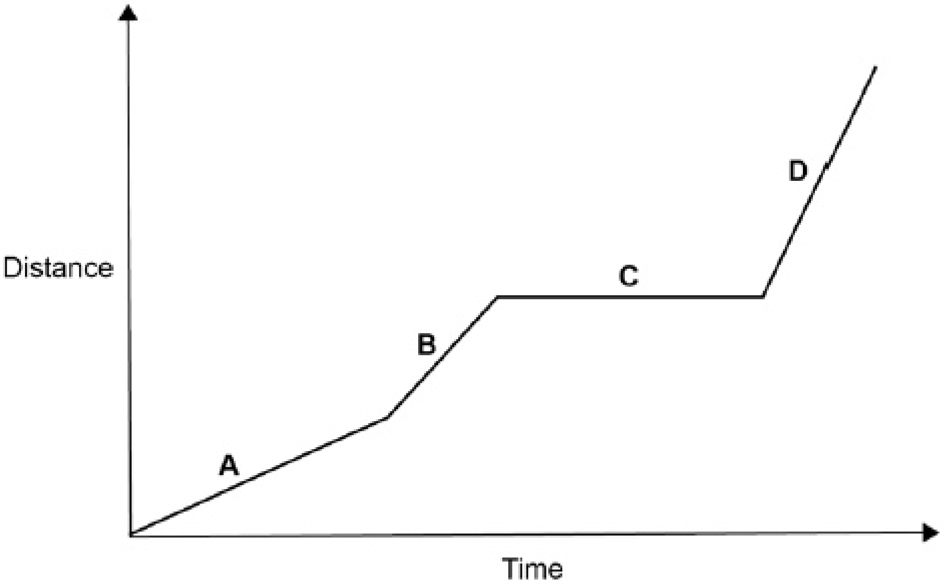
It used more power from its battery. ☐

(1)

A student measured how the distance travelled by the wheelchair changed over time.

Figure 2 shows a sketch-graph of the results.

Figure 2



(c) In which section of the graph, **A**, **B**, **C**, or **D**, did the wheelchair travel fastest?

Give the reason for your answer.

Section D

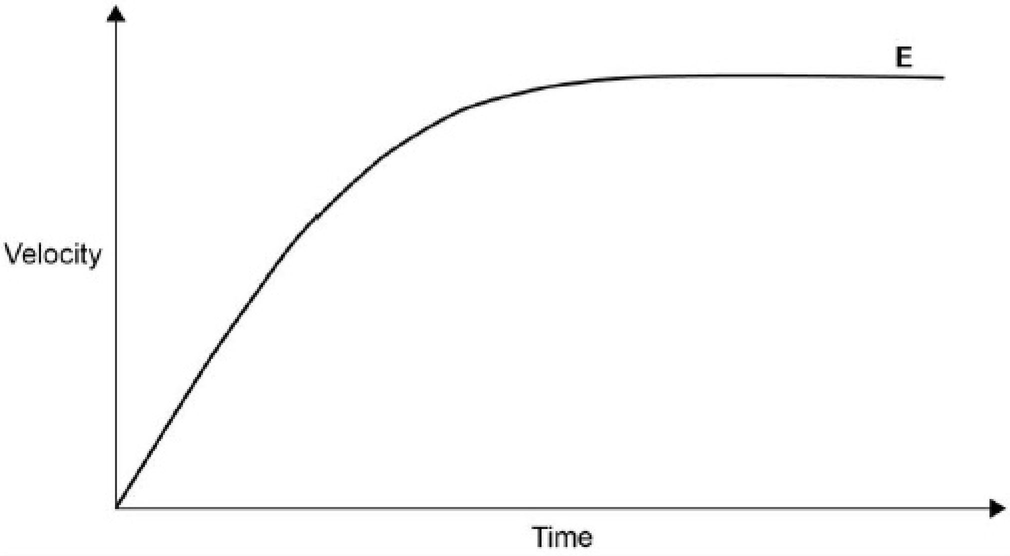
Reason It is steepest / it has the largest gradient

(2)

The velocity of the wheelchair changes as it accelerates to its top speed.

Figure 3 shows a sketch-graph of the changes.

Figure 3



(e) The forward force on the wheelchair is constant as it accelerates on flat ground.

Which force reduces the acceleration? **(1)**

Tick **one** box.

Air resistance ☑

Magnetism ☐

Tension ☐

Weight ☐

(g) The wheelchair starts from rest.

It accelerates at a constant rate until it has a speed of 1.5 m/s

The wheelchair travels a distance of 2.0 m while it is accelerating.

Calculate the acceleration of the wheelchair.

Using the Physics Equations Sheet. **(3)**

$v^2 - u^2 = 2 a s$
$1.5^2 (- 0^2) = 2 \text{ x } a \text{ x } 2$

$a = 1.5^2 / (2 \text{ x } 2)$

$a = 0.56 \text{ m/s}^2$

Newton’s laws

Newton’s 1st law:

An object:

-At rest remains at rest.

-Moving remains moving at constant velocity.

Unless a **resultant force** acts on it.

Newton’s 2nd law:

The acceleration of an object is **directly proportional to the force** applied. The acceleration of an object is also **inversely proportional to the mass** of an object. This can be summarised by the equation below:

Force = mass × acceleration

$$\boldsymbol{F} = \boldsymbol{m} \times \boldsymbol{a}$$

where **F** is the force (in N)

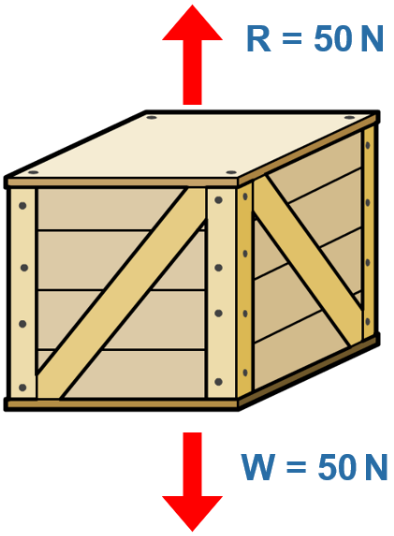
m is the mass (in kg)

a is the acceleration (in m/s^2).

Newton’s 3rd law:

Every force has an **equal and opposite reaction force**.

For example, take the crate to the right. It has a weight of 50 Newtons. Because it is stationary on the ground and not moving it therefore must have an equal force in the opposite direction. This force (when the crate is on a surface) is called the **reaction** force and is also equal to 50 Newtons.



If the crate was floating in the sea, the equal and opposite force would be called the **upthrust**.

Basic

1. Give the **units and symbol** for each term in the table below

Term	**Symbol**	**Unit**
Acceleration	a	metres per second squared (m/s^2)
Force	F	Newtons (N)
Mass	m	kilograms (kg)

2. Work out **force** in each of the following:
   a. mass = 4kg, acceleration = 2 m/s^2 8 N
   b. mass = 150kg, acceleration = 3 m/s^2 450 N
   c. mass = 20kg, acceleration = 2.7 m/s^2 54 N
   d. mass = 500kg, acceleration = 5 m/s^2 2500 N
3. How much **force** is needed to accelerate a 66 kg skier at 2 m/s^2? 132 N
4. What is the **force** on a 1,000 kg elevator that is falling freely at 9.8 m/s^2? 9800 N
5. A 50 kg skater pushed by a friend accelerates 5 m/s^2. How much **force** did the friend apply? 250 N

Medium

7. Complete the equations for mass and acceleration below by rearranging the equation

Force = mass x acceleration	**mass = Force / acceleration**	**acceleration = Force / mass**

8. Work out the **mass** in each of the following:
   a. acceleration = 5 m/s^2, force = 12N 2.4 kg
   b. acceleration = 25 m/s^2, force = 200N 8 kg
   c. acceleration = 15 m/s^2, force = 3N 0.2 kg
   d. acceleration = 0.5 m/s^2, force = 3N 6 kg
9. Work out the **acceleration** in each of the following:
   a. force = 20N, mass = 5kg 4 m/s^2
   b. force = 7N, mass = 14kg 0.5 m/s^2
   c. force = 2,000N, mass = 1250kg 1.6 m/s^2
   d. force = 0.75N, mass = 0.45kg 1.7 m/s^2
10. What is the acceleration of a 50 kg object pushed with a force of 500 newtons? 10 m/s^2
11. A force of 250 N is applied to an object that accelerates at a rate of 5 m/s^2. What is the mass of the object? 50 kg

Hard

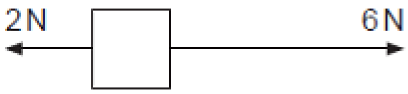
To go from g to kg → ÷ 1000

12. A force of 20 N acts upon a 500 g block. Calculate the acceleration of the object. 40 m/s^2
13. A 200 g block is pulled across a table by a horizontal force of 40 N with a frictional force of 8 N opposing the motion.
    a) Calculate the resultant force. 32 N
    b) Calculate the acceleration of the object. 160 m/s^2
14. An object of mass 300 g is falling in air and experiences a force due to air resistance of 1.5 newtons. Determine the net force acting on the object and calculate the acceleration of the object.
    Force = weight – air resistance = (0.3 x 9.8) - 1.5 = 1.4 N acceleration = 4.8 m/s^2
15. If a 60 kg person on a 15 kg sled is pushed with a force of 300 N, what will be person's acceleration?

    a = F / m = 300 / (60 + 15) = 4 m/s^2

Q1.

