Motion and Kinematic Quantities

Q1.

Which of the following quantities is a vector?

☒ **A** charge

☒ **B** mass

☒ **C** momentum

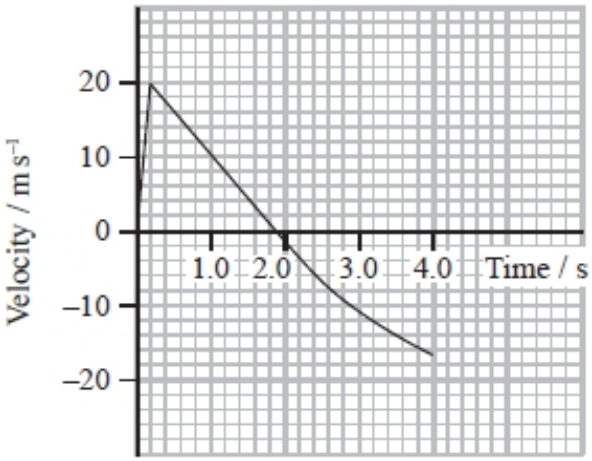
☒ **D** time

(Total for question = 1 mark)

Q2.

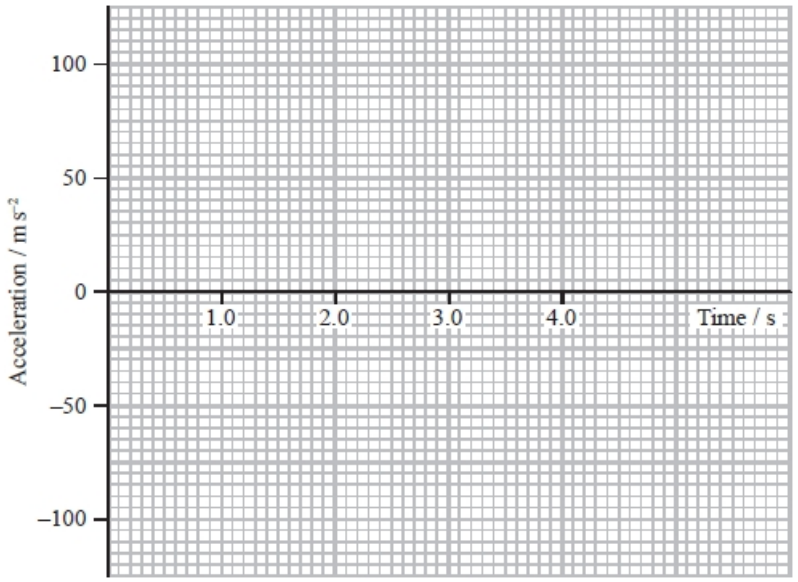
A physics class made a toy rocket. A drinks bottle was partially filled with water and inverted over a valve. An air pump delivered air to the bottle until the pressure forced the bottle from the valve and the water was ejected from the bottle at high speed.

A velocity-time graph for the bottle for the first 4 s after take-off is shown.



Sketch the corresponding acceleration-time graph on the axes below.

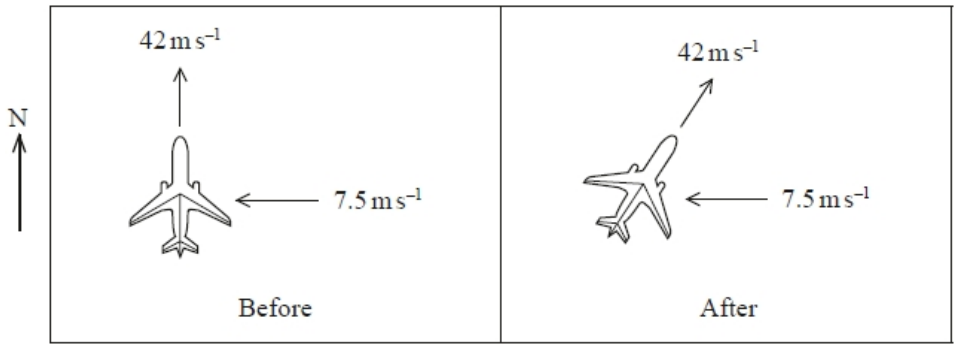
(5)



(Total for question = 5 marks)

Q3.

A plane is travelling north at 42 m s^{-1}. It enters a region with a wind blowing from the east at 7.5 m s^{-1}. To keep travelling north, the plane turns towards the east, without changing the thrust, as shown.



Which of the following could be used to calculate the angle through which the plane turns?

☐ **A** $\cos^{-1}\left(\frac{42}{7.5}\right)$

☐ **B** $\sin^{-1}\left(\frac{7.5}{42}\right)$

☐ **C** $\tan^{-1}\left(\frac{7.5}{42}\right)$

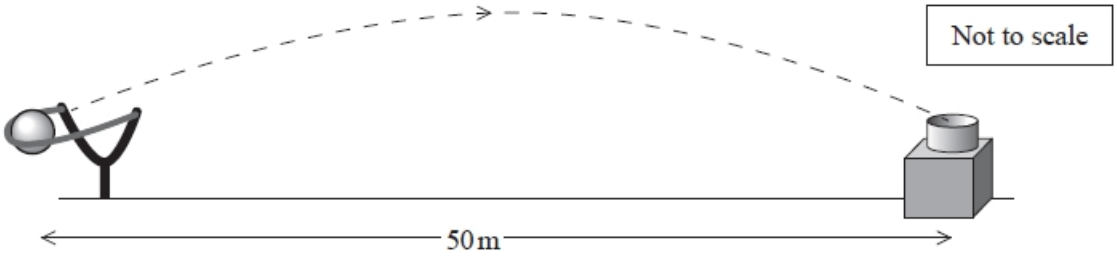
☐ **D** $\tan^{-1}\left(\frac{42}{7.5}\right)$

(Total for question = 1 mark)

Q4.

A fairground game requires the player to catapult a ball towards a target to score points.

The ball is required to reach a target a horizontal distance of 50 m away, at the same vertical height, as shown.



The time taken for the ball to reach the target is 2.0 s.

Calculate the angle to the horizontal at which the ball is launched.

(4)

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Angle to the horizontal = ...

(Total for question = 4 marks)

Q5.

The Shanghai Maglev Train is the first commercially operated high-speed magnetic levitation train in the world, connecting the airport and central Shanghai.

The total distance travelled is 29.9 km and the total journey time is 440 s. The train starts from rest and reaches a speed of 97 m s^{-1} in 120 s.

(i) Calculate the average acceleration of the train during the first 120 s.

(2)

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Average acceleration of train = ...

(ii) Calculate the average speed of the train for the period following the 120 s acceleration.

(3)

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Average speed of train = ...

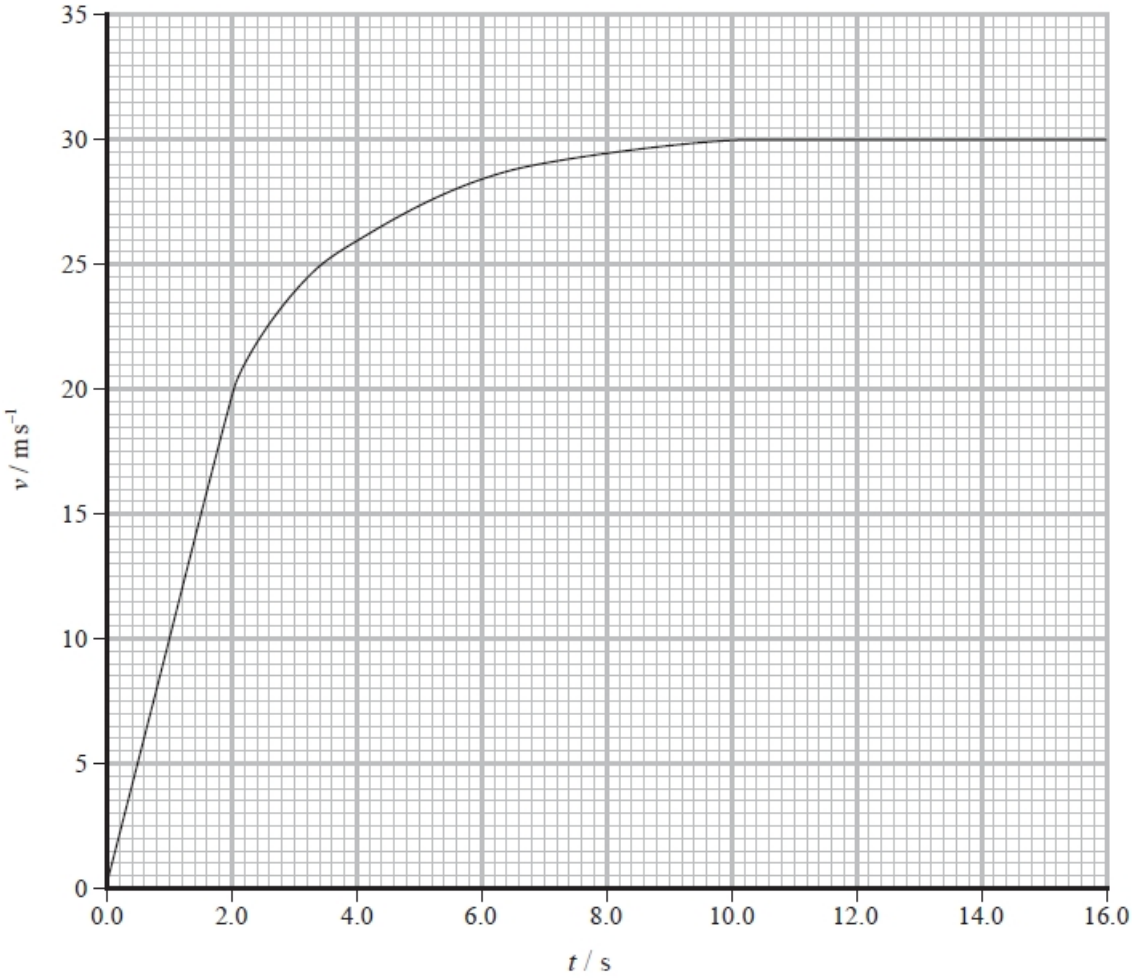
(Total for question = 5 marks)

