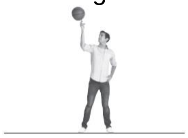
**Q1.**

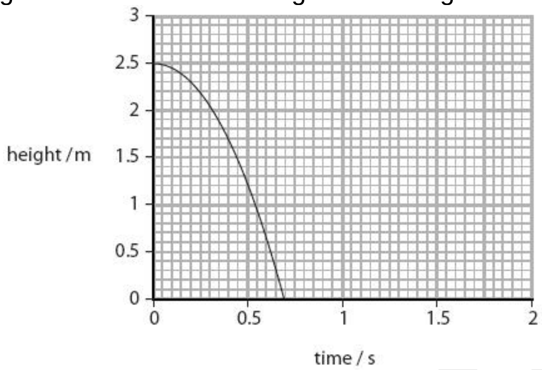
The man in the photograph balances a ball above the ground.



He lets the ball fall.

He starts a timer at the same time.

The graph shows how the height of the ball above the ground changes with time.




(i) From the graph, state the height of the ball above the ground when the timer was started. **(1)**

(ii) From the graph, state the time taken for the ball to reach the ground. **(1)**

(iii) The ball bounces back to a height of 1.9 m.
Continue the line on the graph to show this. **(3)**

(iv) Explain why the ball does not bounce back to its original height. **(2)**

**Q2.**

Figure 4 shows two students investigating their reaction times.
Student B supports his left hand on a desk.
Student A holds a ruler so that the bottom end of the ruler is between the finger and thumb of student B.
When student A releases the ruler, student B catches the ruler as quickly as he can.
The investigation is repeated with the right hand of student B.

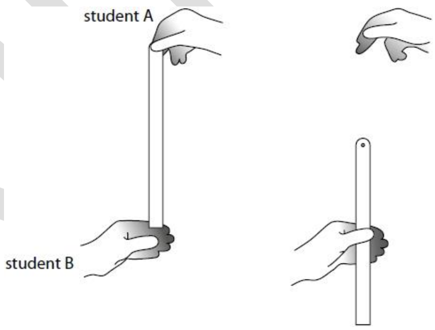



**Figure 4**

(a) The students took five results for the left hand and five results for the right hand.
Figure 5 shows their results.

| which hand | distance dropped (cm) | | | | | |
|---|---|---|---|---|---|---|
| | trial 1 | trial 2 | trial 3 | trial 4 | trial 5 | average |
| left | 10.1 | 25.5 | 18.4 | 14.6 | 11.7 | 14 |
| right | 17.5 | 16.1 | 19.4 | 18.6 | 20.2 | .................... |

**Figure 5**

(i) Calculate the average distance dropped for the right hand.
Give your answer correct to 2 significant figures. **(2)**

(ii) Calculate the average time for the left hand.
Use the equation

$$\text{time}^2 = \frac{\text{distance}}{500}$$

**(2)**

(b) Explain whether any of the readings are anomalous.

**(2)**

(c) Give **two** ways that the students can improve the quality of their data other than ignoring anomalous results.

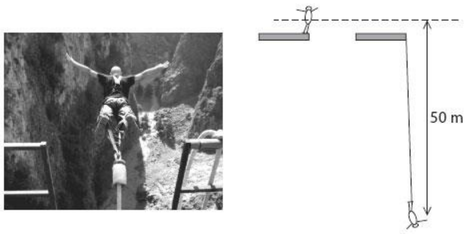
**(2)**

(d) Describe how the students could develop their investigation to investigate how reaction time changes with another variable.

**(2)**

**Q3.**

A 60 kg student weighs 600 N.
He does a bungee jump.

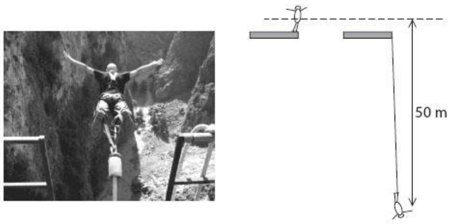



The bungee cord becomes straight and starts to stretch when he has fallen 50 m.
Complete the sentence by putting a cross ( ☒ ) in the box next to your answer.
When his speed is 10 m/s his momentum is

**(1)**

☒ **A** 600 kg m/s
☒ **B** 3 000 kg m/s
☒ **C** 6 000 N m/s
☒ **D** 30 000 N m/s

**Q4.**
A 60 kg student weighs 600 N.
He does a bungee jump.




The bungee cord becomes straight and starts to stretch when he has fallen 50 m.
(a) Complete the sentence by putting a cross ( ■ ) in the box next to your answer.
He first stops moving

**(1)**

☒ **A** before all the energy has disappeared
☒ **B** before the bungee cord starts to stretch
☒ **C** when the bungee cord is stretched the most
☒ **D** when the elastic potential energy is zero

(b) Complete the sentence by putting a cross ( ■ ) in the box next to your answer.
When his speed is 10 m/s his momentum is

**(1)**

☒ **A** 600 kg m/s
☒ **B** 3 000 kg m/s
☒ **C** 6 000 N m/s
☒ **D** 30 000 N m/s

(c) (i) Calculate the change in gravitational potential energy as the student falls 50 m. **(3)**

(ii) State at what point in the bungee jump the student has maximum kinetic energy.

(1)

(iii) Explain why his maximum kinetic energy is likely to be less than your answer to (c)(i).

(2)

**Q5.**

Figure 10a shows a box falling towards a hard floor.

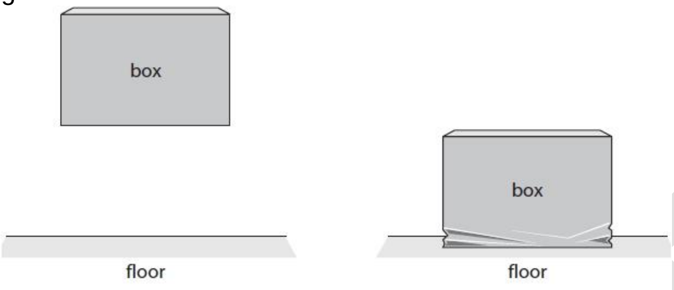



Figure 10a　　Figure 10b

The box hits the floor and crumples a little before it comes to rest as shown in Figure 10b.
The momentum of the box just before it hits the floor is 8.7 kg m/s.
The box comes to rest 0.35 s after it first hits the floor.

(i) Calculate the magnitude of the force exerted by the floor on the box.
Use an equation selected from the list of equations at the end of this paper.

(2)

(ii) State the magnitude and direction of the force exerted by the box on the floor.

(2)

**Q6.**

Figure 8 shows two ice skaters during a performance.

**Figure 8**

(i) The two ice skaters are travelling together in a straight line at 3.50 m/s.
Their total momentum is 371 kgm/s.
The man has a mass of 64.5 kg.
Calculate the mass of the woman.

(4)

(ii) Calculate the kinetic energy of the man.

(2)

**Q7.**

Figure 7 is a velocity/time graph showing a 34 s part of a train's journey.

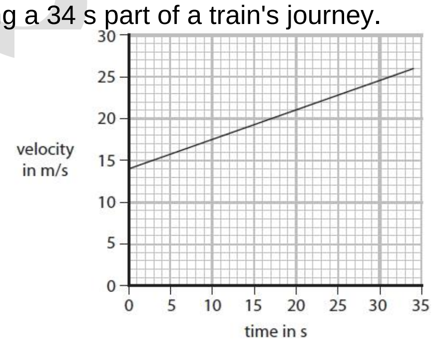



Figure 7

(i) Calculate the acceleration of the train in the 34 s.
Give your answer to an appropriate number of significant figures.

(3)

(ii) Calculate the distance the train travels in the 34 s.