(a) The diagram shows two forces acting on an object.



What is the resultant force acting on the object?

Tick (✓) **one** box.

8 N to the right ☐

8 N to the left ☐

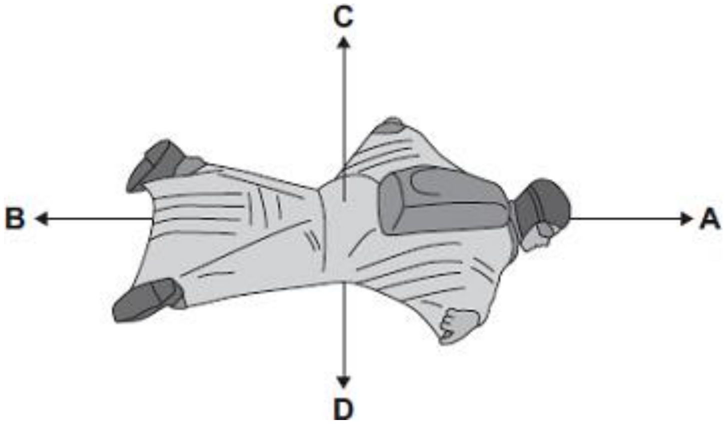
4 N to the right ☑

4 N to the left ☐

(1)

(b) BASE jumpers jump from very high buildings and mountains for sport.

The diagram shows the forces acting on a BASE jumper in flight.
The BASE jumper is wearing a wingsuit.



(i) Draw a ring around the correct answer in the box to complete each sentence.

The BASE jumper accelerates forwards when force **A**

is
smaller than
equal to
[✓ bigger than]
force **B**.

The BASE jumper falls with a constant speed when force **C**

is	smaller than [✓ equal to] bigger than	force **D**.

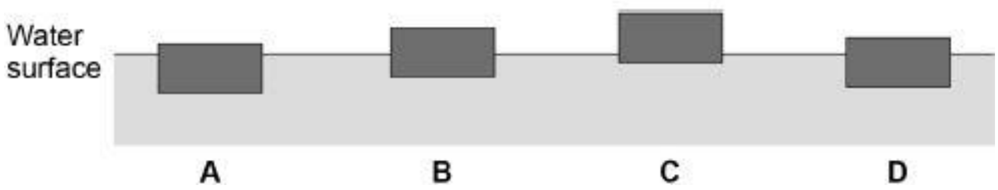
(2)

Q2.

Figure 1 shows four blocks of different materials floating on water.

The four blocks are the same volume.

Figure 1



(a) Which of the blocks has the smallest weight?

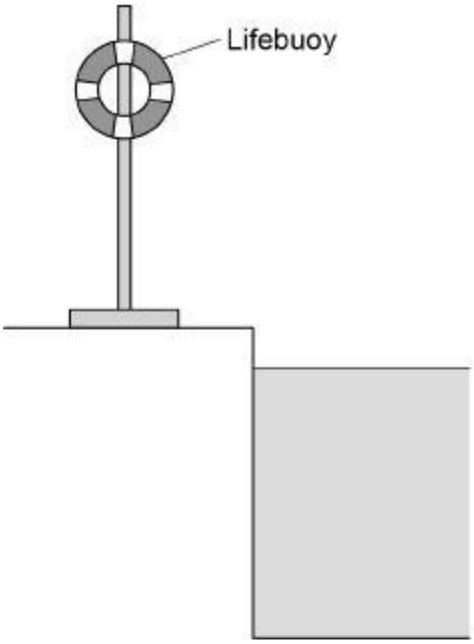
Tick **one** box.

A ☐ **B** ☐ **C** ☑ **D** ☐

(1)

Figure 2 shows a lifebuoy next to a deep swimming pool.

Figure 2



(b) The lifebuoy has a mass of 2.5 kg.

gravitational field strength = 9.8 N/kg

Calculate the weight of the lifebuoy. **(2)**

Weight = mass x gravitational field strength

Weight = 2.5 x 9.8 = 24.5 N

(c) When thrown into the water the lifebuoy floats. The two forces acting on the lifebuoy are the weight of the lifebuoy downwards and upthrust upwards.

How big is the upthrust on the lifebuoy compared to the weight of the lifebuoy?

Tick **one** box. **(1)**

The upthrust is greater than the weight. ☐

The upthrust is less than the weight. ☐

The upthrust is the same as the weight. ☑

(d) Write down the equation which links acceleration, mass and resultant force. **(1)**

Resultant force = mass x acceleration

(e) A rope is used to pull the lifebuoy to the side of the swimming pool.

A resultant force of 4.0 N acts on the lifebuoy.

The mass of the lifebuoy is 2500g.

Calculate the acceleration of the lifebuoy. **(4)**

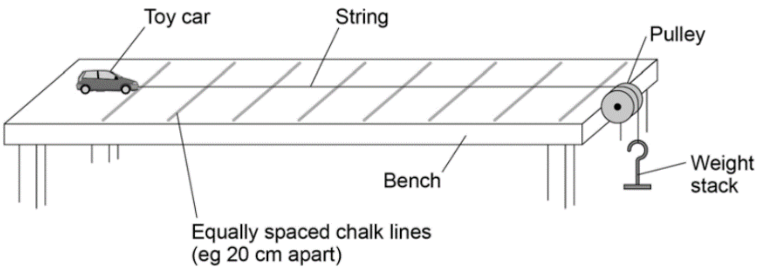
F = m x a 2500 g = 2.5 kg

a = F / m

a = 4.0 / 2.5 = 1.6 m/s^2

Required practical 7

Hypothesis: I think that the car will accelerate faster when more masses are applied to the string. This is because Newton's second law says that the force is equal to the mass multiplied by the acceleration. The larger the force applied the larger the acceleration.



acceleration – second – masses – faster – force

(Sample Data)

Mass (kg)	Force (N)	Time (s)	Acceleration (m/s^2)
0.01	0.1	10.2	0.019
0.02	0.2	7.0	0.041
0.03	0.3	5.9	0.057
0.04	0.4	5.1	0.077
0.05	0.5	4.3	0.109
0.06	0.6	4.1	0.120
0.07	0.7	3.8	0.138
0.08	0.8	3.5	0.162

Equation for weight:

W = m × g

(We have rounded g up to 10 N/kg)

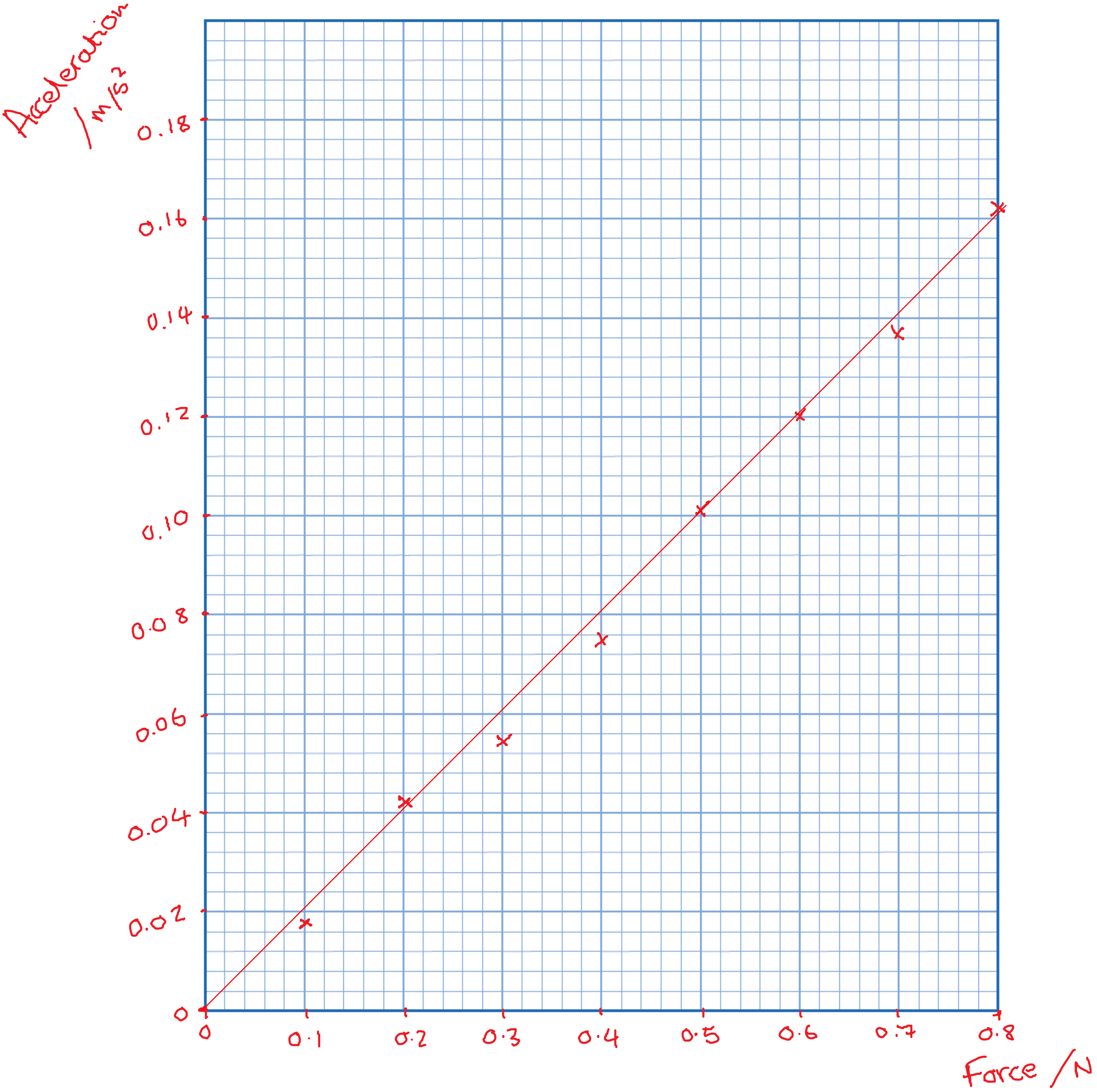
Calculate this by using $\mathbf{a = (2 \times s) \div t^2}$ (It's an A-level equation but we can use it anyway).
Distance **s** of the ramp = 1 metre.