Q6.

A skydiver made a skydive from a plane.

(Source: © Sky Antonio/Shutterstock)

The graph shows how the velocity *v* of the skydiver varied with time *t*, from the instant she left the plane to the instant just before the parachute opened.



Determine the **acceleration** of the skydiver when t = 4.0 s.

(3)

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Acceleration of skydiver = ...

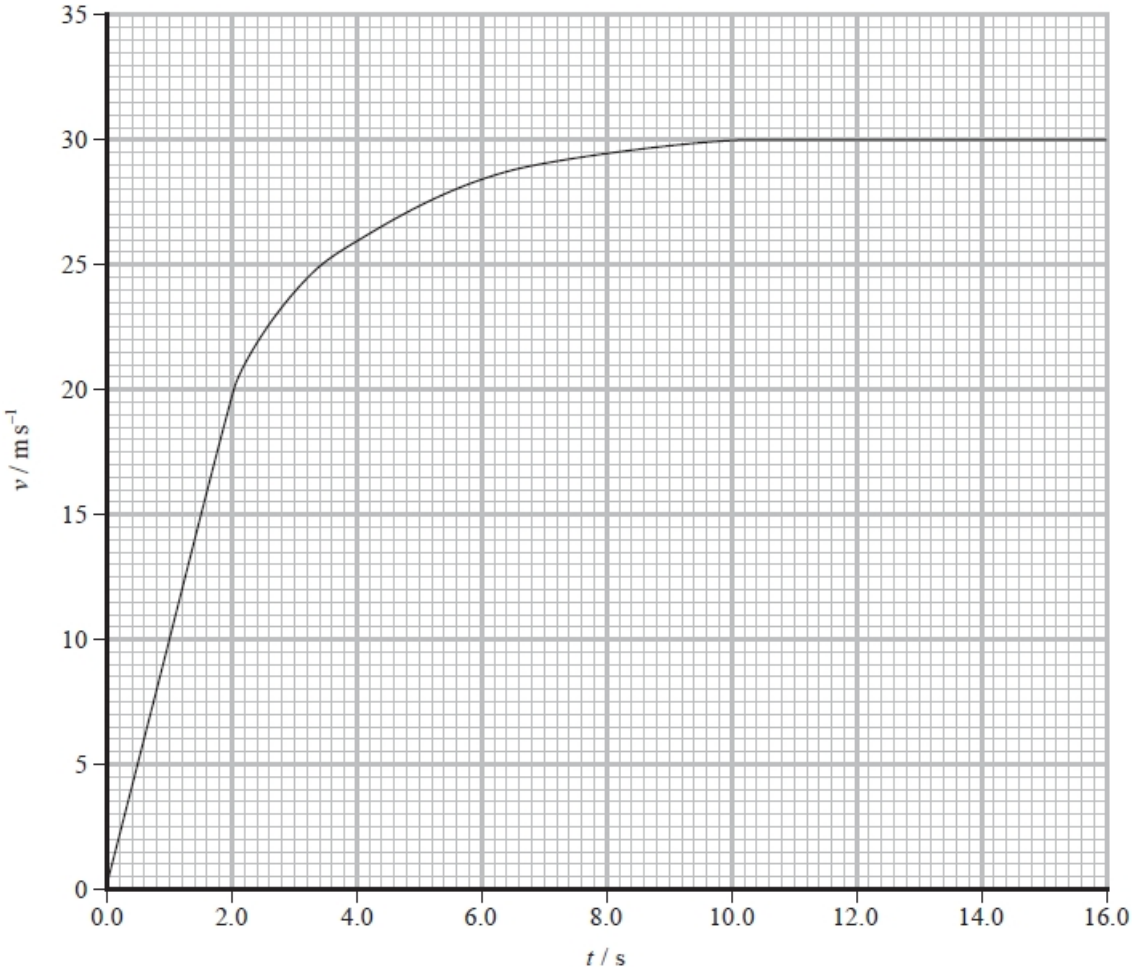
(Total for question = 3 marks)

Q7.

A skydiver made a skydive from a plane.

(Source: © Sky Antonio/Shutterstock)

The graph shows how the velocity v of the skydiver varied with time t, from the instant she left the plane to the instant just before the parachute opened.



Determine an approximate value for the **displacement** of the skydiver over the first 16.0 s of the skydive.

(3)

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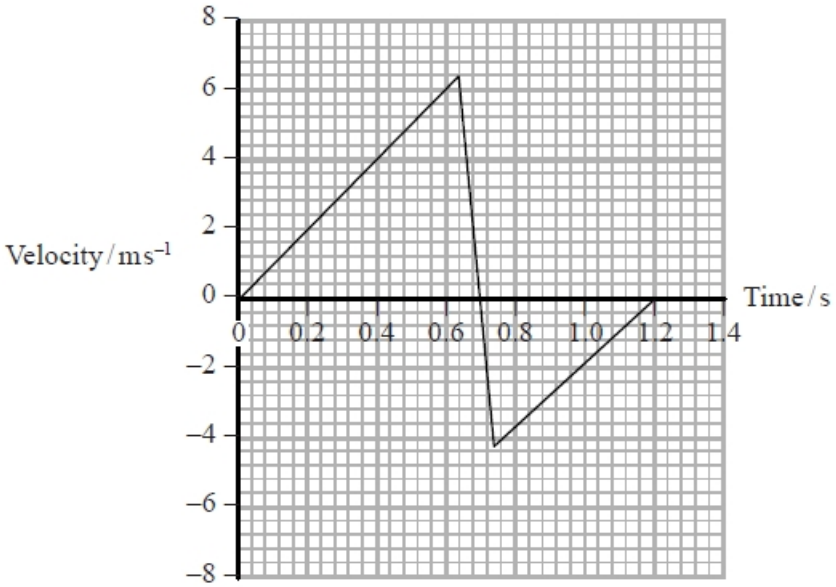
Displacement of skydiver = ...

(Total for question = 3 marks)

Q8.

A stationary ball is released from a height of 2.0 m onto a hard surface.

The simplified velocity-time graph shows the motion of the ball as it falls and bounces back to its maximum height.



(a) Calculate the maximum height reached by the ball after bouncing.

(2)

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Maximum height = ...

(b) Calculate the decrease in kinetic energy of the ball as it bounces.

mass of ball = 60 g

(2)

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Decrease in kinetic energy = ...

(c) Calculate the resultant force on the ball when it is in contact with the ground.

(3)

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Resultant force = ...

(d) The ball is replaced with one that is softer. It is released from a height of 2.0 m onto the same surface as before. A velocity-time graph is drawn to show the motion of the new ball.

Describe the similarities and differences between the two graphs.

(3)

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(Total for question = 10 marks)

Q9.

A motorist received a speeding penalty notice, from the police, for a short journey along 120 m of road.

(a) The car's specification states that the minimum time for the car to accelerate from 0 to 60 miles per hour is 9.5 seconds.

Show that the maximum value for the average acceleration of the car over 9.5 s is about 3 m s^{-2}.
1 mile = 1600 m

(2)

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(b) The police recorded a maximum speed for the car of 20 m s^{-1}.

The motorist knows that the speed at the start and at the end of the 120 m journey was zero.
Assume that the car had:

- constant positive acceleration, equal to the value in part (a), for the first 60 m of the journey
- constant negative acceleration of the same magnitude for the final 60 m of the journey.