(3)

**Q8.**

Figure 5 shows a racket and a tennis ball.
The tennis ball is travelling towards the racket at a velocity of 8.2 m/s.
The ball is hit back in the opposite direction at a velocity of 15 m/s.
The ball has a mass of 0.075 kg.
The ball is in contact with the racket for 12 ms.

(i) Calculate the average force exerted by the ball on the racket.
Use the equation

$$F = \frac{mv - mu}{t}$$

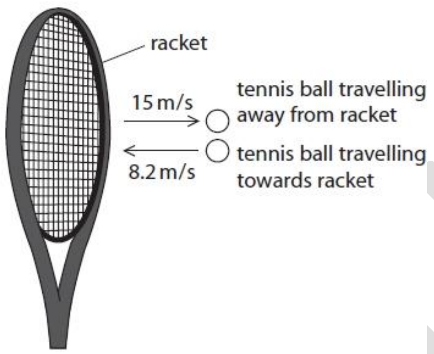



**Figure 5**

**(3)**

(ii) Describe how Newton's Third Law of Motion applies to the collision between the racket and the ball.

**(2)**

**Q9.**

Figure 9 shows a skier on a slope.
The skier travels down the slope with a constant acceleration.
The speed of the skier is measured at points P and Q.

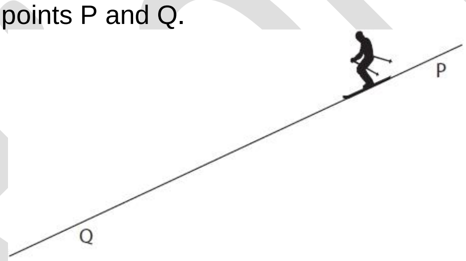



**Figure 9**

The table in Figure 10 gives some data about the skier making one downhill run.

| | |
|---|---|
| acceleration | 3.0 m/s² |
| speed at P | 7.6 m/s |
| speed at Q | 24 m/s |

**Figure 10**

(i) Calculate the distance from P to Q.
Use an equation selected from the list of equations at the end of this paper.

**(3)**

(ii) Calculate the time taken for the skier to travel from P to Q.

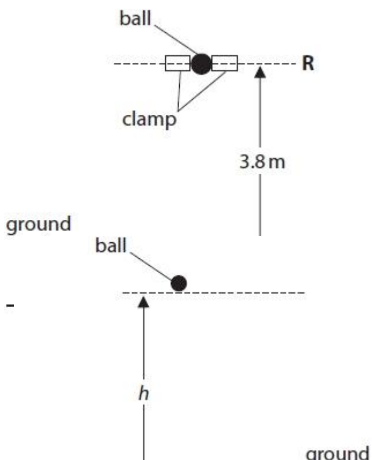
**(3)**

**Q10.**

Figure 11 shows a ball held in a clamp at **R**, above the ground.

The ball is released from the clamp and falls.
**S** is 3.8 m below **R**.
At **S** the momentum of the ball is 0.40 kg m/s.
Calculate the mass of the ball.
Acceleration due to gravity, $g$, = 10 m / s²

**(4)**




**Q11.**

Figure 9 shows a small steel ball held at a height, *h*, above the ground.

The ball is released and allowed to fall to the ground.
The height *h* is 1.4 m.
Calculate the time, *t*, for the ball to reach the ground.
Use the equation

$$t^2 = \frac{2h}{g}$$

g = 10 m/s$^2$

**(2)**

**Q12.**
A car travelling at 15 m/s comes to rest in a distance of 14 m when the brakes are applied.
Calculate the deceleration of the car.
Use an equation selected from the list of equations at the end of this paper.

**(3)**

**Q13.**

The photograph shows a man dropping an egg inside a padded box from a height.

He is investigating to see if the padding stops the egg from breaking.
The velocity of the container was 18 m/s as it hit the floor.
The mass of the container was 0.5 kg.
Calculate the momentum of the container.

**(2)**

**Q14.**
(a) A car accelerates at a constant rate of 1.83 m/s$^2$ along a flat straight road.
The force acting on the car is 1.870 kN.
Calculate the mass of the car.
Give your answer to three significant figures.

**(3)**

(b) The car accelerates from rest for 16 s.
Calculate the speed of the car after 16 s.

**(3)**

(c) The car starts on another journey.
Figure 6 shows the graph of the car's movement.

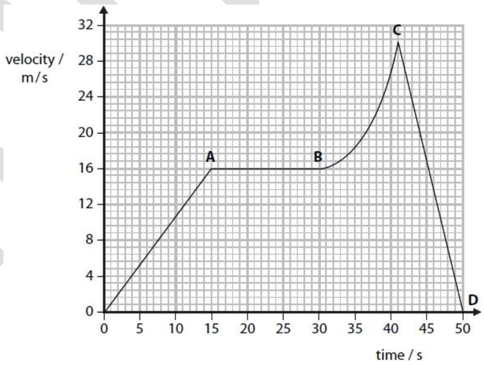



**Figure 6**

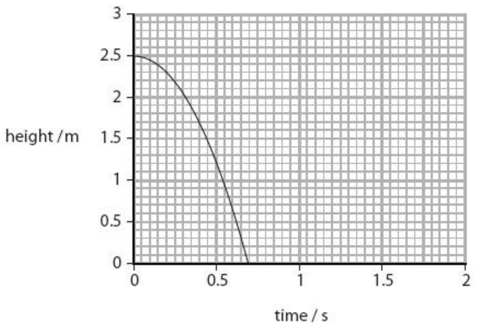
Show that the distance travelled when the car is moving at a constant speed is greater than the distance travelled when the car is slowing down.

**(4)**

**Q15.**

(a) The man in the photograph balances a ball above the ground.

He lets the ball fall.
He starts a timer at the same time.
The graph shows how the height of the ball above the ground changes with time.




(i) From the graph, state the height of the ball above the ground when the timer was started.

**(1)**

(ii) From the graph, state the time taken for the ball to reach the ground.

**(1)**

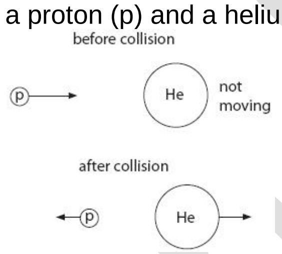
(iii) The ball bounces back to a height of 1.9 m.
Continue the line on the graph to show this.

**(3)**

(iv) Explain why the ball does not bounce back to its original height.

**(2)**

(b) The diagram shows a collision between a proton (p) and a helium nucleus (He).




(i) The table gives some information about the collision.

| | | before collision | after collision |
|---|---|---|---|
| proton | kinetic energy (arbitrary units) | 12.5 | 4.5 |
| helium nucleus | kinetic energy (arbitrary units) | 0 | 8 |

Use information from the table to show that the collision is elastic.

**(2)**

(ii) State the name of one device that can be used to accelerate protons to very high speeds.

**(1)**

**Q16.**

* Figure 13 shows two objects, Q and R, before and after they collide.

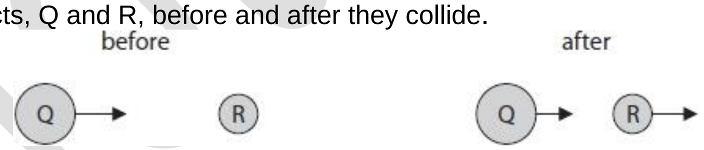



**Figure 13**

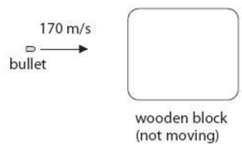
The arrows show the direction of movement of the objects.
The arrows are not to scale.
Explain how momentum is conserved in the collision.
Use Newton's third law and Newton's second law in your answer.
Newton's second law can be written as

$$\text{force} = \frac{\text{change in momentum}}{\text{time}}$$

**(6)**

**Q17.**

(a) The diagram shows a bullet moving towards a wooden block.