Conclusion:

As I added more masses the time taken for the car to travel one metre decreased. This is because the car accelerated faster because of a larger force. My graph shows that the force is directly proportional to the acceleration, and proves Newton's second law.

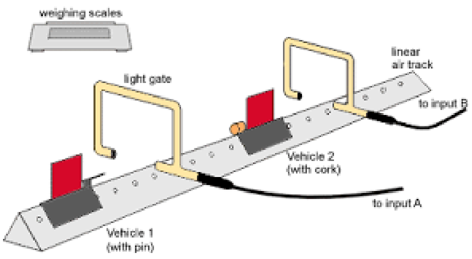
accelerated – decreased – larger – second – proportional

Task: Plot a graph of acceleration (on the y axis) against the force (on the x axis). Using a ruler, draw a line of best fit and calculate the gradient.



Note: This practical can also be carried out with **light gates**. A light gate is a device that gives out light. It can detect the amount of time that light is blocked by a moving object.

From **v = s ÷ t** we can then calculate the velocity (and the acceleration if we have two light gates).



Two students investigated how the acceleration of a trolley depends on the force applied to the trolley.

Before starting the investigation, each student wrote a hypothesis.

Hypothesis of student **A**:

> ‘The acceleration of the trolley is directly proportional to the force applied to the trolley.'

Hypothesis of student **B**:

> ‘Changing the force applied to the trolley will change the acceleration of the trolley.'

(a) Consider the hypothesis of student **A**.

Predict what would happen to the acceleration of the trolley if the force applied to the trolley is doubled. **(1)**

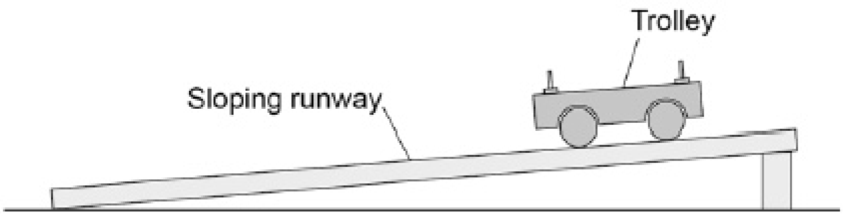
It would double

(b) Why is it difficult to make a valid prediction using the hypothesis of student **B**? **(1)**

The hypothesis does not say how increasing or decreasing the force would increase or decrease the acceleration

Figure 1 shows some of the equipment used by the students.

Figure 1



(c) Write a list of any other equipment the students will need to complete the investigation. **(2)**

Equipment to apply and measure force: eg. Newton meter, slotted masses, string, pulley

Equipment to measure change in velocity and time: eg. Ticker timer and tape, light gates and datalogger

(d) Why should the students use a sloping runway?

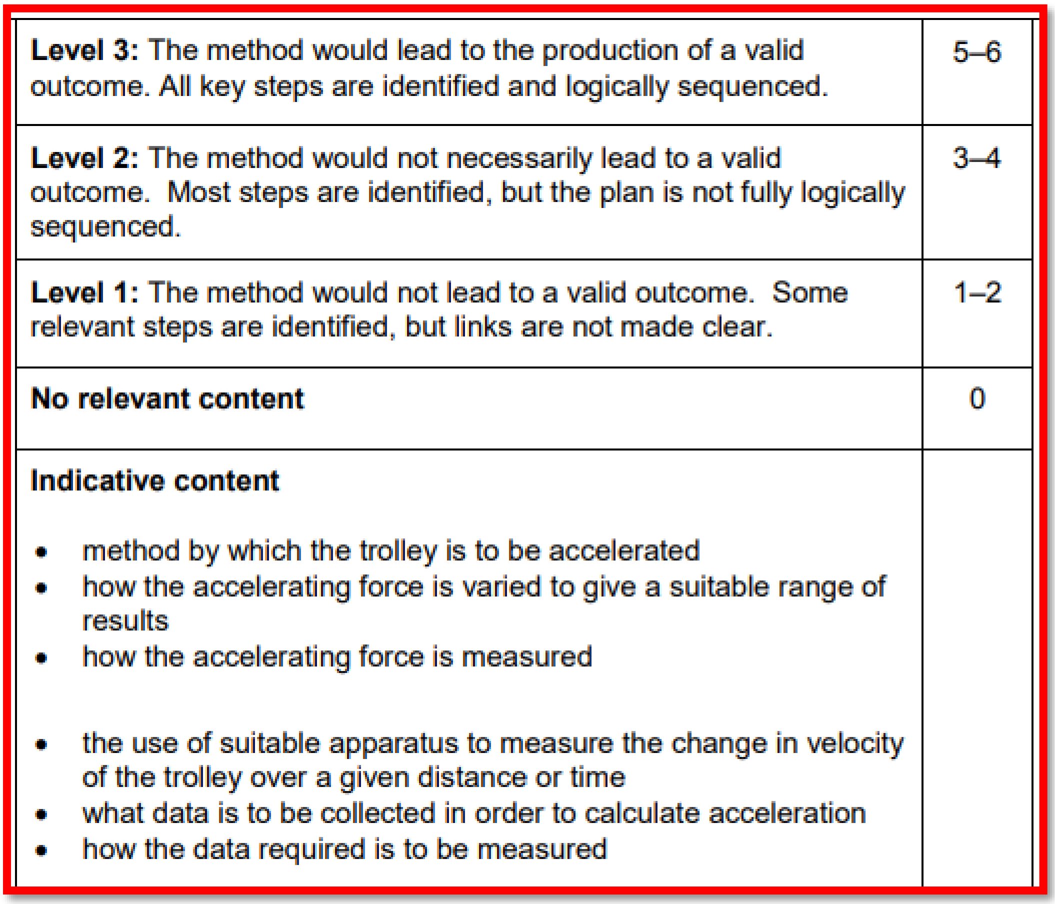
Tick **one** box. **(1)**

To reduce the effect of friction on the trolley. ☑

To decrease the acceleration of the trolley. ☐

To stop the trolley rolling back up the runway. ☐

(e) Describe a method the students could have used for their investigation. **(6)**



Level 3: The method would lead to the production of a valid outcome. All key steps are identified and logically sequenced.	5–6
Level 2: The method would not necessarily lead to a valid outcome. Most steps are identified, but the plan is not fully logically sequenced.	3–4
Level 1: The method would not lead to a valid outcome. Some relevant steps are identified, but links are not made clear.	1–2
No relevant content	0
Indicative content • method by which the trolley is to be accelerated • how the accelerating force is varied to give a suitable range of results • how the accelerating force is measured • the use of suitable apparatus to measure the change in velocity of the trolley over a given distance or time • what data is to be collected in order to calculate acceleration • how the data required is to be measured	

(f) The students used the same trolley throughout the investigation.