Determine whether the motorist should challenge the penalty notice.

(3)

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(c) Explain why the assumptions about the acceleration in (b) may not be correct in practice.

(2)

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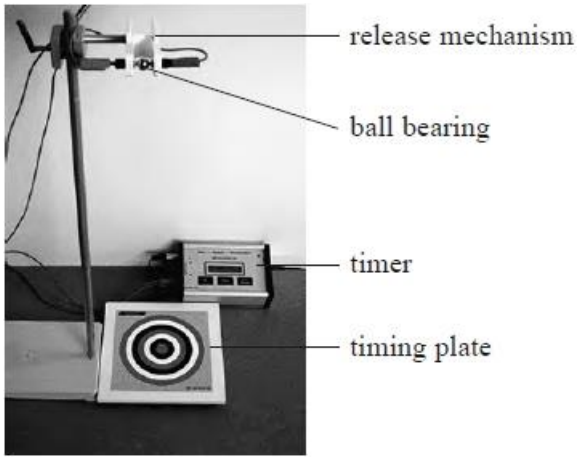
(Total for question = 7 marks)

Q10.

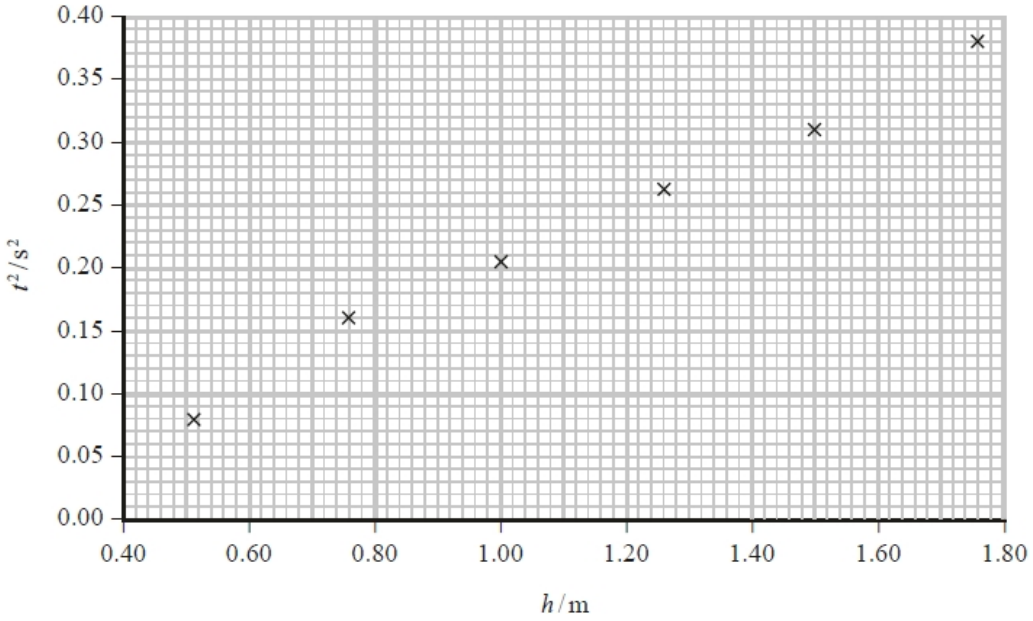
A student carried out an experiment to determine the acceleration of free-fall *g* using the apparatus shown in the photograph.

A ball bearing was released from a measured height *h* and a timer automatically started. On hitting a timing plate, the ball bearing stopped the timer and the time *t* was displayed on the timer. This was repeated for different values of *h*.



The uncertainty in *t* was ± 3%. The uncertainty in *h* was ± 1%.

The student plotted a graph of t^2 against h and used it to determine a value for g.



The student concluded that her value for g was consistent with the accepted value.

Comment on the student's conclusion. Your answer should include a calculation of g from the student's data.

You may assume that the percentage uncertainty in your value of g is the same as if the value were calculated from just one pair of readings.

(5)

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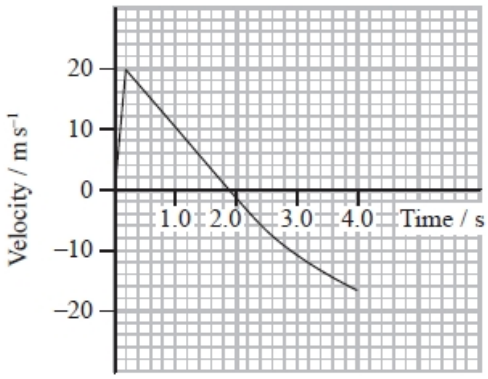
(Total for question = 5 marks)

Q11.

A physics class made a toy rocket. A drinks bottle was partially filled with water and inverted over a valve. An air pump delivered air to the bottle until the pressure forced the bottle from the valve and the water was ejected from the bottle at high speed.

A velocity-time graph for the bottle for the first 4 s after take-off is shown.



Determine the height to which the rocket travelled.

(2)

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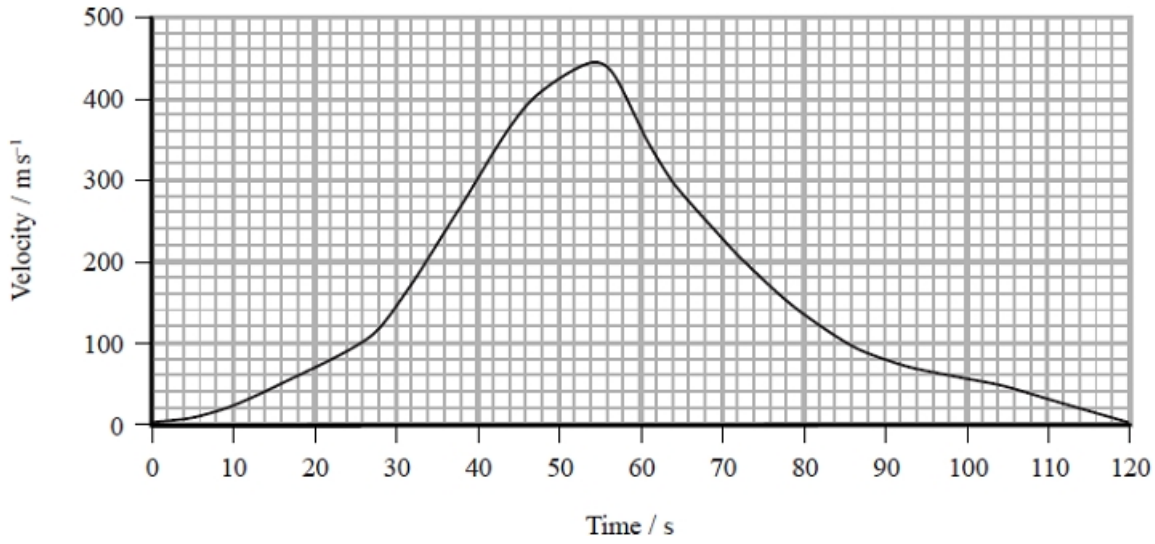
Height = ...

(Total for question = 2 marks)

Q12.

The world land speed record of 341 m s^{-1} was set in October 1997. In an attempt to break this record, a new supersonic car has been developed called the Bloodhound.

The developers of the Bloodhound have used computer modelling to produce a velocity-time graph for the predicted motion of the car, on a straight track, during the record attempt.



A track of length 23 km is available for the record attempt.

Determine whether this track is long enough.

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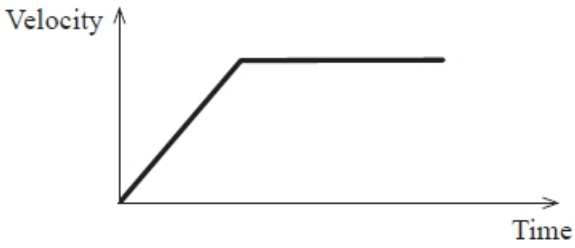
(Total for question = 3 marks)

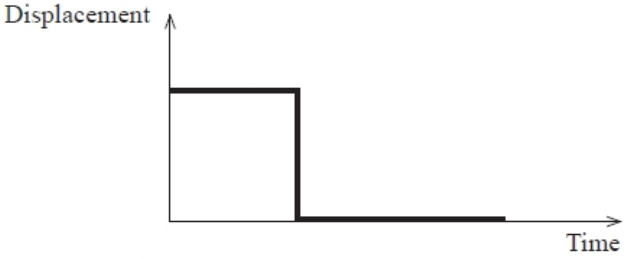
Q13.

The graph shows how the velocity varies with time for an object.