(i) The bullet is moving with a velocity of 170 m/s.
The mass of the bullet is 0.030 kg.
Show that the momentum of the bullet is about 5.0 kg m/s.

**(1)**

(ii) The bullet collides with the wooden block and sticks in it.
The bullet and the wooden block move off together.
The mass of the wooden block is 0.80 kg.
Calculate the velocity of the wooden block and bullet immediately after the collision.

**(3)**

(iii) The collision between the bullet and the wooden block is an inelastic collision.
State what is meant by an **inelastic collision.**

**(2)**

(b) An electron and a positron collide and annihilate each other.
Two photons are produced.
(i) Explain why two photons must be produced, rather than just one.

**(2)**

(ii) Calculate the minimum total energy of the photons produced when an electron and positron collide.
Use the equation

$E = mc^2$

mass of an electron = $9.1 \times 10^{-31}$ kg
speed of light = $3.0 \times 10^{8}$ m/s

**(2)**

**Q18.**

The force that keeps an object moving in a circular path is known as the

**(1)**

- ☐ **A** balancing force
- ☐ **B** centripetal force
- ☐ **C** reaction force
- ☐ **D** resistance force

**Q19.**

(a) A cyclotron accelerates charged particles.
(i) Describe the shape of the path a charged particle takes in the cyclotron.

**(1)**

(ii) Explain how radioactive isotopes can be produced using cyclotrons.

**(3)**

(b) (i) Complete the sentence by putting a cross (☒) in the box next to your answer.
In an **inelastic** collision there is conservation of

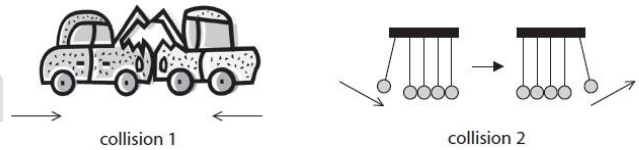
**(1)**

- ☐ **A** kinetic energy
- ☐ **B** momentum
- ☐ **C** kinetic energy and momentum
- ☐ **D** velocity

(ii) State why momentum has the unit kg.m/s.

**(1)**

*(iii) Different types of collision are shown in the diagrams.
Analyse both collisions in terms of momentum and kinetic energy.




**(6)**

**Q20.**

Students investigate conservation of momentum using two identical trolleys.
A card is then added to trolley A.
Some of the apparatus is set up as shown in Figure 4.

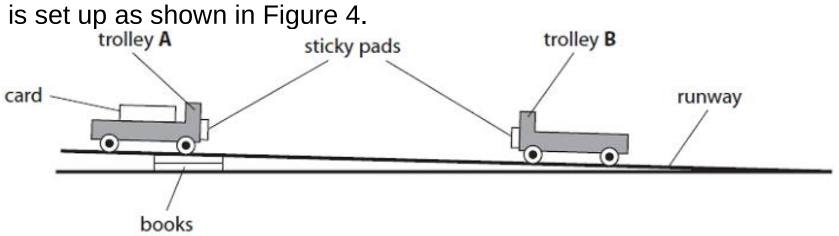



**Figure 4**

(i) Describe an investigation the students could carry out to show that momentum is conserved when these two trolleys collide.

You may add to the diagram to help with your answer.

**(4)**

(ii) Give a reason for the runway being at a slope.

**(1)**

**Q21.**

A student lifts a toy car from a bench and places the toy car at the top of a slope as shown in Figure 1.

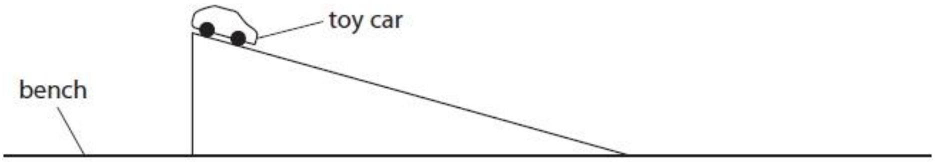



**Figure 1**

The student lets the toy car roll down the slope.
Describe how the student could find, by experiment, the speed of the toy car at the bottom of the slope.

**(4)**

**Q22.**

Figure 2 shows a way of projecting a small trolley up a sloping track.

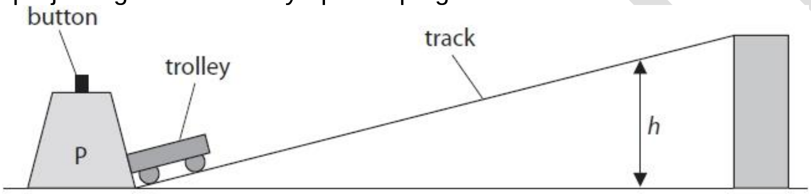



**Figure 2**

When the button is pressed, a spring is released in P that projects the trolley up the track.
The trolley travels up the track, stops and then rolls back down.
The spring in P always exerts the same force when projecting the trolley.
A student investigates how the mass of the trolley affects the maximum vertical height, *h*, reached by the trolley.
Describe how the student could extend the investigation to determine the average speed of the trolley as it rolls back down the track.

**(3)**

**Q23.**

A pilot begins to land an aircraft.

(a) The height of the aircraft decreases from 200 m above the ground to 100 m.

(i) What happens to the gravitational potential energy of the aircraft?

Put a cross ( ■ ) in the box next to your answer.

**(1)**

☐ **A** it becomes zero
☐ **B** it decreases
☐ **C** it does not change
☐ **D** it increases

(ii) The velocity of the aircraft remains constant.

What happens to the kinetic energy of the aircraft?

Put a cross ( ■ ) in the box next to your answer.

**(1)**

☐ **A** it becomes zero
☐ **B** it decreases
☐ **C** it does not change
☐ **D** it increases

(b) The aircraft lands with its wheels on the runway as shown.


The aircraft is moving forwards.
(i) Draw an arrow on the diagram to show the direction of the momentum of the aircraft.

**(1)**

(ii) The velocity of the aircraft when it lands is 75 m/s.
The mass of the aircraft is 130 000 kg.
Calculate the momentum of the aircraft.

**(2)**

(iii) The aircraft comes to a stop.
State the momentum change of the aircraft from when it lands to when it stops.

**(1)**

(c) When the aircraft lands, the momentum of each passenger also changes.
(i) Explain why it is more comfortable for a passenger if the aircraft takes a longer time to slow down.

**(2)**

(ii) Suggest why some aircraft need a very long runway to land safely.

**(2)**

**Q24.**

The photograph shows a man dropping an egg inside a padded box from a height.

He is investigating to see if the padding stops the egg from breaking.
(a) State the type of energy which the egg gains as it falls.

**(1)**

(b) The weight of the egg is 0.6 N.
Calculate the work done on the egg to lift it up by 20 m. State the unit.

**(3)**

The mass of the container was 0.5 kg.
Calculate the momentum of the container.

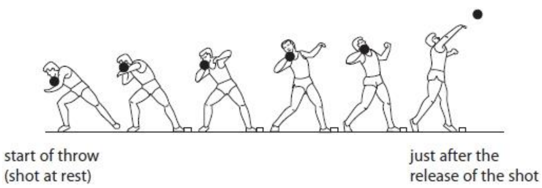
**(2)**

*(d) A student stands on the ground with an egg in his hand.
He throws the egg vertically upwards.
The egg rises to a height of 10 m.
Then the egg falls and lands on the ground.
Describe the energy changes of the egg during this sequence of events.

**(6)**

**Q25.**

Shot-put is an Olympic event.
The shot is a heavy ball.
An athlete throws the shot as far as possible.
A sports scientist analyses an athlete's throw to help improve performance.




(a) The scientist takes pictures of the athlete every 0.1 s during one throw.
Figure 3 shows the pictures of one throw.

(i) Estimate the amount of time during the throw when the shot is in the athlete's hand.

**(1)**

(ii) Explain how the scientist could improve this method of analysing the throw.