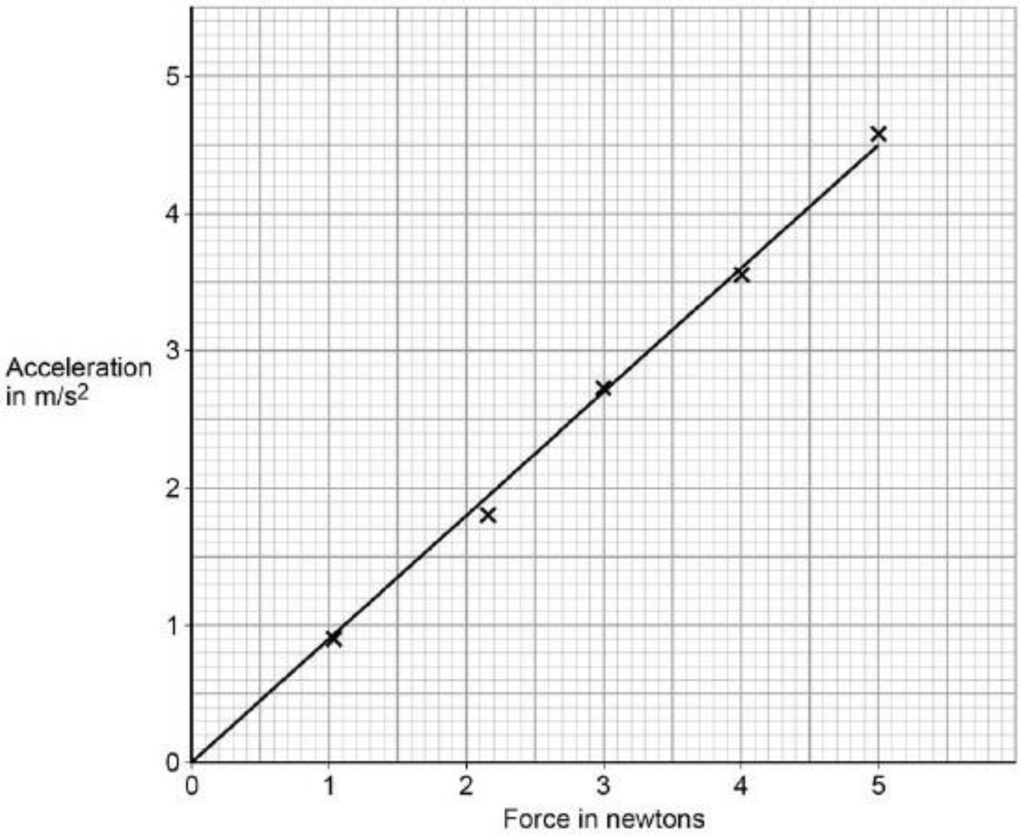
Suggest why. **(2)**

So that the mass is constant / so that there is only one independent variable

… because changing the mass of the trolley would change the acceleration

The students' results are shown as a graph in **Figure 2**.

Figure 2



(g) Explain why hypothesis **A** gives a better explanation of the results. **(2)**

The results give a straight line that passes through the origin

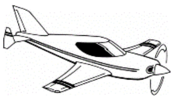
… showing direct proportionality

(Total 8 marks)

Terminal velocity

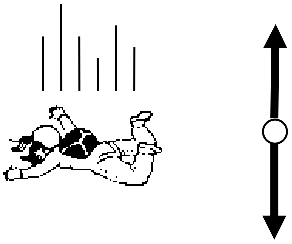
Fill in the missing gaps in the sentences. Some words can be used more than once.

Constant Terminal Upward Unbalanced Increases Decreases Small
Increase Weight Balanced Same Accelerate Decelerate Large

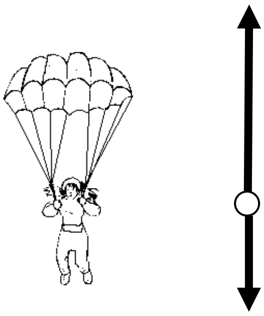


A The skydiver jumps out of the plane and the downward force of her weight pulls her down, her air resistance at the start is very small but soon she starts to accelerate,

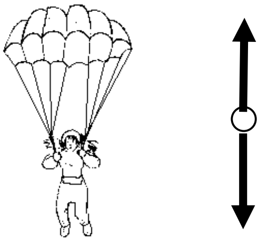
B As she accelerates the air resistance force increases and acts in the opposite direction to her weight .



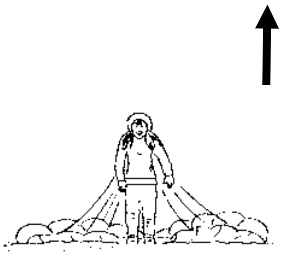
C As she accelerates faster the air resistance force continues to increase until eventually it is the same as her weight. She is now moving at a constant speed and her weight is equal to the air resistance. Her speed is called her terminal velocity (She cannot go any faster). The two forces are balanced .



D She opens her parachute. There is now a very large air resistance force so she starts to decelerate (slow down).



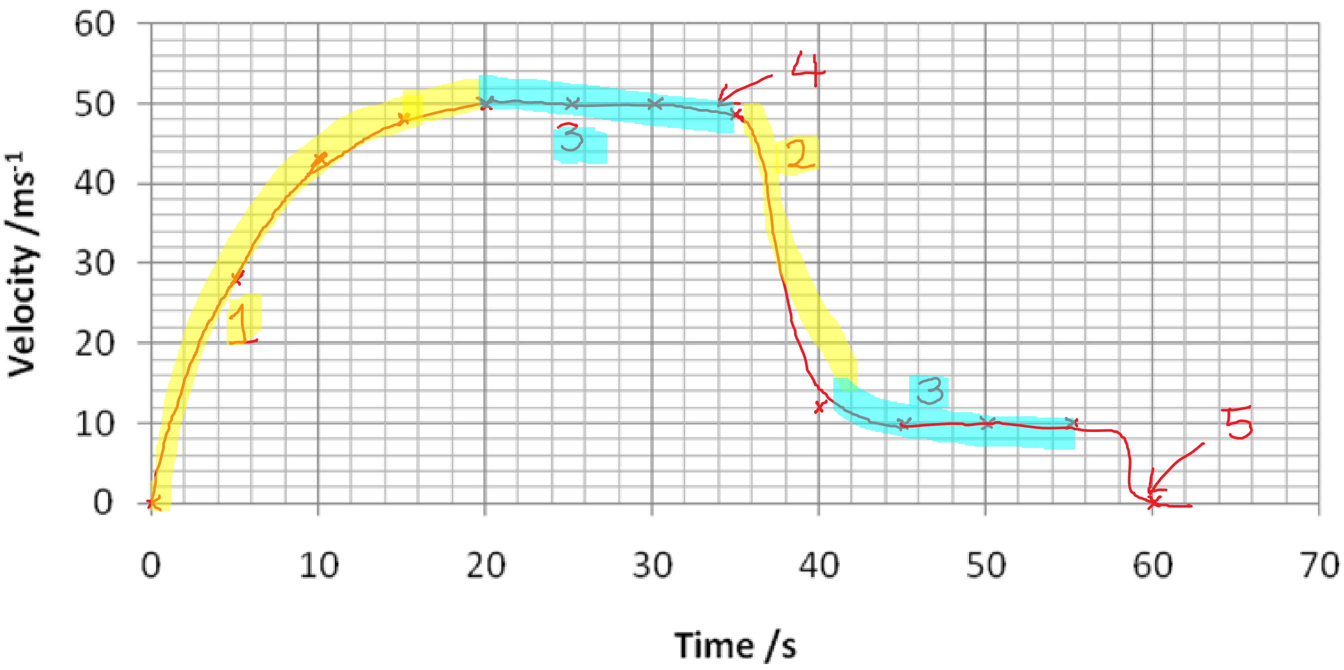
E As she decelerates the air resistance force on her parachute decreases until it is the same size as her weight. She is now again falling at a constant speed but she has a new and slower terminal velocity.



F On the ground her weight is now equal to the upwards force from the ground, the forces are balanced.

Task: The table below shows how the velocity of a skydiver changes over time. Plot a velocity-time graph below and draw a smooth curve that passes through each point.

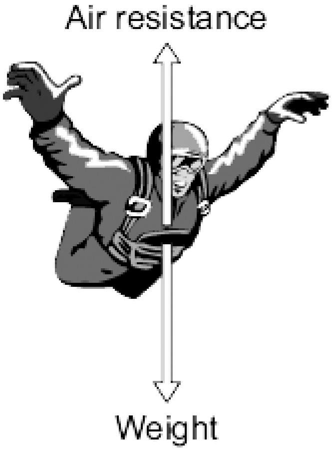
Time (s)	0	5	10	15	20	25	30	35	40	45	50	55	60
Velocity (m/s)	0	28	43	48	50	50	50	49	12	10	10	10	0



Label the following part of the skydivers descent:

1. Acceleration
2. Deceleration
3. Terminal velocity
4. Parachute open
5. Speed jumper hit the ground.

(a) The diagram shows the forces acting on a parachutist in free fall.



The parachutist has a mass of 75 kg.

Calculate the weight of the parachutist.