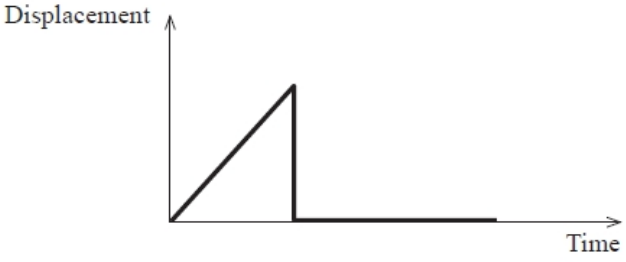


Which of the following graphs shows how the displacement varies with time for this object?

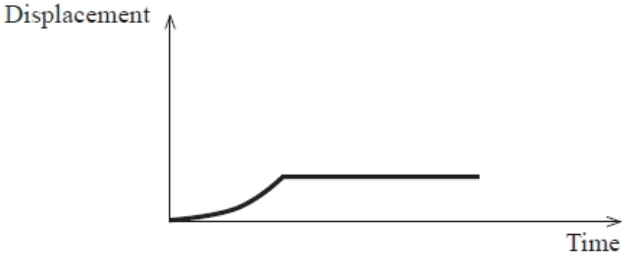
☒ **A**



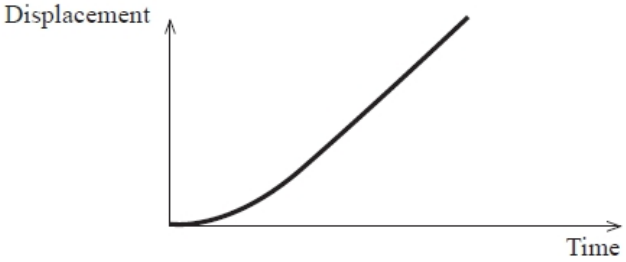
☒ **B**



☒ **C**



☒ **D**



(Total for question = 1 mark)

Q14.

A ball is kicked, giving it an initial velocity *v* at an angle of 35° to the vertical. The ball remains in the air for a time *t*.

Which of the following gives the distance travelled over the ground?

(1)

☒ **A** $vt\cos 35°$

☒ **B** $\frac{v\cos 35°}{t}$

☒ **C** $vt\sin 35°$

☒ **D** $\frac{v\sin 35°}{t}$

(Total for question = 1 mark)

Q15.

The photograph shows cars travelling on a straight section of a motorway.

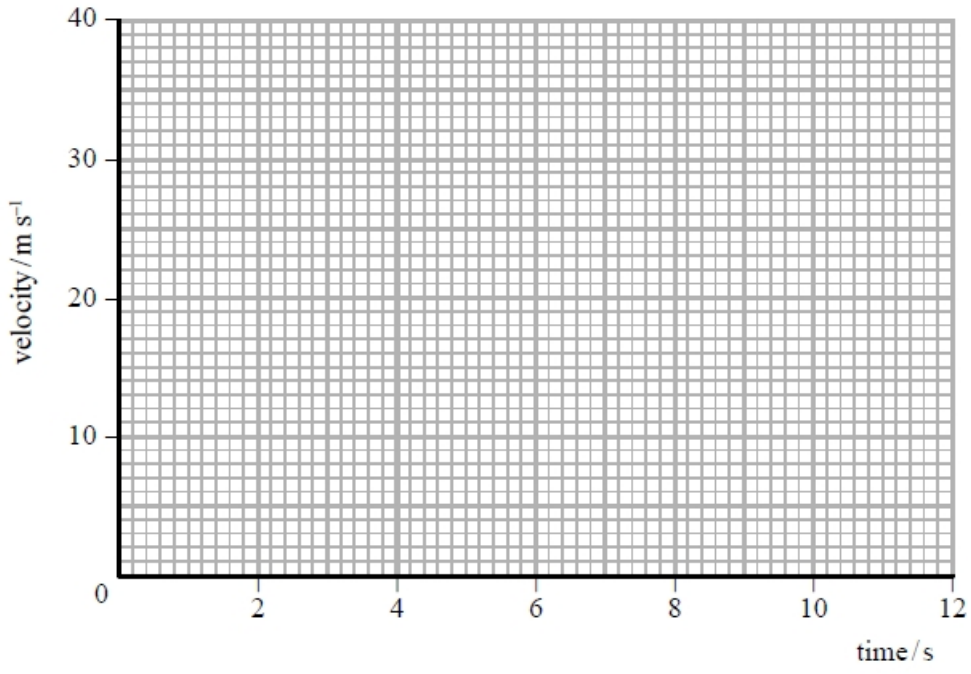
The maximum speed limit on a motorway in the U.K. is 31ms^{-1}.

(source: http://tracksideviews.com/tag/motorway/)

A car is travelling along the motorway at 31ms^{-1}. The driver sees stationary traffic 180 m ahead. After 0.6 s the driver reacts by applying a constant braking force that stops the car in 10 s.

(i) Draw a velocity-time graph of the car's motion, from the instant the driver sees the stationary traffic until the car stops.

(1)



(ii) Analyse the data to determine whether the car stops without colliding with the stationary traffic.

(2)

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(Total for question = 3 marks)

Q16.

Road trains are used in Australia to transport freight across large, flat areas of the country. They consist of a minimum of three trailers connected to a cab unit to pull them along.

(a) The braking distance of a road train travelling at 15m s^{-1} is 70m.

Assuming that the same braking force is applied at all speeds, show that the braking distance of a road train when travelling at 25m s^{-1} is about 190m.

(3)

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(b) A car accelerates uniformly at 3.7m s^{-2} as it passes a stationary road train.

The initial speed of the car is 30m s^{-1} and it reaches the speed limit of 130km h^{-1} as it passes the front of the cab.
Calculate the length of the road train.

(3)

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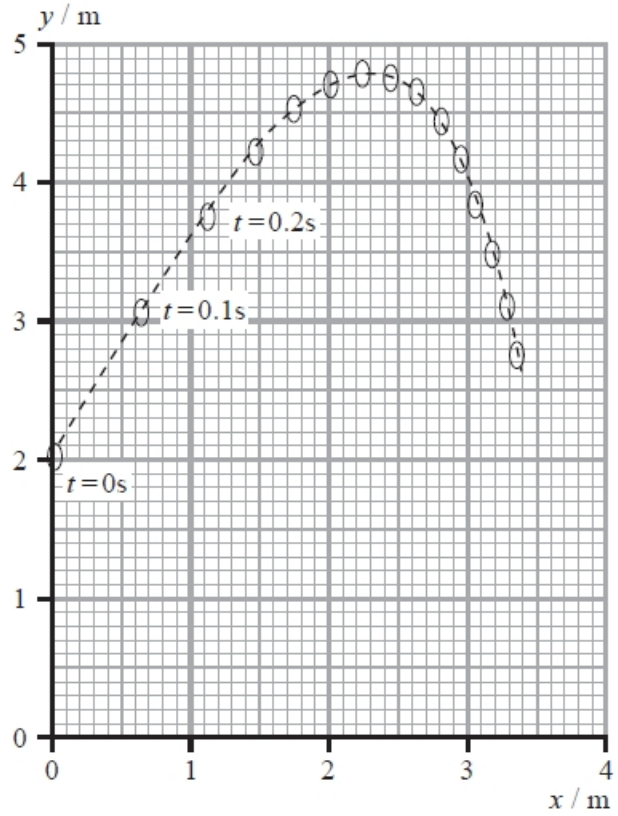
Length of the road train = ...

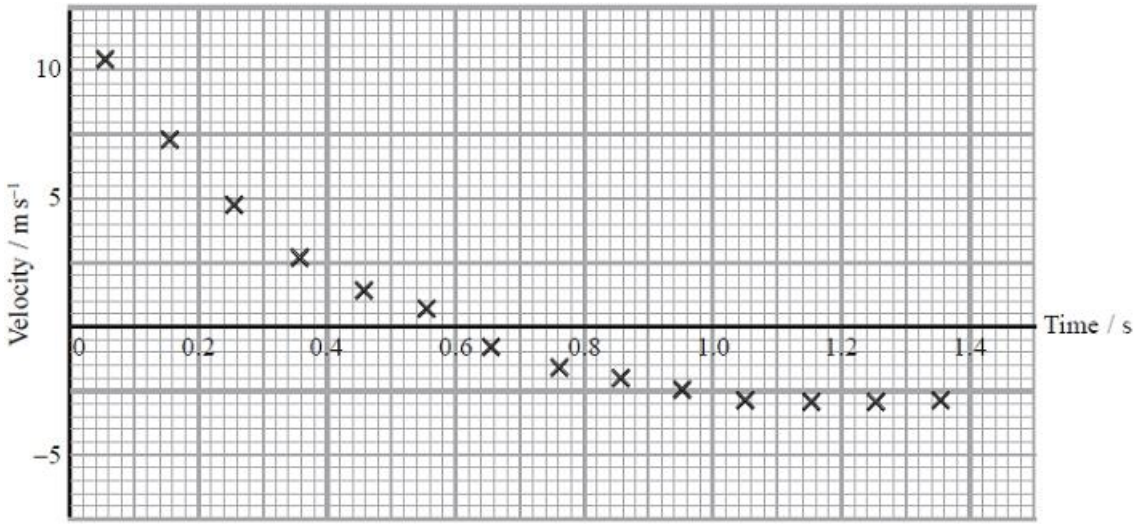
(Total for question = 6 marks)

Q17.