**(2)**

(iii) The average acceleration of the shot while in the athlete's hand is 20.6 m/s$^2$.
The mass of the shot is 7.26 kg.
Calculate the average force that the athlete applies to the shot during the throw.

**(2)**

(iv) In another throw, the shot is in the athlete's hand for 0.48 s.
The average acceleration during this time is 23 m/s$^2$.
Calculate the velocity of the shot as it leaves the athlete's hand.

**(3)**

(b) In one throw, the shot continues to rise by another 1.3 m after it leaves the athlete's hand.
The mass of the shot is 7.26 kg.
Calculate the amount of gravitational potential energy gained by the shot.

(2)

**Q26.**

Figure 9 is a diagram showing a rocket that is sent into space to try and change the path of a small asteroid.

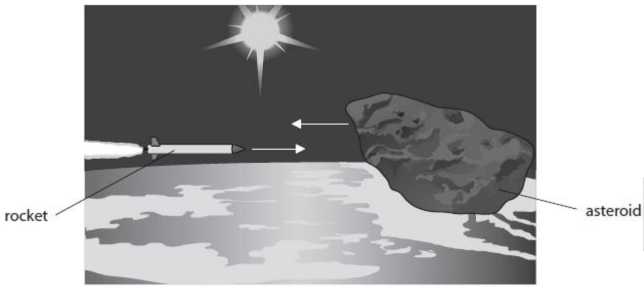



Figure 9

Newton's third law, when applied to the collision of the rocket and the asteroid as shown in Figure 9, can be stated as follows:

***The force exerted by the rocket on the asteroid is equal and opposite to the force exerted by the asteroid on the rocket.***

Explain how this statement links to the conservation of momentum in the collision.

(4)

**Q27.**

Shot-put is an Olympic event.
The shot is a heavy ball.
An athlete throws the shot as far as possible.
A sports scientist analyses an athlete's throw to help improve performance.
The scientist examines the images to find ways of increasing the momentum of the shot when it leaves the athlete's hand without the athlete using any extra force.
The scientist advises the athlete to
lean further down at the start
and make his arm straight before he releases the shot.
Explain the scientific principles behind this advice.

(3)

**Q28.**

(Source: © Alones/Shutterstock)

Figure 8

Figure 8 shows a rocket soon after it takes off from the ground.

The force that the rocket engines produce remains constant during the first few seconds after take-off.
Explain what happens to the acceleration during the first few seconds.

(3)

**Q29.**

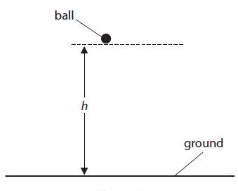



Figure 9

Figure 9 shows a small steel ball held at a height, *h*, above the ground.

Two students use the arrangement shown in Figure 9.
They use a stopwatch to time the ball falling through the height of 1.4 m.
The students repeat the measurement many times, but their average value for *t* is different from the calculated value.

(i) Suggest a reason why the students' value for *t* is different from the calculated value.

(1)

(ii) Suggest **one** improvement the students could make to their procedure so that their value for t is closer to the calculated value.

(1)

**Q30.**

Figure 3 is a speed limit sign from a European motorway.
The speeds shown are in km/h (kilometres per hour).

(i) The sign tells drivers to drive at a slower speed in wet weather.

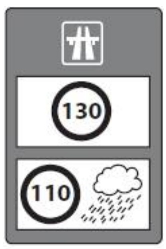



Figure 3

Explain why it is safer for drivers to drive at a slower speed in wet weather.

**(2)**

(ii) Show that a speed of 31 m/s is less than a speed of 130 km/h.

**(2)**

(iii)

> The driver's reaction time is the time between the driver seeing an emergency and starting to brake.

A car is travelling at a speed of 31 m/s.
The car travels 46 m between the driver seeing an emergency and starting to brake.
Calculate the driver's reaction time.
Give your answer to 2 significant figures.

**(3)**

**Q31.**

A student investigates the motion of a trolley along a horizontal runway.
Figure 6 shows the apparatus.

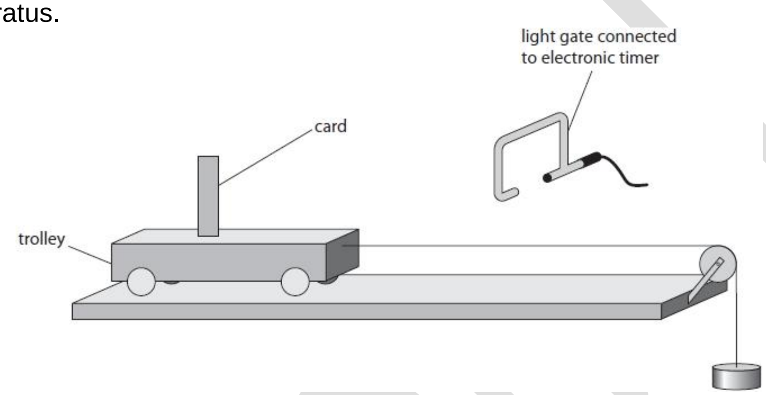



**Figure 6**

The trolley is attached to a string passing over a pulley.
A 100 g metal disc hangs on the end of the string.
The light gate measures the time it takes for the card to pass through it.
When the trolley is released, it accelerates along the track.

(i) Explain why the trolley accelerates along the track.

**(2)**

(ii) The card takes 0.040 s to travel through the light gate.
The student calculates that the average speed of the trolley through the light gate is 1.15 m/s.
Calculate the width of the card.

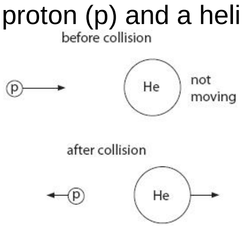
**(2)**

(iii) The trolley travels 1.2 m along the track from the start before the card reaches the light gate.
Show that acceleration of the trolley along this distance is approximately 0.55 $m/s^2$.

**(2)**

**Q32.**

The diagram shows a collision between a proton (p) and a helium nucleus (He).




(i) The table gives some information about the collision.

| | | before collision | after collision |
|---|---|---|---|
| proton | kinetic energy (arbitrary units) | 12.5 | 4.5 |
| helium nucleus | kinetic energy (arbitrary units) | 0 | 8 |

Use information from the table to show that the collision is elastic.

**(2)**

(ii) State the name of one device that can be used to accelerate protons to very high speeds.

**Q33.**

* After going to the shops, a car driver places a bag of shopping on the passenger seat. During the journey home, the driver has to use the brakes to stop very suddenly. The driver is wearing a seat belt.
Explain what happens next to the car, the driver and the shopping bag.

(6)

**Q34.**

(a) A car is travelling along a level road.

(i) Complete the sentence by putting a cross ( ☒ ) in the box next to your answer.
When the velocity of the car is constant, the force of friction on it is

(1)

☐ **A** zero
☐ **B** greater than the driving force
☐ **C** smaller than the driving force
☐ **D** the same size as the driving force

(ii) The car now accelerates in a straight line.
Its average acceleration is 12 $m/s^2$.
Calculate the increase in velocity of the car in 4.0 s.

(3)

(b) This table shows data about two other cars.

| car | mass | time taken to reach 30 m/s from rest |
|---|---|---|
| family car | 1400 kg | 10 s |
| sports car | 600 kg | 5 s |

The owner of the family car claims that although the sports car has greater acceleration, it produces a smaller accelerating force than his family car.
Explain how these figures support his claim.

(2)

*(c) After going to the shops, a car driver places a bag of shopping on the passenger seat. During the journey home, the driver has to use the brakes to stop very suddenly. The driver is wearing a seat belt.
Explain what happens next to the car, the driver and the shopping bag.

(6)

**Q35.**

* Figure 9 shows two ice skaters during a sequence in their performance.