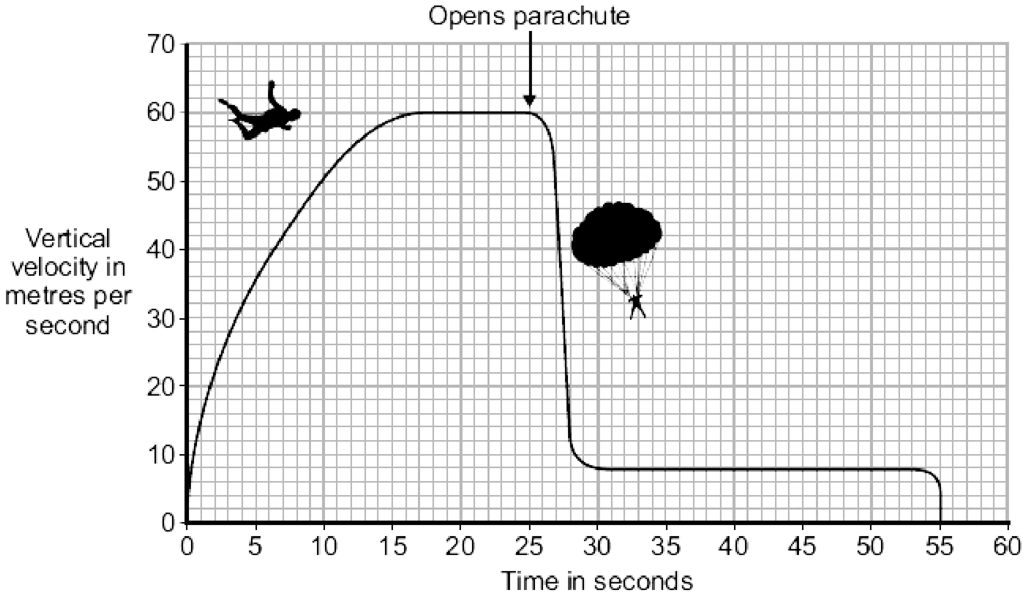
gravitational field strength = 9.8 N/kg

Show clearly how you work out your answer and give the unit.

Weight = mass x gravitational field strength = 75 x 9.8 = 735 N

(3)

(b) The graph shows how the vertical velocity of a parachutist changes from the moment the parachutist jumps from the aircraft until landing on the ground.



Using the idea of forces, explain why the parachutist reaches a terminal velocity and why opening the parachute reduces the terminal velocity. **(6)**

First terminal velocity:

- on leaving the plane the only force acting is weight (downwards)
- as parachutist falls air resistance acts (upwards)
- weight greater than air resistance
- (resultant force downwards) so parachutist accelerates
- as velocity / speed increases so does air resistance
- terminal velocity reached when air resistance = weight

to explain second lower terminal velocity:

- opening parachute increases surface area
- opening parachute increases air resistance
- air resistance is greater than weight
- resultant force acts upwards / opposite direction to motion
- parachutist decelerates / slows down
- the lower velocity means a reduced air resistance
- air resistance and weight become equal but at a lower (terminal) velocity

Level 1 (1-2 marks)

There is a brief attempt to explain why the velocity / speed of the parachutist changes.

Or the effect of opening the parachute on velocity/speed is given.

Level 2 (3-4 marks)

The change in velocity / speed is clearly explained in terms of force(s)

Or a reasoned argument for the open parachute producing a lower speed.

Level 3 (5-6 marks)

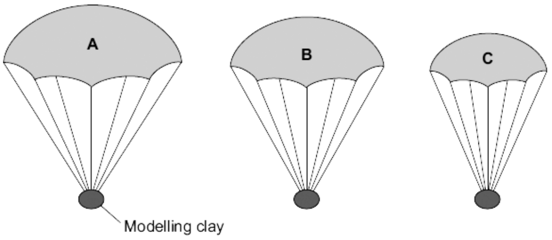
There is a clear and detailed explanation as to why the parachutist

reaches terminal velocity and a reasoned argument for the open parachute producing a lower speed

(c) A student wrote the following hypothesis.

'*The larger the area of a parachute, the slower a parachutist falls.*'

To test this hypothesis the student made three model parachutes, **A**, **B** and **C**, from one large plastic bag. The student dropped each parachute from the same height and timed how long each parachute took to fall to the ground.



(i) The height that the student dropped the parachute from was a control variable.

Name **one** other control variable in this experiment. **(1)**

Mass of modelling clay

size and/or shape of modelling clay

material of parachute

number of strings

(ii) Use the student's hypothesis to predict which parachute, **A**, **B** or **C**, will hit the ground first.

Write your answer in the box. C

Give a reason for your answer. **(2)**

Smallest surface area so falls fastest/takes the least time to reach the ground

(2)

(Total 12 marks)

Momentum

Any mass that is moving carries **momentum**. The equation for this is below:

Momentum = mass × velocity

$p = m \times v$

Where p is momentum in kg m/s

m is mass in kg

v is velocity in m/s

Note that because the equation for momentum contains velocity, momentum must be a **vector**.

If two objects collide or interact, the forces acting on each one will be the same size but in opposite directions. The same is true for the change in momentum of each object.

This means that the momentum lost by one of the objects will be gained by the other object. Therefore, whenever two objects collide or interact, **momentum is conserved**.

Example question: Dr. Edmunds drops his iPad. Just before it hits the ground it has a velocity of 5 m/s. If the iPad has a mass of 500g, what is its momentum?

Step 1: Write the equation. Rearrange if necessary.

$p = m \times v$

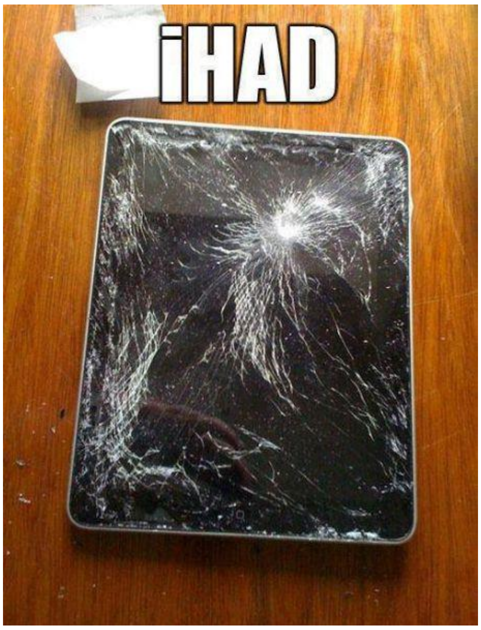
Step 2: Write down the variables

$m = 500$ g $= 0.5$ kg

$v = 5$ m/s

Step 3: Calculate the answer

$p = m \times v = 0.5 \times 5 = 2.5$ kg m/s



Task: Complete in your exercise book.

Basic

Q1. The momentum of this snowball increases because two factors increase as it rolls down the hill. What do you think the two factors are?

- Mass (it gathers more snow)
- Velocity (it speeds up)

Q2. Momentum can be calculated using this equation:

Momentum = mass x velocity

Q3. The units of momentum are kg m/s (kilogram metres per second)

Q4. Calculate the **momentum** if:

a) m = 0.3 kg, v = 7 m/s 2.1 kg m/s b) m = 5 kg, v = 12 m/s 60 kg m/s

Q5. Calculate the **velocity** if:

a) p = 1.5 kg m/s, m = 0.3 kg 5m/s b) p = 17 kg m/s, m = 8.5 kg 2 m/s

Q6. Calculate the **mass** if:

a) p = 1400 kg m/s, v = 20 m/s 70 kg b) p = 1,800,000 kg m/s, v =9 m/s. 200 000 kg

Medium (re-arranging and unit conversion)

Q7. Calculate the **momentum** of a football of mass 500g travelling at a velocity of 10 m/s. 5 kg m/s

Q8. Calculate the **momentum** of a mouse of mass 400g running through the grass at 3 m/s. 1.2 kg m/s

Q9. An athlete running at 8 m/s has a momentum of 520 kg m/s. What is her **mass**? 65 kg

Q10. Cristiano Ronaldo kicks a football at a momentum of 50 kg m/s. If the mass of the football is 500g, what **velocity** has he kicked the football at? 100 m/s

Q11. Dr. Edmunds is late for a lesson and runs with a momentum of 700 kg m/s. If his velocity is 10 m/s, what is his **mass**? (be nice…) 70 kg

Q12. 10H1 is going on a school trip to the moon. The rocket we're using has a momentum of 700,000,000 kg m/s and is travelling at a speed of 1,400 m/s. What is the **mass** of the rocket? 500 000 kg

Hard (hard unit conversion or using more than one equation)

Tonne → kg × 1000

Q13. A car that weighs 2 tonnes is travelling at a velocity of 20 m/s. Calculate its **momentum**. 40 000 kg m/s

miles → metres × 1600

Q14. A train is travelling at 80 mph, and has a mass of 100 Tonnes. Calculate its **momentum**. 3 600 000 kg m/s

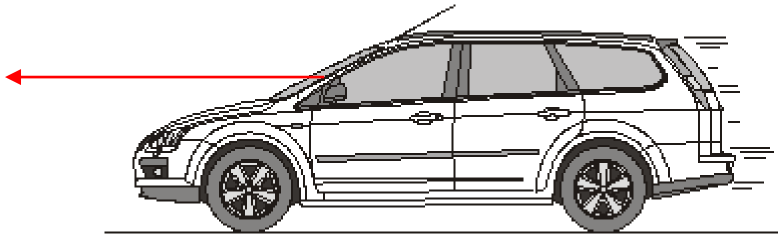
Q15 Usain Bolt runs at a maximum speed of 27 mph. If he has a momentum of 960 kgm/s, what is his **mass**? 80 kg

Q16 An eagle travels a distance of 150m in a time of 12 seconds. If the eagle weighs 4kg, what is the **momentum** of the eagle. 50 kg m/s

Q17. An aeroplane of mass 200 tonnes travels a distance of 900 km in a time of 90 minutes. Calculate the **momentum** of the aeroplane. 33 000 000 kg m/s

Q1.