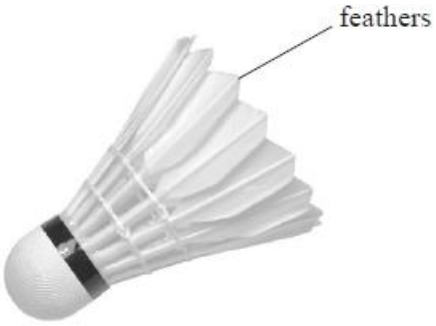
In a game of badminton, a shuttlecock is hit by a racket. The graph shows how the vertical displacement (*y*) and horizontal displacement (*x*) of the shuttlecock vary from the moment it leaves the racket. The positions are recorded every 0.10 s.



The graph below shows how the velocity of the shuttlecock in the vertical direction varies with time.



The photograph shows a shuttlecock.



The shuttlecock always moves through the air with the 'feathers' trailing behind.

Explain how the feathers affect the motion of the shuttlecock along its path.

(3)

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(Total for question = 3 marks)

Q18.

Which of the following is a scalar quantity?

☒ **A** displacement

☒ **B** force

☒ **C** weight

☒ **D** work

(Total for question = 1 mark)

Q19.

A ball is thrown with an initial horizontal component of velocity *u* and an initial vertical component of velocity *v*. The effects of air resistance are negligible.

Which of the following statements about the motion of the ball is **not** correct?

☒ **A** The magnitude of the acceleration in the vertical plane is *g*.

☒ **B** The horizontal component of velocity is constant.

☒ **C** The time taken for the ball to reach its maximum height is equal to $\frac{v}{g}$.

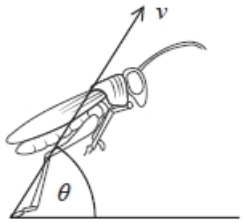
☒ **D** The maximum height of the ball depends on the values of *u* and *v*.

(Total for question = 1 mark)

Q20.

Grasshoppers can jump up to twenty times their length to escape predators. The magnitude of the launch velocity *v* does not vary significantly for a given grasshopper, so the length of the jump mostly depends on the launch angle *θ*.

The diagram shows a grasshopper at the instant it launches.



(Source: adapted from http://gclipart.com/grasshopper-clipart_28241/)

The grasshopper jumps from rest on level ground. The launch velocity is 2.6 m s^{-1} at an angle of 57° to the horizontal.

(i) Show that the vertical component of the launch velocity is about 2 m s^{-1}.

(1)

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(ii) Assess whether the horizontal distance travelled by the grasshopper in the jump is about 20 times the grasshopper's length.

length of grasshopper = 5.0 cm

(5)

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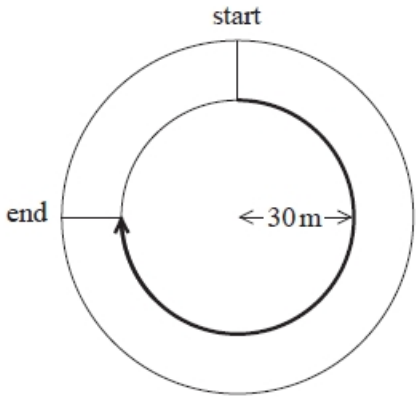
(Total for question = 6 marks)

Q21.

An athlete runs a race around three quarters of a circular track of radius 30 m using the inside lane.



What is the magnitude of the displacement of the athlete at the end of the race?

- ☒ **A** 141 m
- ☒ **B** 47 m
- ☒ **C** 42 m
- ☒ **D** 30 m

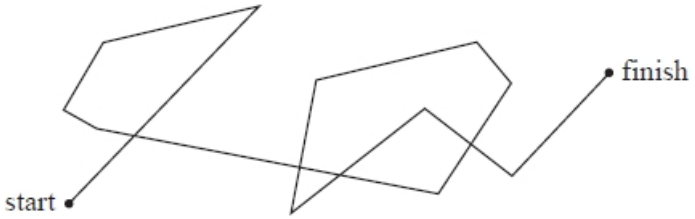
(Total for question = 1 mark)

Q22.

The diagram shows the path of a pollen particle on the surface of water as it is hit by water molecules.

Scale

1 cm : 0.5 mm



Which of the following is the magnitude of the displacement of the pollen particle in mm?

- ☒ **A** 260
- ☒ **B** 80
- ☒ **C** 13
- ☒ **D** 4

(Total for question = 1 mark)

Q23.

Which of the following can be used to determine the magnitude of velocity?

(1)

☒ **A** area under an acceleration-time graph

☒ **B** area under a velocity-time graph

☒ **C** gradient of an acceleration-time graph

☒ **D** gradient of a velocity-time graph

(Total for question = 1 mark)

Q24.

A student carried out an experiment to measure the acceleration of free fall *g*.

The student recorded the time taken for an object to fall from rest through a measured height.

Which equation would enable the student to obtain a value for g without any additional measurements or calculations?

☒ **A** $a = \frac{v - u}{t}$

☒ **B** $s = ut + \frac{1}{2}at^2$

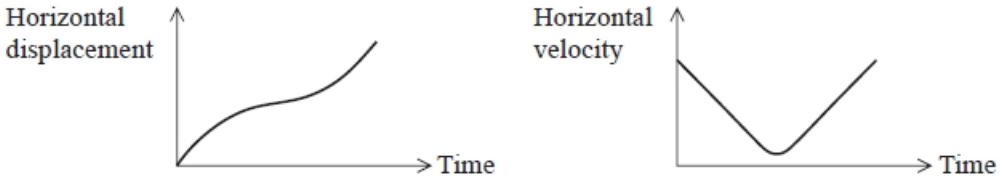
☒ **C** $s = \frac{(v + u)t}{2}$

☒ **D** $v^2 = u^2 + 2as$

(Total for question = 1 mark)

Q25.

The graphs shown represent the displacement-time and velocity-time graphs for the horizontal component of the motion of a ball.



Which of the following situations could produce this motion of the ball?

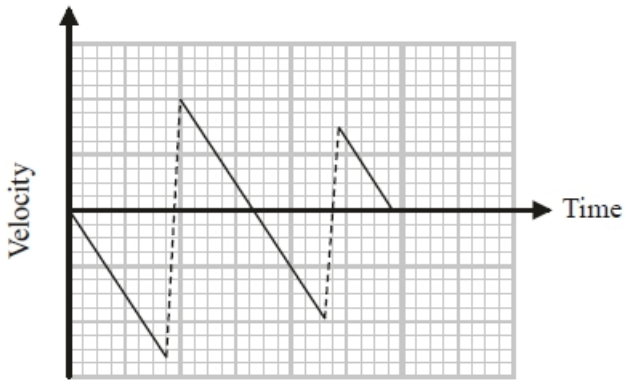
(1)

- ☒ **A** Rolling down one ramp and then rolling up a second ramp.
- ☒ **B** Rolling down a ramp then along the floor.
- ☒ **C** Rolling up one ramp and down a second ramp.
- ☒ **D** Rolling up a ramp and rolling back down the same ramp.

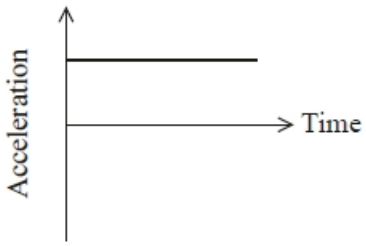
(Total for question = 1 mark)

Q26.

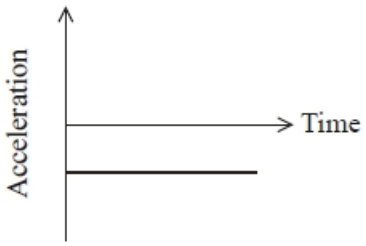
A ball is dropped vertically onto a horizontal surface and bounces twice before being caught. The graph shows how the velocity of the ball varies with time for the motion of the ball.



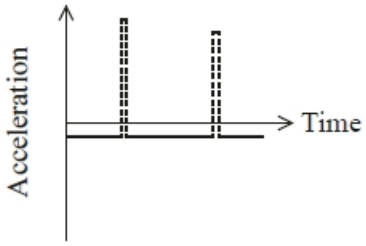
Which of the following is the acceleration-time graph for the motion of the ball?