**Figure 9**

The man stays at the same place on the ice throughout the sequence.
At the start of the sequence, the woman is moving at a constant speed around the man while the man holds her arm.
After she has gone round the man several times, the man lets go of the woman's arm.
The sequence ends a few seconds later.
Explain the motion of the woman, in terms of the forces acting and the effects on her motion, for the whole sequence.

(6)

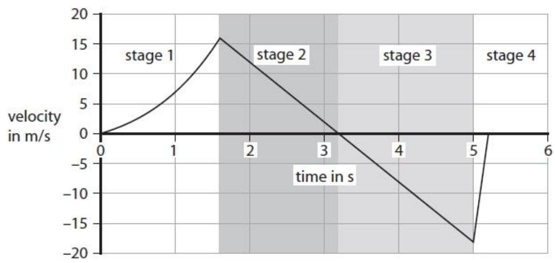
**Q36.**

Another rocket has a total mass of 90 g when it takes off. The acceleration of the rocket when it takes off is 3.3 $m/s^2$.

(i) Calculate the resultant force on the rocket when it takes off.

(2)

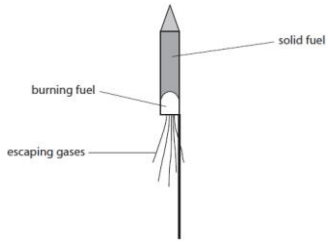
*(ii) The rocket contains 50 g of fuel when it takes off.
The fuel burns and the rocket rises vertically.
After a while, there is no fuel left.
Eventually the empty rocket falls back to the ground.
The graph is a velocity–time graph for the rocket.
Four stages are labelled on the graph.




Explain why the velocity of the rocket changes as shown in the graph.

(6)

**Q37.**




A firework rocket contains a solid fuel inside a cardboard tube.
The burning of the fuel creates a thrust to propel the rocket upwards.

(i) Scientists can refer to several different quantities when describing the motion of the rocket.

| | | | |
|---|---|---|---|
| mass | energy | speed | force |

Only one of these quantities is a vector.
Complete this sentence using **one** of the words from the box.

The vector quantity is ..........................................................

**(1)**

(ii) Before the fuse is lit, the total weight of a rocket including fuel is 0.7N.
The gravitational field strength is 10 N/kg.
Complete the sentence by putting a cross (☒) in the box next to your answer.
The total mass of the rocket including fuel is


**(1)**

- ☐ **A** 0.007 kg
- ☐ **B** 0.07 kg
- ☐ **C** 0.7 kg
- ☐ **D** 7 kg

(iii) There is a resultant force on the rocket of 0.5 N upwards when it takes off.
The arrow on the diagram shows the size and direction of the force of gravity acting on the rocket when it takes off.

Add another arrow to the diagram to show the thrust produced by the burning fuel at the time the rocket takes off.
You should label the arrow with the size of the thrust.

**(2)**

**Q38.**
A student investigates the motion of a trolley along a horizontal runway.
Figure 6 shows the apparatus.

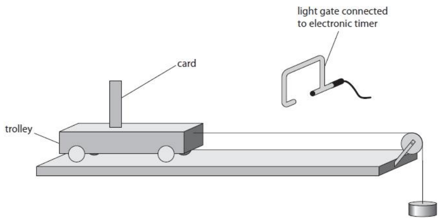



**Figure 6**

The trolley is attached to a string passing over a pulley.
A 100 g metal disc hangs on the end of the string.
The light gate measures the time it takes for the card to pass through it.
When the trolley is released, it accelerates along the track.
The student repeats the process several times by adding extra 100 g metal discs.
Figure 7 shows a graph of the results.

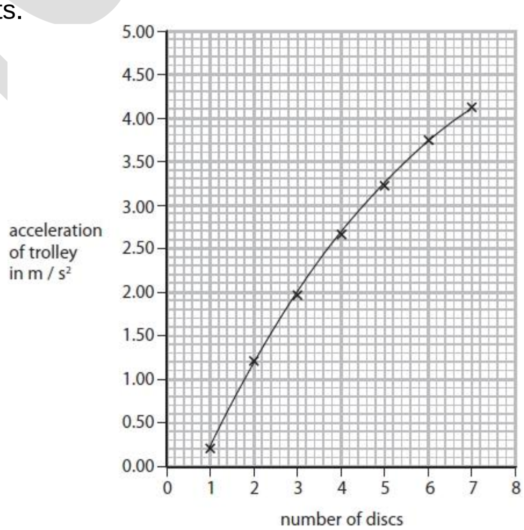



**Figure 7**

(i) Predict the acceleration if discs with a total mass of 800 g are used. **(1)**

(ii) There are frictional forces in the system.
Identify a feature of the graph that shows there are frictional forces in the system.

**(1)**

(iii) Explain how the investigation could be developed to remove the effects of friction.

**(2)**

**Q39.**

Andrew skis down a hill.

(a) Andrew starts from the top of the hill and his speed increases as he goes downhill.
He controls his speed and direction by using his skis.
He brings himself to a stop at the bottom of the hill.
Describe the energy changes that happen between starting and stopping.

**(3)**

(b) Andrew returns to the top of the hill and starts again.
(i) His mass is 67 kg.
Show that his momentum is about 2000 kg m/s when his velocity is 31 m/s.

**(2)**

(ii) He falls over when his momentum is 2000 kg m/s.
After he falls over, he slows down by sliding across the snow.
It takes 2.3 s for his momentum to reduce to zero.
Calculate the average force on Andrew as he slows down.

**(2)**

(iii) Andrew is not injured by the fall even though he was moving quickly.
Use ideas about force and momentum to explain why he is not injured.

**(2)**

**Q40.**

Figure 9 is a diagram showing a rocket that is sent into space to try and change the path of a small asteroid.

(i) The rocket has a mass of $5.5 \times 10^5$ kg and is travelling to the right at 14 km / s.
Which of these is a correct calculation of the momentum of the rocket in kg m / s?
Use the equation

$$p = m \times v$$

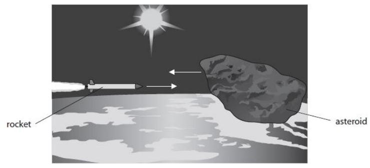



Figure 9

**(1)**

- ☐ **A** $7.7 \times 10^3$ kg m / s
- ☐ **B** $7.7 \times 10^6$ kg m / s
- ☐ **C** $7.7 \times 10^9$ kg m / s
- ☐ **D** $7.7 \times 10^{12}$ kg m / s

(ii) The asteroid has a momentum of $7.5 \times 10^{10}$ kg m / s and a mass of $8.0 \times 10^6$ kg.
Calculate the speed of the asteroid.

**(2)**

**Q41.**
Which of these is a vector?

**(1)**

- ☐ **A** energy
- ☐ **B** force
- ☐ **C** mass
- ☐ **D** work

**Q42.**
Two students try to determine a value for $g$, the acceleration due to gravity.
They measure the time, $t$, for a small steel ball to fall through a height, $h$, from rest.
They measure $t$ to be 0.74 s, using a stopwatch.
They measure $h$ to be 2.50 m, using a metre rule.

$$g = \frac{2h}{t^2}$$

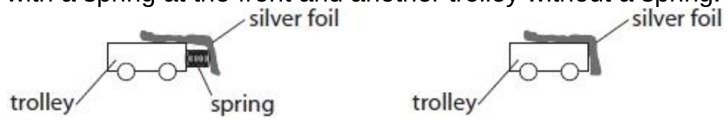
They record the time $t$ for two more drops from the same height.
The three values for time $t$ are

0.74 s, 0.69 s, 0.81 s.

Explain **one** way the students could improve their procedure to obtain a more accurate value for $g$. **(2)**

**Q43.**

A student investigates the effect of a crumple zone on the force exerted during a collision.
The student has one trolley with a spring at the front and another trolley without a spring.