(a) The diagram shows a car travelling at a speed of 12 m/s along a straight road.



(i) Calculate the momentum of the car.

Mass of the car = 900 kg

Show clearly how you work out your answer.

p = m v

p = 900 x 12 = 10 800 kg m/s

(2)

(ii) Momentum has direction.

Draw an arrow on the diagram to show the direction of the car's momentum.

(1)

(b) The car stops at a set of traffic lights.

How much momentum does the car have when it is stopped at the traffic lights?

Zero

Give a reason for your answer.

Velocity is zero / it is not moving

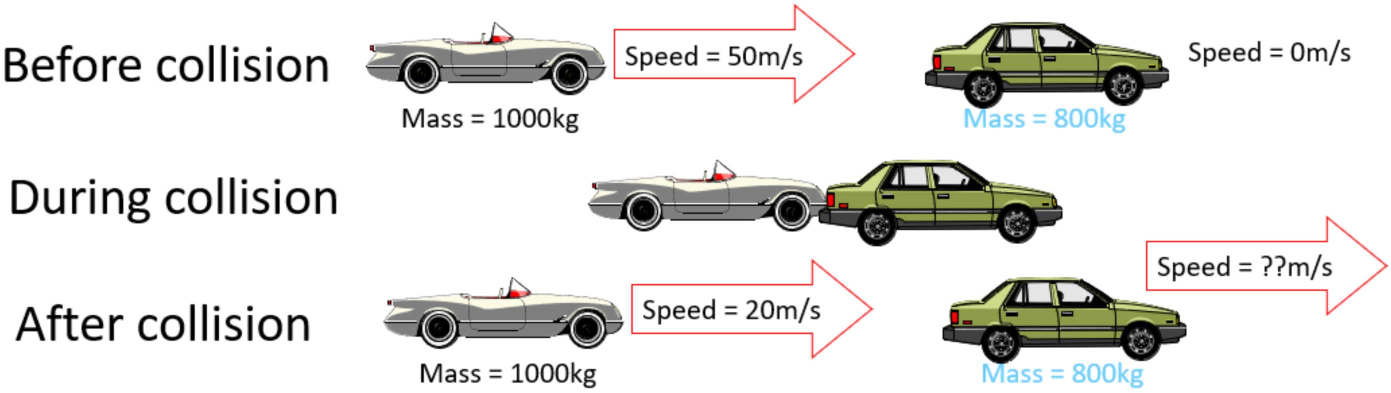
(2)

(Total 5 marks)

Conservation of momentum

Conservation of momentum means that momentum before a collision/explosion is the same as after.

Examples of this include car crashes, balls hitting each other and explosions.



Worked example:

a) Calculate the change in momentum of the white car.

Initial momentum = p × v = 1000 × 50 = 50,000 kg m/s
Final momentum = p × v = 1000 × 20 = 20,000 kg m/s
Change in momentum = 50,000 – 20,000 = 30,000 kg m/s

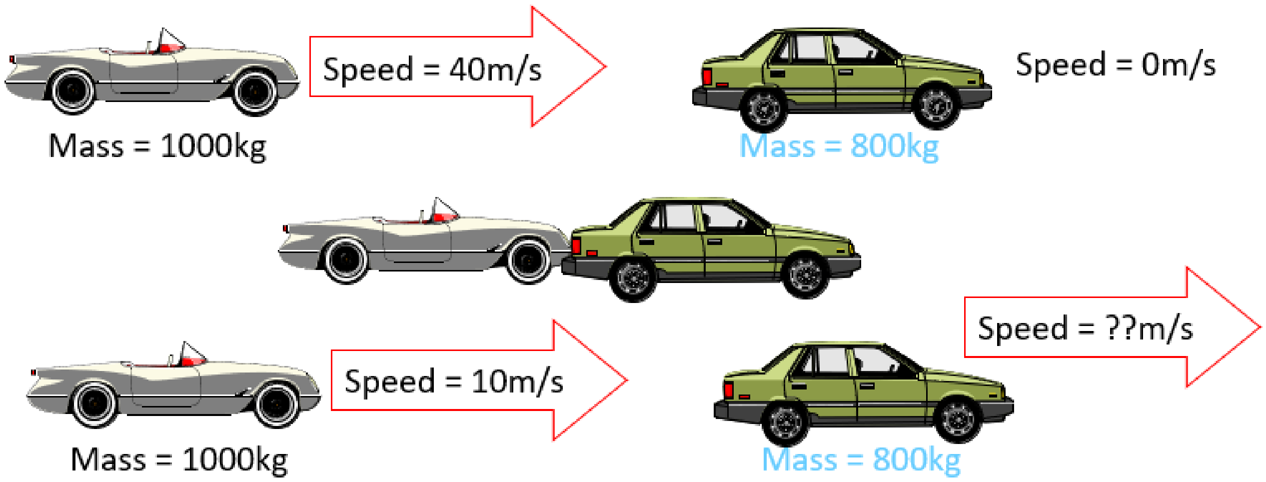
b) Calculate the velocity after the collision of the green car.

If the momentum of the white car has gone down by 30,000 kg m/s. The velocity of the green car must have gone up by 30,000 kg m/s as momentum is **conserved**.

Therefore p = m × v → 30,000 = 800 × v

→ v = 30,000 ÷ 800 = 37.5 m/s

Task: Complete in your exercise book.



a) Calculate the change in momentum of the first car.

p_{before} = 1000 x 40 = 40 000 kg m/s

p_{after} = 1000 x 10 = 10 000 kg m/s

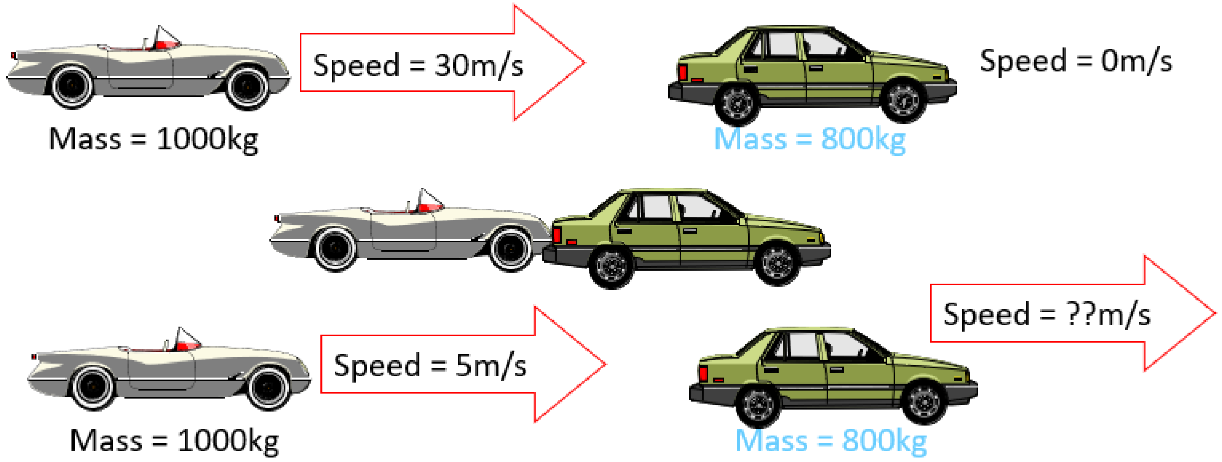
change in momentum = 30 000 kg m/s

b) Calculate the velocity after the collision of the second car.