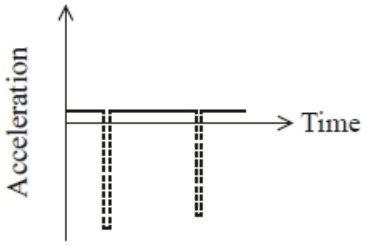
☐ **A**



☐ **B**



☐ **C**



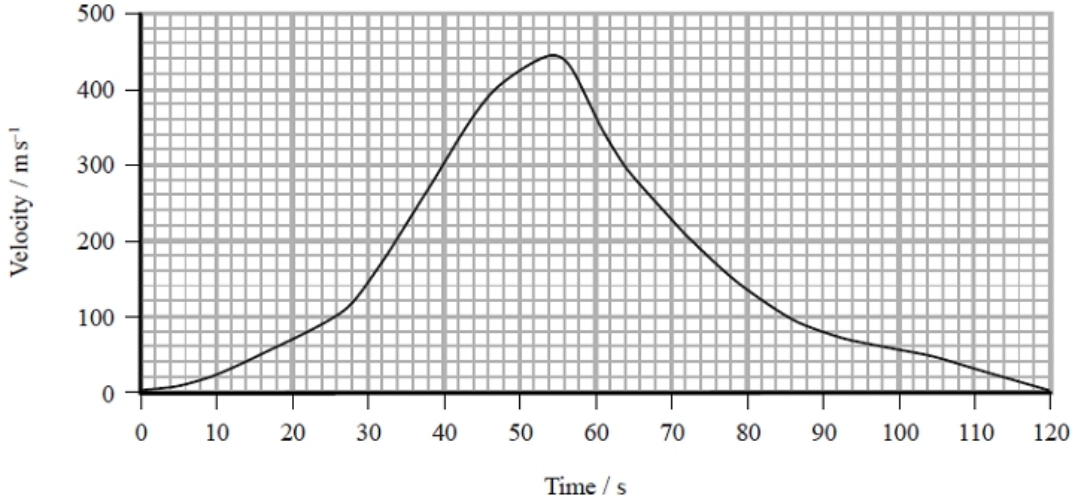
☐ **D**

(Total for question = 1 mark)

Q27.

The world land speed record of 341 m s^{-1} was set in October 1997. In an attempt to break this record, a new supersonic car has been developed called the Bloodhound.

The developers of the Bloodhound have used computer modelling to produce a velocity-time graph for the predicted motion of the car, on a straight track, during the record attempt.



* Discuss, with reference to the graph, the factors that would have been used to predict the motion of the car over the 120 s.

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(Total for question = 6 marks)

Q28.

Which of the following is an example of a scalar quantity?

- ☒ **A** displacement
- ☒ **B** energy
- ☒ **C** momentum
- ☒ **D** velocity

(Total for question = 1 mark)

Q29.

The winner of a 400m race must have the greatest

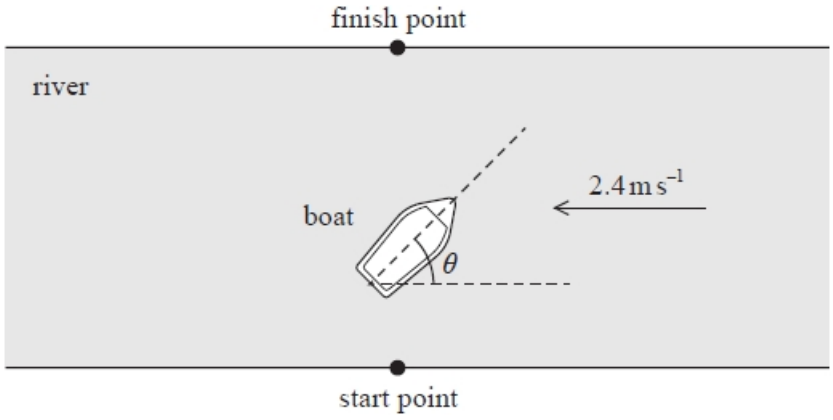
(1)

- ☒ **A** acceleration.
- ☒ **B** average speed.
- ☒ **C** instantaneous speed.
- ☒ **D** maximum speed.

(Total for question = 1 mark)

Q30.

A boat crosses a river, to a point on the bank directly opposite the starting point as shown. The velocity of the water in the river is 2.4 m s^{-1}.

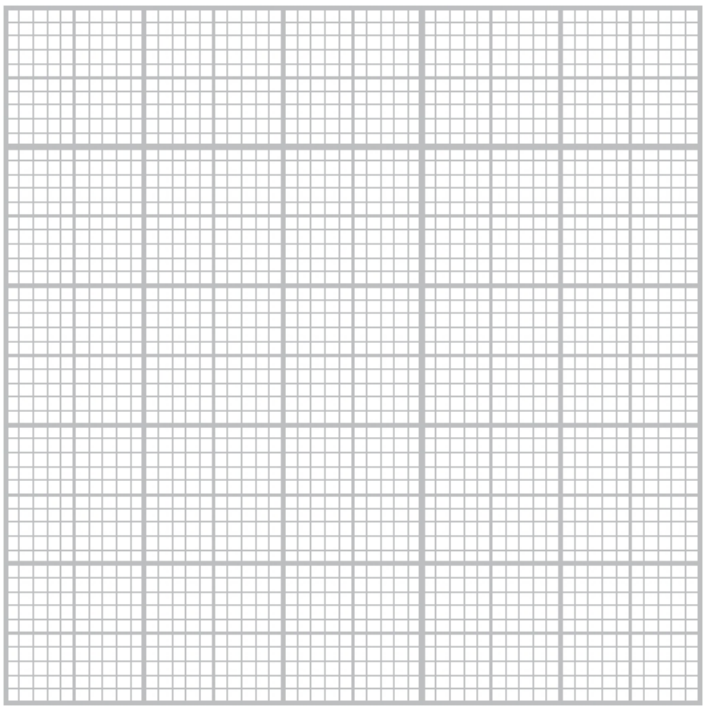


The boat is steered at an angle θ to the velocity of the water in the river in order to travel in a straight line across to the finish point.

The speed of the boat relative to the water is 4.3 m s^{-1}.

Determine the value of θ by drawing a scaled vector diagram.

(3)

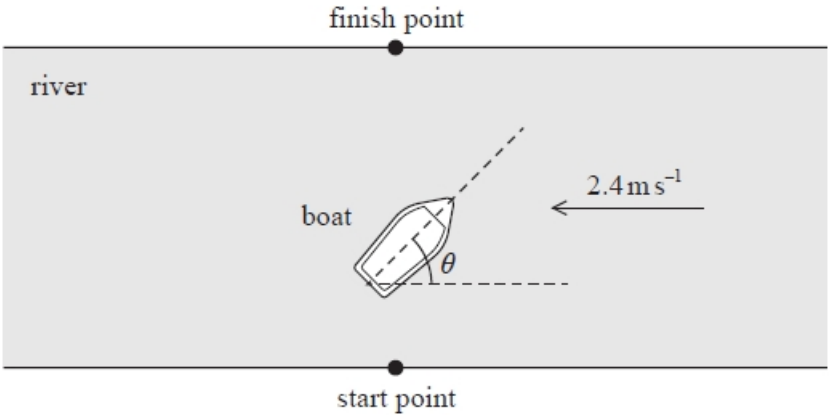


θ = ...

(Total for question = 3 mark)

Q31.

A boat crosses a river, to a point on the bank directly opposite the starting point as shown. The velocity of the water in the river is 2.4 m s^{-1}.



The boat repeats the crossing, at the same speed, when the velocity of the water in the river is greater.

Explain how the time taken for the crossing will change.

(3)

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(Total for question = 3 marks)

Q32.

Physical quantities can be vectors or scalars.

A car travels 45 km due north and then 30 km due east.

(i) Calculate the total distance travelled by the car.

(1)

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Total distance travelled = ...

(ii) Calculate the displacement of the car.

(3)

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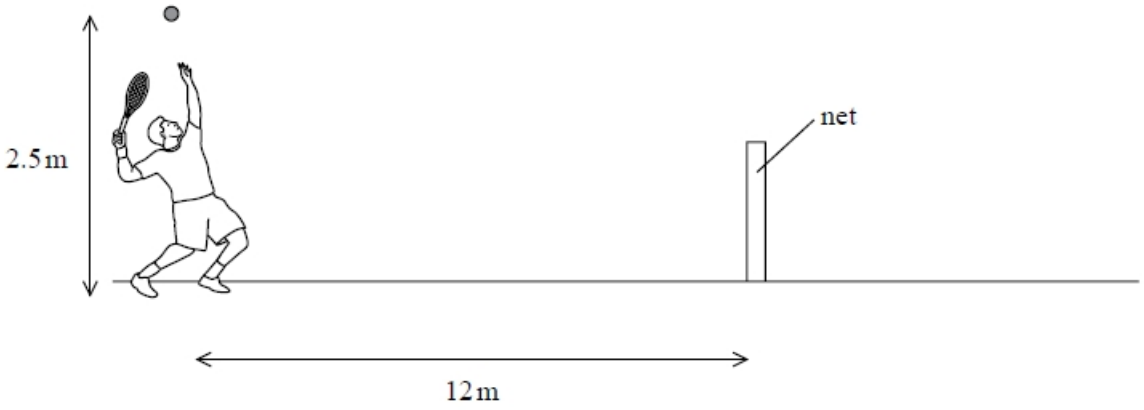
Magnitude of displacement = ...