The student uses the arrangement in Figure 10.

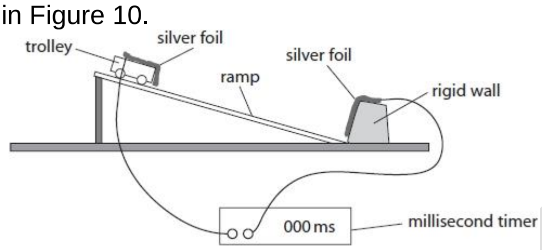


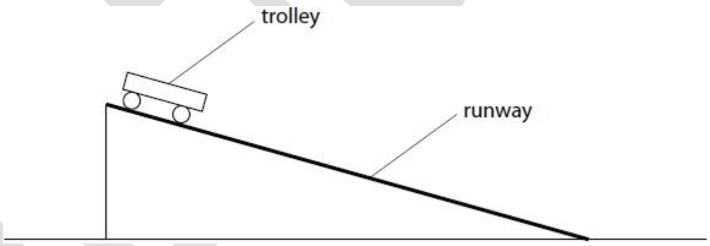

Figure 10

After a trolley is released, it accelerates down a slope and bounces off a rigid wall.
The speed of a trolley can be measured just before a collision with the wall and just after a collision with the wall.
The silver foils are connected to a millisecond timer.
The silver foils make contact with each other during the collision, so the time they are in contact can be read from the millisecond timer.
Explain how the student could investigate the effect of a crumple zone on the average force exerted during the collision.
Your explanation should include:

- how to determine the force (you may wish to refer to an equation from the list of equations)
- how the effect of crumple zones may be shown in the investigation
- precautions that may be necessary to achieve accurate results.

**(6)**

**Q44.**
A student investigates how the average speed of the trolley varies with starting height.
Figure 9 shows the trolley and runway.




(a) Describe how the student can determine the average speed of the trolley.

**(4)**

(b) Figure 10 shows his results.

| starting height / m | v / ms$^{-1}$ |
|---|---|
| 0.01 | 0.22 |
| 0.02 | 0.31 |
| 0.04 | 0.44 |
| 0.09 | 0.66 |
| 0.12 | 0.77 |
| 0.14 | 0.83 |
| 0.18 | 0.94 |

**Figure 10**

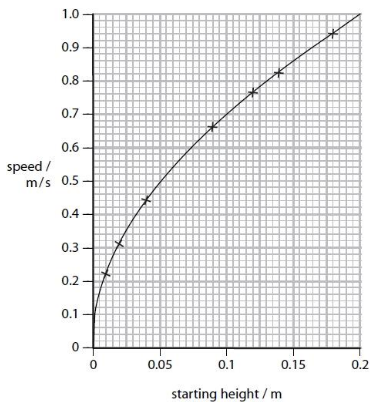



Figure 11 shows the student's graph.

(i) The trolley has a mass of 650 g.
Calculate the average kinetic energy of the trolley which had a starting height of 0.075 m.

**(2)**

(ii) Determine the gradient of the graph when the height is 0.1 m.

**(2)**

(iii) Describe how the speed of the trolley varies with the changes in height made by the student between 0.04 m and 0.12 m.

**(2)**

(c) The student wants to change his experiment to investigate how different surfaces of the runway affect the speed of the trolley down the slope.

Devise an experiment that would allow him to investigate the effect of different surfaces on the average speed of the trolley.

**(3)**

**Q45.**

A pilot begins to land an aircraft.

The aircraft lands with its wheels on the runway as shown.


The aircraft is moving forwards.

(i) Draw an arrow on the diagram to show the direction of the momentum of the aircraft.

**(1)**

(ii) The velocity of the aircraft when it lands is 75 m/s.

The mass of the aircraft is 130 000 kg.

Calculate the momentum of the aircraft.

**(2)**

(iii) The aircraft comes to a stop.

State the momentum change of the aircraft from when it lands to when it stops.

**(1)**

**Q46.**

A pilot begins to land an aircraft.

When the aircraft lands, the momentum of each passenger also changes.

(i) Explain why it is more comfortable for a passenger if the aircraft takes a longer time to slow down.

**(2)**

(ii) Suggest why some aircraft need a very long runway to land safely.

**(2)**

**Q47.**

Two students try to determine a value for *g*, the acceleration due to gravity.

(i) They measure the time, *t*, for a small steel ball to fall through a height, *h*, from rest.

They measure *t* to be 0.74 s, using a stopwatch.

They measure *h* to be 2.50 m, using a metre rule.

Calculate a value for *g* from the students' measurements.

Use the equation

$$g = \frac{2h}{t^2}$$

**(2)**

(ii) They record the time *t* for two more drops from the same height.

The three values for time *t* are

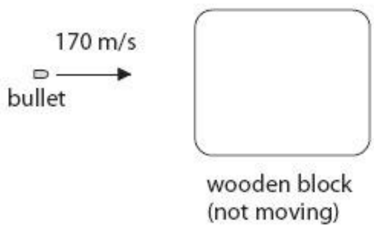
0.74 s, 0.69 s, 0.81 s.

Calculate the average value of time *t* to an appropriate number of significant figures.

**(2)**

**Q48.**

The diagram shows a bullet moving towards a wooden block.




(i) The bullet is moving with a velocity of 170 m/s.

The mass of the bullet is 0.030 kg.

Show that the momentum of the bullet is about 5.0 kg m/s.

**(1)**

(ii) The bullet collides with the wooden block and sticks in it.
The bullet and the wooden block move off together.
The mass of the wooden block is 0.80 kg.
Calculate the velocity of the wooden block and bullet immediately after the collision.

**(3)**

(iii) The collision between the bullet and the wooden block is an inelastic collision.
State what is meant by an **inelastic collision.**

**(2)**

**Q49.**

Andrew skis down a hill.

Andrew returns to the top of the hill and starts again.

(i) His mass is 67 kg.
Show that his momentum is about 2000 kg m/s when his velocity is 31 m/s.

**(2)**

(ii) He falls over when his momentum is 2000 kg m/s.
After he falls over, he slows down by sliding across the snow.
It takes 2.3 s for his momentum to reduce to zero.
Calculate the average force on Andrew as he slows down.

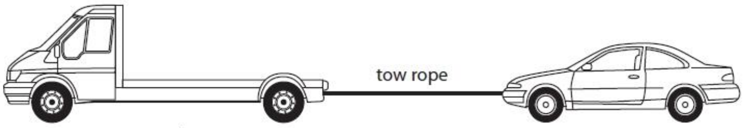
**(2)**

(iii) Andrew is not injured by the fall even though he was moving quickly.
Use ideas about force and momentum to explain why he is not injured.

**(2)**

**Q50.**

A truck is towing a car along a level road at a constant velocity.
A tow rope is attached to the truck and the car.




(a) Which of these shows the directions of the forces between the car and the tow rope?
Put a cross (☒) in the box next to your answer.

**(1)**

| | force exerted by car on tow rope | force exerted by tow rope on car |
|---|---|---|
| ☐ **A** | ← | → |
| ☐ **B** | → | ← |
| ☐ **C** | → | → |
| ☐ **D** | ← | ← |

(b) The truck has to provide a force of 4000 N to the left on the car to keep the car at a constant velocity.
Complete the sentence by putting a cross (☒) in the box next to your answer.
The resultant force on the car is

**(1)**

☐ **A** 0 N
☐ **B** 4000 N to the left
☐ **C** 4000 N to the right
☐ **D** 8000 N to the left

(c) Both vehicles are travelling at 13 m/s.
The driver of the truck then accelerates at 1.2 $m/s^2$ until both vehicles are travelling at 20 m/s.
(i) Calculate the time taken for this acceleration.

**(3)**

(ii) The mass of the car is 1400 kg.
Calculate the resultant force on the car needed to produce an acceleration of 1.2 $m/s^2$.