Total momentum = 40 000 kg m/s

10 000 + (800 x v) = 40 000

v = 37.5 m/s



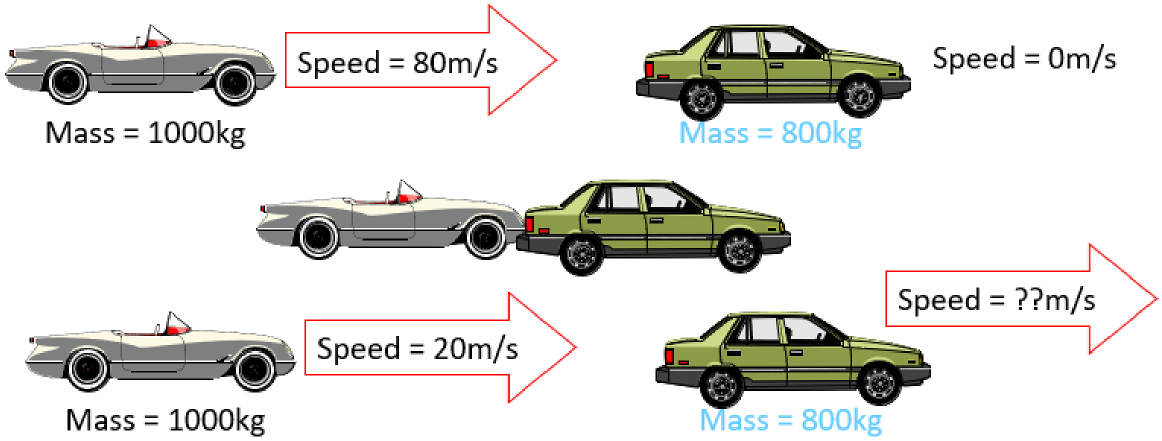
a) Calculate the change in momentum of the first car.

30 000 – 5000 = 25 000 kg m/s

b) Calculate the velocity after the collision of the second car.

5000 + (800 x v) = 30 000

v = 31.3 m/s



a) Calculate the change in momentum of the first car.

80 000 – 20 000 = 60 000 m/s

b) Calculate the velocity after the collision of the second car.

60 000 + (800 x v) = 80 000

v = 25 m/s

Q1.

(a) In any collision, the total momentum of the colliding objects is usually conserved.

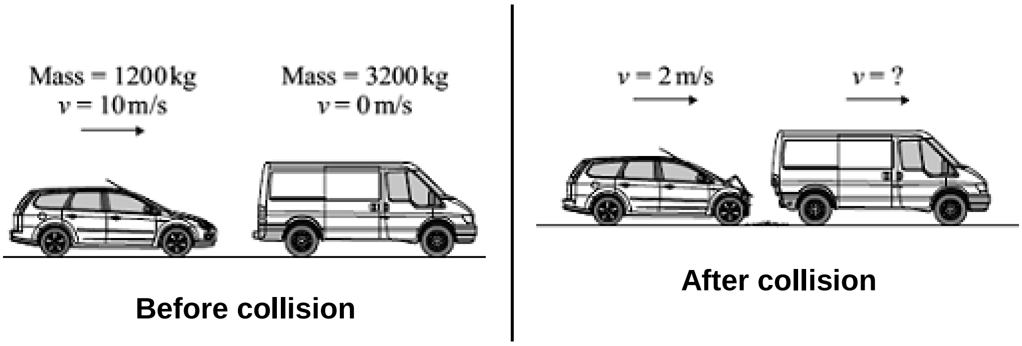
What is meant by the term ‘momentum is conserved’?

Momentum before a collision = momentum after the collision

/ no momentum is lost or gained

(1)

(b) The diagram shows a car and a van, just before and just after the car collided with the van.



Before collision

After collision

(i) Use the information in the diagram to calculate the **change** in the momentum of the car.

Show clearly how you work out your answer and give the unit.

Momentum before = 1200 x 10 = 12 000 kg m/s

Momentum after = 1200 x 2 = 2400 kg m/s

Change in momentum = 12 000 – 2400 = 9600 kg m/s

(3)

(ii) Use the idea of conservation of momentum to calculate the velocity of the van when it is pushed forward by the collision.

Show clearly how you work out your answer.

Momentum before = 12 000 kg m/s = Momentum after collision

12 000 = (momentum of car) + (momentum of van)

12 000 = (1200 x 2) + (3200 x v)

9600 = 3200 x v

v = 3 m/s

(2)

(Total 6 marks)

When you fire a rifle, the explosion causes the bullet to fly out of the barrel. It also causes the rifle to push back into your shoulder (**recoil**). The velocity of the bullet can be calculated using the equation $p = m \times v$.

Worked example:

A bullet of mass 0.01kg is fired from a rifle of mass 2kg, which recoils with a velocity of 1m/s. What is the velocity of the bullet?

Momentum of Rifle = Momentum of bullet (just in opposite directions)

Momentum of rifle = $m \times v = 2 \times 1 = 2$ kg m/s

Therefore momentum of bullet = 2 kg m/s

$p = m \times v \rightarrow 2 = 0.01 \times v$

$\rightarrow v = 2 \div 0.01 = 200$ m/s

Note how even though the bullet has much less mass than the rifle, it has the same momentum because its velocity is much higher.

A paintball gun is used to fire a small ball of paint, called a paintball, at a target. The figure below shows someone just about to fire a paintball gun. The paintball is inside the gun.

(a) What is the momentum of the paintball before the gun is fired? **(2)**

Zero

Give a reason for your answer.

Velocity = 0 (it is not moving)

(b) The gun fires the paintball forwards at a velocity of 90 m / s. The paintball has a mass of 0.0030 kg. Calculate the momentum of the paintball just after the gun is fired. **(2)**

$p = m v$

$p = 0.0030 \times 90$

Momentum = 0.27 kg m / s

(c) The momentum of the gun and paintball is conserved.

Use the correct answer from the box to complete the sentence. **(1)**

equal to	**greater than**	**less than**

The total momentum of the gun and paintball just after the gun is fired

will be equal to the total momentum of the gun and

paintball before the gun is fired.

d) The gun has a mass of 500g. Using conservation of momentum, calculate the recoil speed of the gun. **(4)**

Momentum of paintball = 0.27 kg m/s

So momentum of gun = 0.27 kg m/s (in the opposite direction)

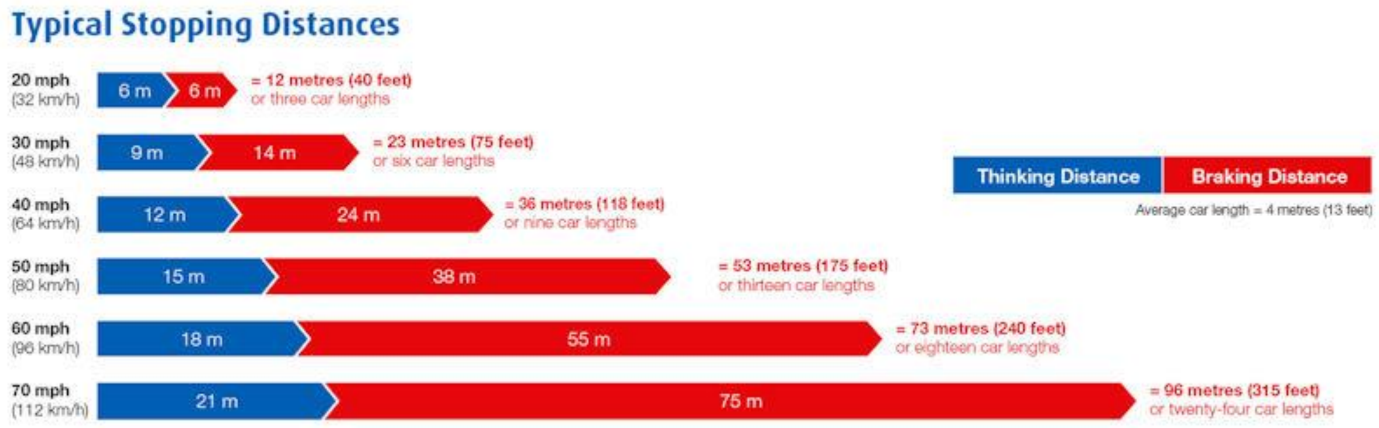
$p = m v$ -> $v = p / m = 0.27 / 0.500$

$v = 0.54$ m/s

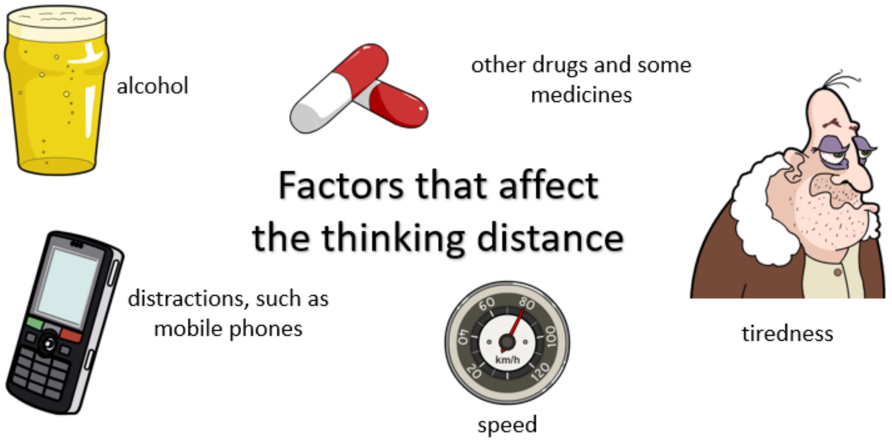
Stopping distance

The stopping distance of a car is the minimum distance that a car can safely stop in. It is made up of the thinking distance and the braking distance.