Direction = ...

Q33.

A tennis player uses a racket to hit a ball over a net.



The player stands 12 m from the net. He throws the ball vertically upwards and hits the ball at a height of 2.5 m above the ground. The ball leaves the racket **horizontally** with a velocity of 25 m s^{-1}. The ball has a mass of 0.06 kg.

The ball must land within 6.1 m of the other side of the net.

Determine whether the ball hits the ground within this distance. Support your answer with a calculation. Ignore the height of the net.

(6)

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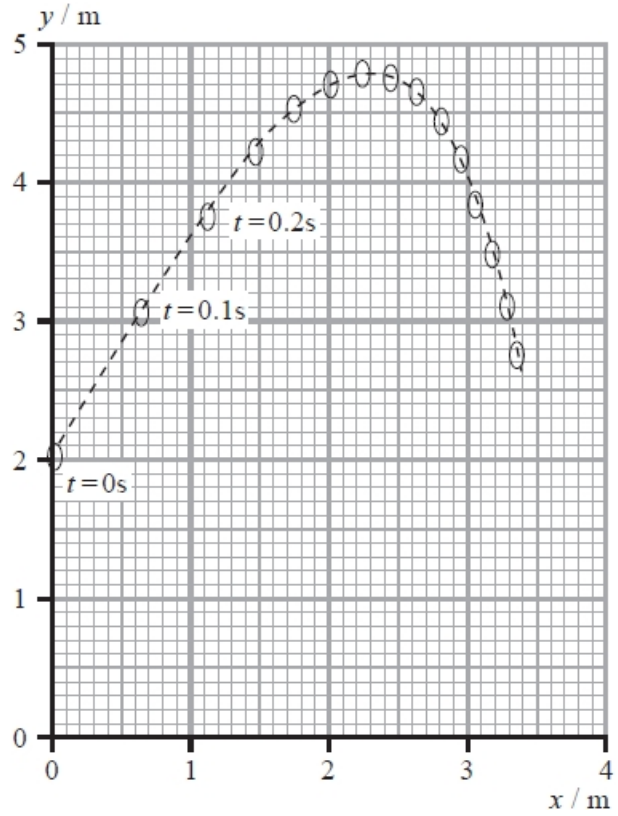
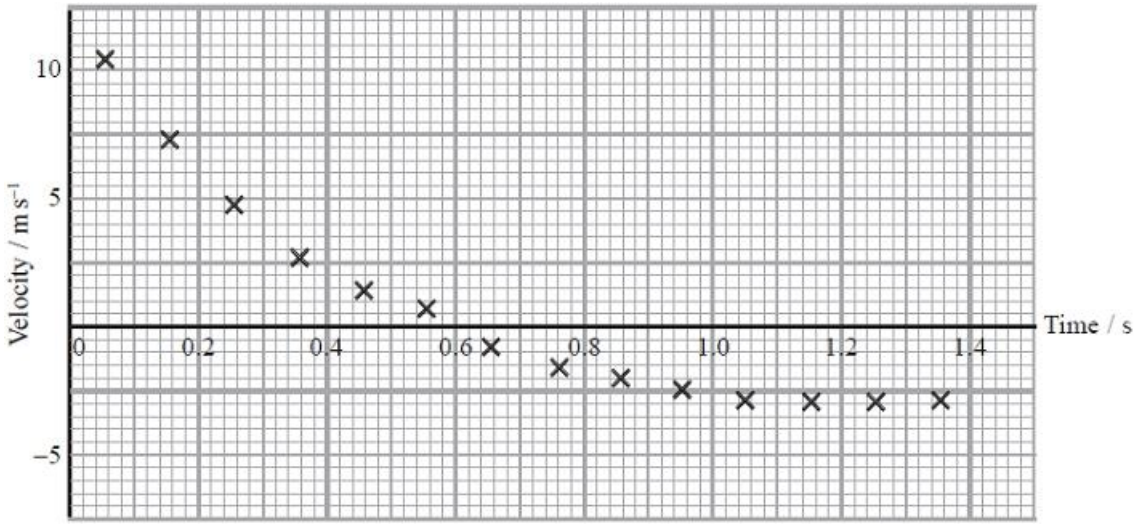
(Total for question = 6 marks)

Q34.

In a game of badminton, a shuttlecock is hit by a racket. The graph shows how the vertical displacement (*y*) and horizontal displacement (*x*) of the shuttlecock vary from the moment it leaves the racket. The positions are recorded every 0.10 s.



The graph below shows how the velocity of the shuttlecock in the vertical direction varies with time.



(i) Explain how the velocities have been calculated from the successive vertical positions of the shuttlecock.

(2)

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(ii) State why these velocities have been plotted at the mid-range of the time interval.

(1)

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(iii) State, with a reason, two pieces of evidence from the graphs that show that the shuttlecock does **not** follow the motion of a projectile moving freely under gravity.

(3)

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(iv) Show, using the velocity-time graph, that the maximum height gained by the shuttlecock is about 3 m.

(3)

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(Total for question = 9 marks)

Q35.

Which of the following is a vector quantity?

- ☒ **A** kinetic energy
- ☒ **B** momentum
- ☒ **C** time
- ☒ **D** work done

(Total for question = 1 mark)

Q36.

Which of the following is **not** a vector quantity?

(1)

- ☒ **A** acceleration
- ☒ **B** distance
- ☒ **C** momentum
- ☒ **D** velocity

(Total for question = 1 mark)

Q37.

A pilot wishes to fly due east. A wind is blowing in a northerly direction.

The direction of north is as shown.

Which of the following correctly shows the direction the plane should point?

(1)

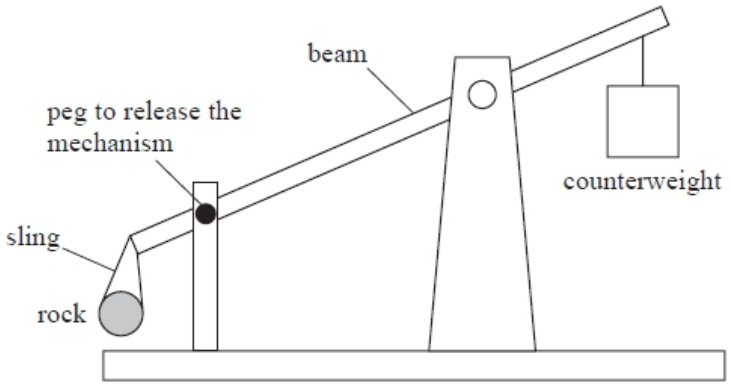
☒ **A** ☒ **B** ☒ **C** ☒ **D**

(Total for question = 1 mark)

Q38.

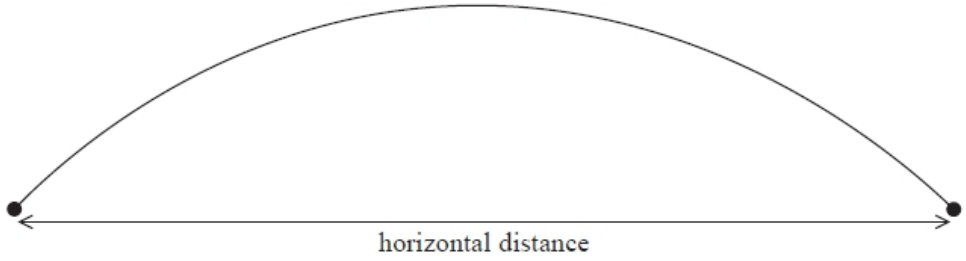
A trebuchet is a medieval catapult designed to project a rock over large distances.

A simplified diagram of a trebuchet is shown.



The rock is held in a sling. When the peg is removed the counterweight falls and the rock is projected through the air.

The rock was projected with a velocity of 41.5 m s^{-1} at an angle of 30° to the horizontal. The diagram shows the flight of the rock after it has left the trebuchet.



The rock rises to a maximum height and then falls back to the same height as its release height.

Calculate the horizontal distance travelled by the rock in this time.