**(2)**

(iii) A rope can withstand a tension of 12 000 N before it breaks. The weight of the car is 14 000 N.
Discuss whether this rope could be strong enough to tow the car with the truck.

**(3)**

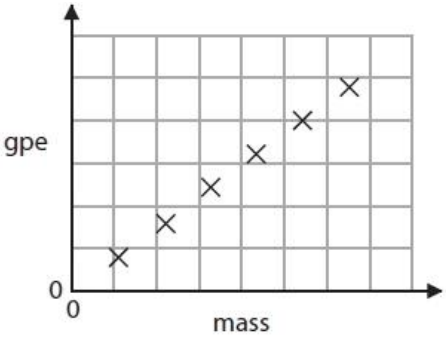
**Q51.**

Some students investigate a model of the craters produced by meteorite impacts.
They drop balls into a tray filled with sand.
They use six balls with different masses.
They drop each ball from the same height.

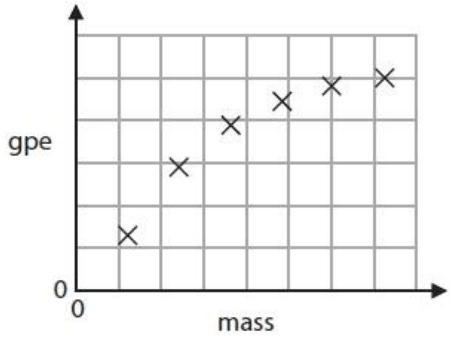
(a) (i) Which one of these graphs shows the relationship between the gravitational potential energy (gpe) of the balls and their mass when they are all at the same height?

Put a cross (☒) in the box next to your answer.

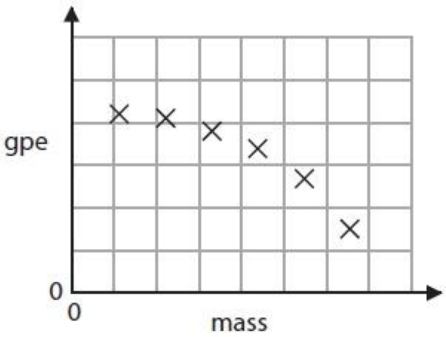
**(1)**



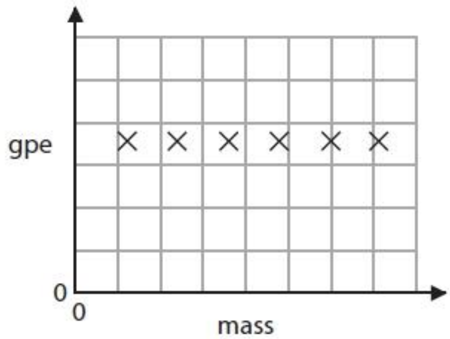

☐ **A**




☐ **B**




☐ **C**




☐ **D**

(ii) Describe how the energy of a ball changes as it drops towards the sand.

**(2)**

(b) This photograph shows the sand after several balls have hit it.

The students read this information in a textbook:

'When work is done, energy is transferred.'

Explain how work is done when the balls impact on the sand.

**(2)**

(c) When one ball hits the sand, it has a velocity of 6.2 m/s.
It has a momentum of 0.46 kg m/s.

(i) Calculate the mass of the ball.

**(3)**

(ii) The ball takes 0.17 s to come to rest after it hits the sand.
Calculate the average impact force.

**(2)**

**Q52.**

A student investigates the relationship between force and acceleration for a trolley on a runway.
Figure 12 shows some of the apparatus the student uses.

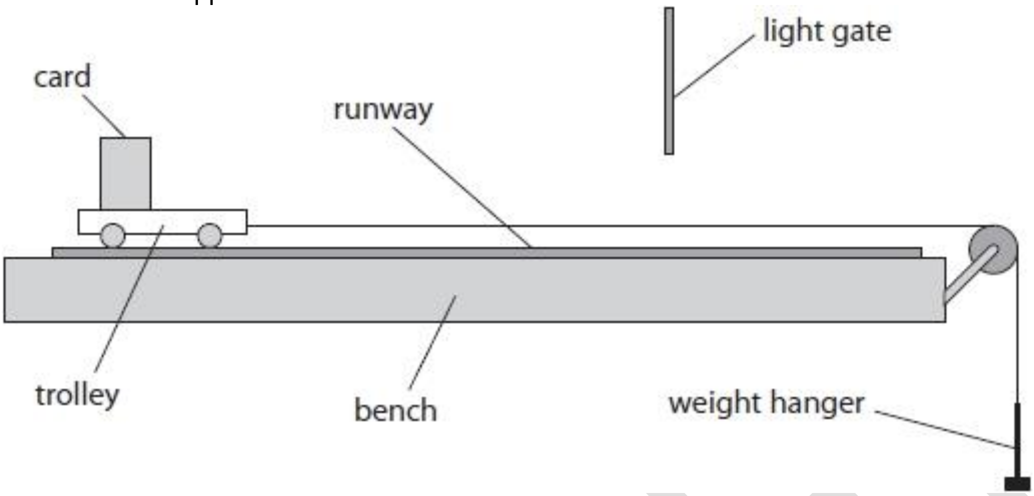



**Figure 12**

(i) Describe how the student could increase the accelerating force applied to the trolley.

**(2)**

(ii) Describe how the mass of the moving system can be kept constant.

**(2)**

(iii) Explain how the student could improve the procedure to compensate for the effects of frictional forces acting on the trolley.

**(2)**

**Q53.**

(i) An aircraft starts from rest and accelerates along the runway for 36 s to reach take-off velocity.
Take-off velocity for this aircraft is 82 m/s.
Show that the acceleration of the aircraft along the runway is about 2 $m/s^2$ .
Assume the acceleration is constant.

**(2)**

(ii) Calculate the distance the aircraft travels along the runway before take-off.
Use the equation

$$v^2 – u^2 = 2ax$$

**(3)**

(iii) Suggest **one** reason why the length of the runway used is always much longer than the calculated distance that the aircraft travels along the runway before take-off.

**(1)**

**Q54.**

Figure 8 shows an object moving in a circular path.

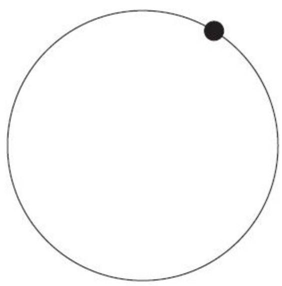


Figure 8

(i) Draw an arrow on Figure 8 to show the direction of the force that keeps the object moving in a circular path.

**(1)**

(ii) The object in Figure 8 is moving at constant speed.
Explain why it is not moving with constant velocity.

**(2)**

**Q55.**

(i) State the equation that relates acceleration to change in velocity and time taken.

**(1)**

A van accelerates from a velocity of 2 m / s to a velocity of 20 m / s in 12 s.
Calculate the acceleration of the van.

**(2)**

**Q56.**

The symbol '*g*' can be used to refer to the acceleration due to gravity.
The acceleration due to gravity '*g*' has the unit of m/s$^2$.
'*g*' can also have another unit.
Which of these is also a unit for *g*?

**(1)**

- ☐ **A** J/kg
- ☐ **B** J/kg$^2$
- ☐ **C** N/kg
- ☐ **D** N/kg$^2$

**Q57.**

Figure 2 is a velocity / time graph for 15 s of a cyclist's journey.