Stopping distance = thinking distance + braking distance

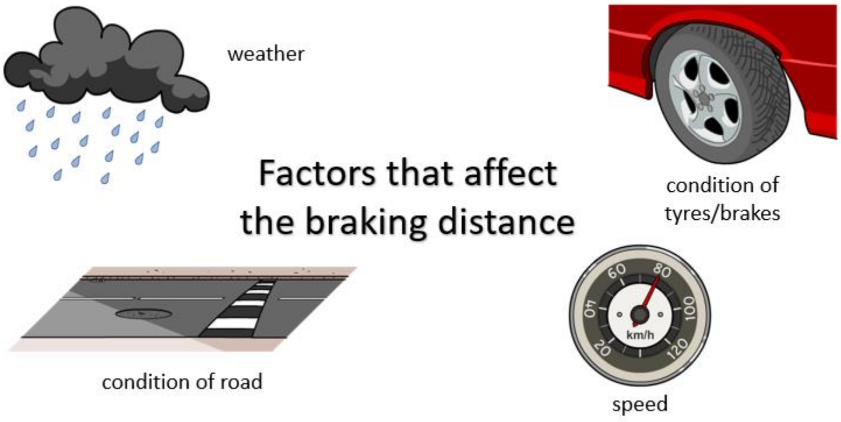


The thinking distance is the distance travelled by the vehicle in the time it takes for the driver to react. If the vehicle is travelling quickly, or if the drivers **reaction time** is slowed then the thinking distance will be increased.



The braking distance is the distance travelled by the vehicle during the time the braking force acts.

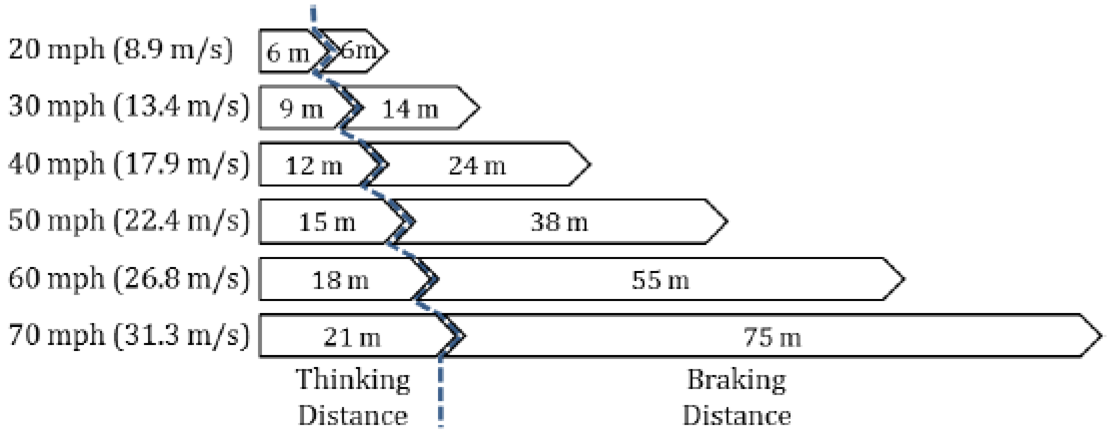
Speed also effects the braking distance, but so do conditions that reduce **friction**.



Task: Complete in your exercise book.

1. Vehicle stopping distances are made up from the thinking distance and the braking distance.
   a) Describe two factors that could affect the thinking distance.
   Drugs, alcohol, age, tiredness, distractions
   b) The braking distance is how far the vehicle travels from when the brakes are first pressed to when the vehicle stops. Explain the energy change that happens during this time. Kinetic -> heat

2. The diagram shows typical stopping distances at different speeds.



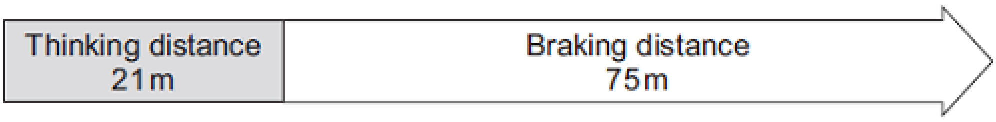
   a) During the thinking distance, the speed of the vehicle does not change. Use the equation for speed, distance and time to work out the time taken to cover the thinking distance at 50 mph. 0.67 s
   b) Look at the stopping distances at 30 mph and 60 mph. Compare how the thinking distance and braking distance change with this doubling of speed. Thinking distance is double, braking distance is four times as far
   c) At 40 mph, the thinking distance is 12 m and the braking distance is 24m. Estimate the size of the stopping distance at 80 mph.
   Thinking distance: 2 x 12 = 24 m, braking distance: 4 x 24 = 96 m
   Total stopping distance = 120 m
3. Many modern vehicles can stop in a shorter distance than those in the chart.

   What difference do modern brakes and tyres make to the physics of the slowing down of the vehicle?

   Tyres: Better grip between road and tyre, increased friction (less likely to skid), Brakes: good quality brakes increase energy transfer to heat.

(a) A car driver makes an emergency stop.

The chart shows the ‘thinking distance’ and the ‘braking distance’ needed to stop the car.

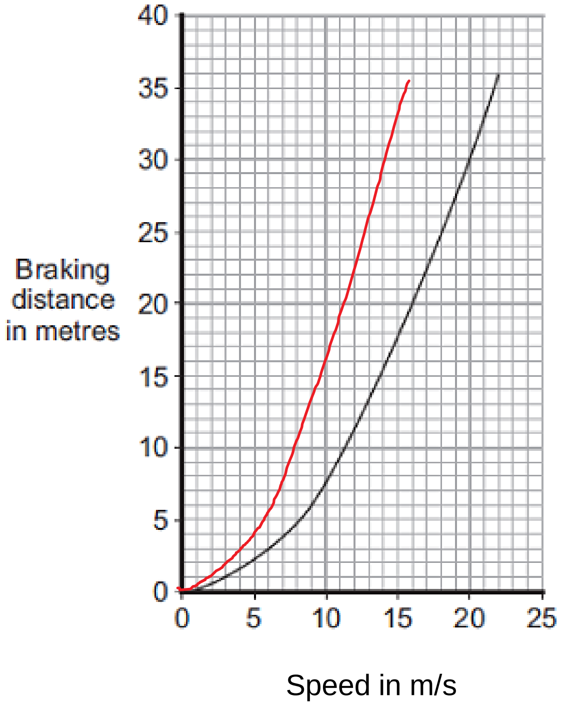


Calculate the total stopping distance of the car. **(1)**

21 + 75

Stopping distance = 96 m

(b) The graph shows how the braking distance of a car driven on a dry road changes with the car’s speed.



The braking distance of the car on an icy road is longer than the braking distance of the car on a dry road.

(i) Draw a new line on the graph to show how the braking distance of the car on an icy road changes with speed. **(2)**

(ii) Which **one** of the following would also increase the braking distance of the car? Put a tick (✓) in the box next to your answer. **(1)**

Rain on the road ☑

The driver having drunk alcohol ☐

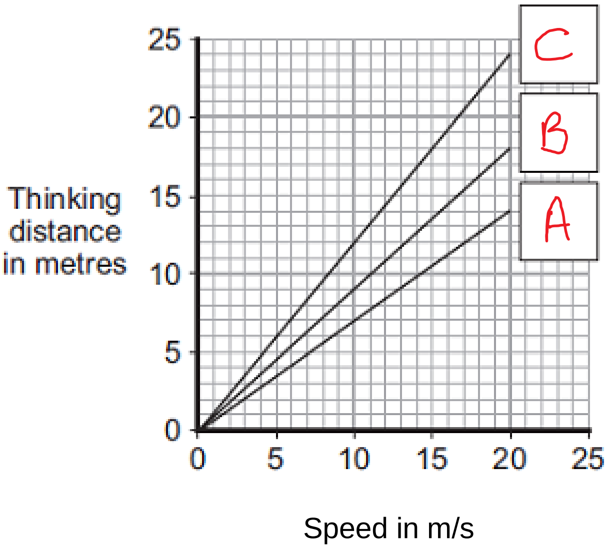
The driver having taken drugs ☐

(c) The thinking distance depends on the driver’s reaction time.

The table shows the reaction times of three people driving under different conditions.

Car driver	**Condition**	**Reaction time in second**
A	Wide awake with no distractions	0.7
B	Using a hands-free mobile phone	0.9
C	Very tired and listening to music	1.2

The graph lines show how the thinking distance for the three drivers, **A**, **B**, and **C**, depends on how fast they are driving the car.



(i) Match each graph line to the correct driver by writing **A**, **B**, or **C** in the box next to the correct line. **(2)**

(ii) The information in the table cannot be used to tell if driver **C**’s reaction time is increased by being tired **or** by listening to music. Explain why. **(2)**

Both variables are together

Both variables could affect reaction time

Cannot tell which is contributing to the reaction time increase

Would need to test each variable separately/need to control one of the variables