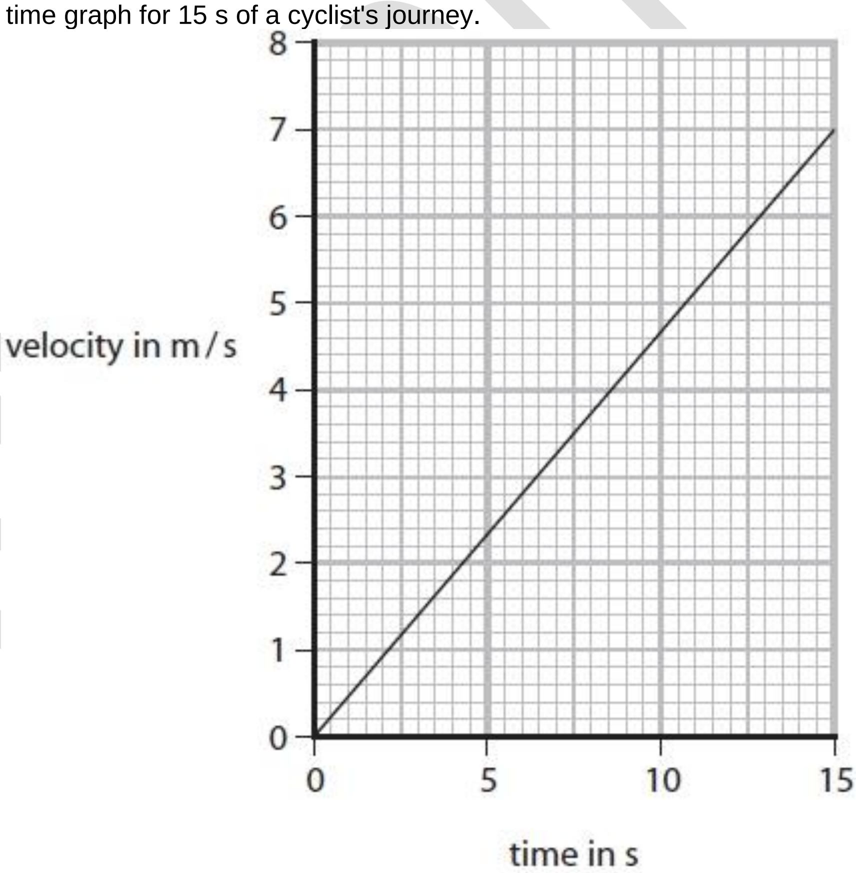



**Figure 2**

(i) Calculate the distance the cyclist travels in the 15 s.

**(3)**

(ii) Another cyclist starts from rest, but his acceleration decreases as time increases.
Sketch the velocity / time graph for this cyclist on Figure 2.

**(2)**

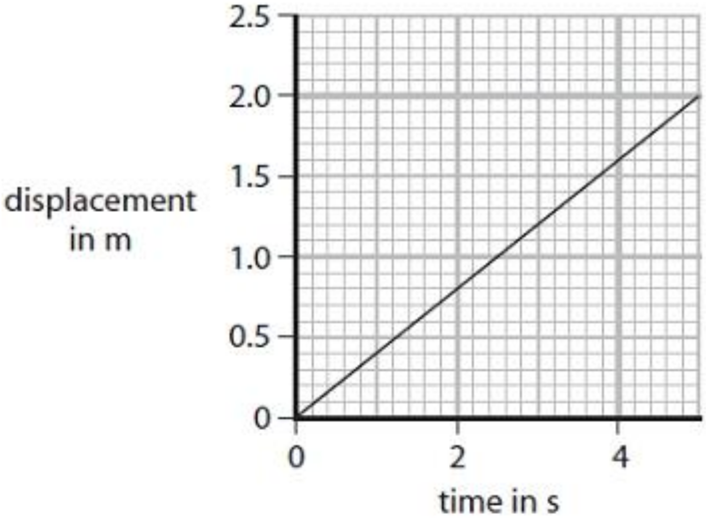
**Q58.**

**Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.**

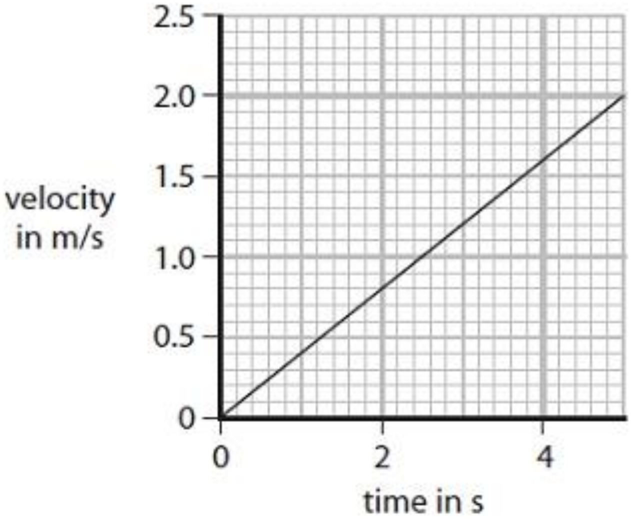
Which of these graphs represents an object moving with a constant velocity of 2 m/s?

**(1)**

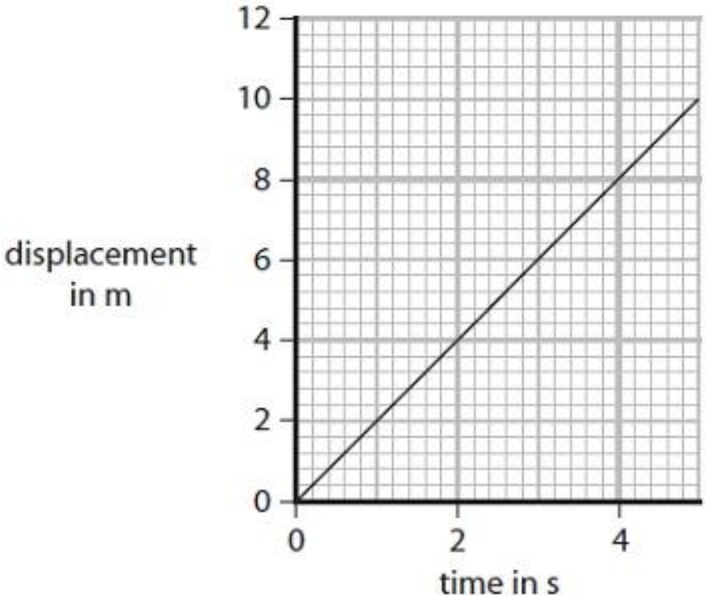
☐ **A**



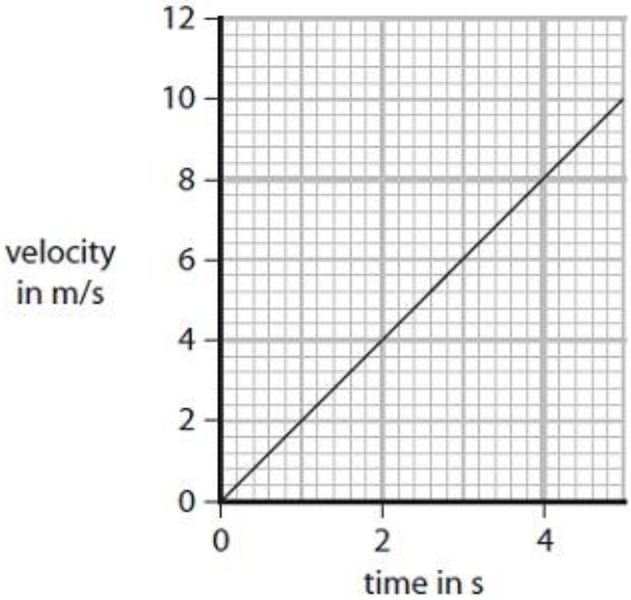

☐ **B**




☐ **C**




☐ **D**




**(Total for question = 1 mark)**

**Q59.**

**Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.**

Which of these is a unit of momentum?

**(1)**

- ☐ **A** kg m/s
- ☐ **B** kg/m/s
- ☐ **C** kg m/$s^2$
- ☐ **D** kg/m/$s^2$