(4)

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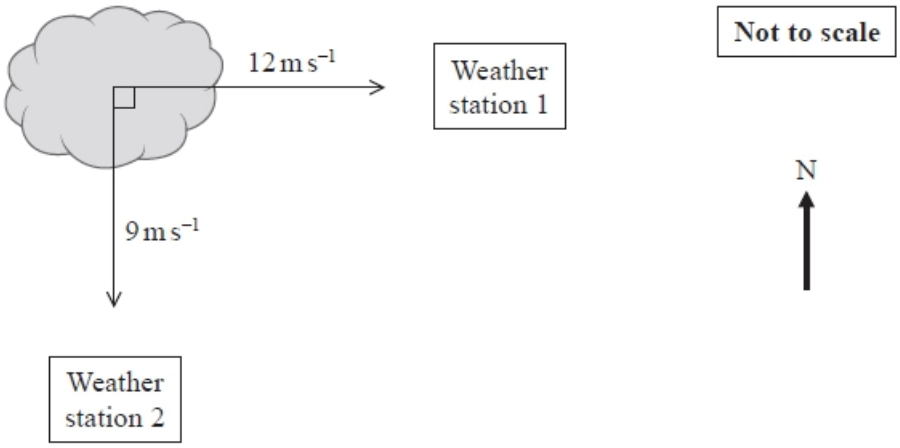
Horizontal distance = ...

(Total for question = 4 marks)

Q39.

Weather stations monitor the position of storm clouds.

The movement of a storm cloud is monitored by two weather stations. The components of the velocity of the storm cloud towards each weather station are shown in the diagram.



Determine the velocity of the storm cloud.

(4)

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Magnitude of velocity = ...

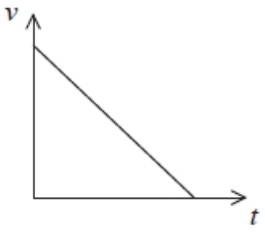
Direction of velocity = ...

(Total for question = 4 marks)

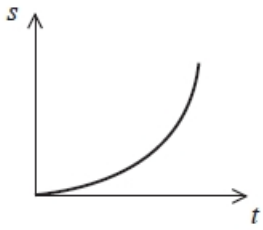
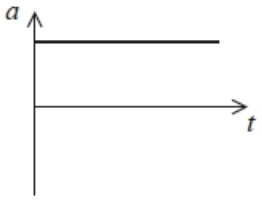
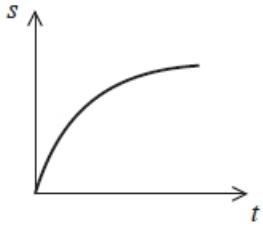
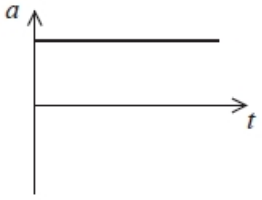
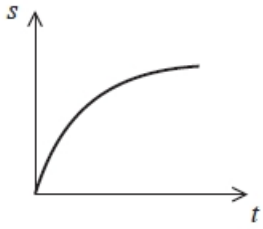
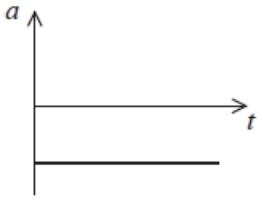
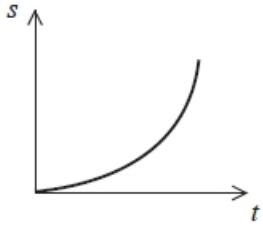
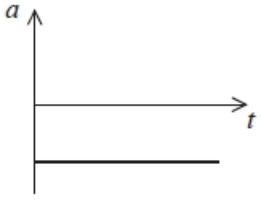
Q40.

A ball is rolled along a horizontal surface. Frictional forces slow the ball to rest.

The velocity-time graph for the ball is shown.



Select the row of the table that correctly gives the corresponding displacement-time and acceleration-time graphs for the ball.

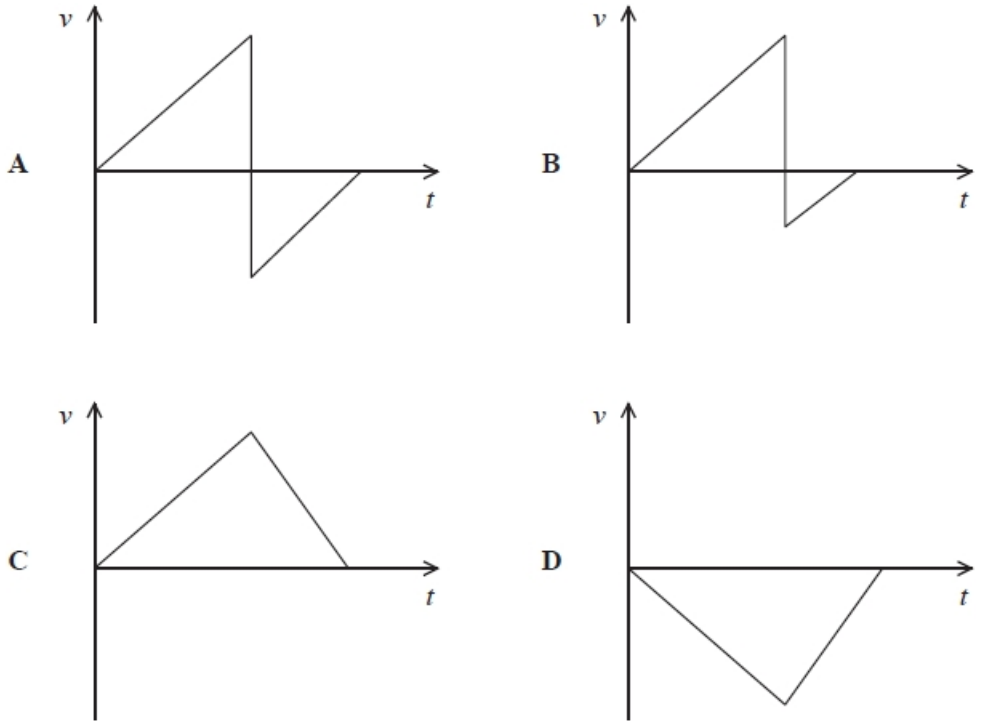
	Displacement-time graph	Acceleration-time graph
☐ A		
☐ B		
☐ C		
☐ D		

(Total for question = 1 mark)

Q41.

A ball was dropped from rest, from a height above the ground. The ball bounced back up to about half its initial height.

Which graph shows how the velocity *v* of the ball varied with time *t* ?



☒ **A**

☒ **B**

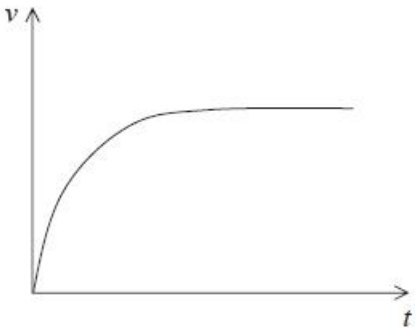
☒ **C**

☒ **D**

(Total for question = 1 mark)

Q42.

A sports class is studying cycling. They produce a video of a cyclist on a horizontal lawn.
The cyclist starts from rest.
They produce a sketch graph of the velocity *v* of the cyclist against time *t*.



Explain the shape of this graph and include a consideration of force as part of your answer.

(3)

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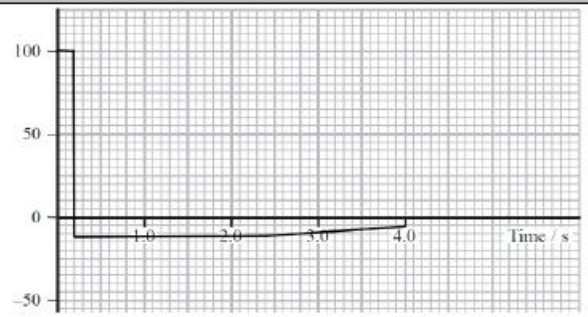
(Total for question = 3 marks)

Mark Scheme – Motion and Kinematic Quantities

Q1.

Question Number	Acceptable answers	Additional guidance	Mark
	The only correct answer is C *A is not correct because charge is a scalar quantity* *B is not correct because mass is a scalar quantity* *D is not correct because time is a scalar quantity*		1

Q2.

Question Number	Acceptable Answers	Additional Guidance	Mark
	• Positive value of acceleration for first 0.2 s (1) • Constant at 100 m s^{-2} (1) • Negative value of acceleration up to 4 s (1)		5
	• Initially at -12 m s^{-2} (value between -10 and -15 on graph) (1) • Negative value reducing in magnitude in last 1.0 s to 2.0 s (can be a step change) (1)		

Q3.

Question Number	Acceptable answers	Additional guidance	Mark
	B		1

Q4.

Question Number	Acceptable answers	Additional guidance	Mark
	• Use of $v = s/t$ for the horizontal motion **Or** see $u_h = 25\ m\ s^{-1}$ (1) • Use of $s = ut + ½\ at^2$ with $s = 0$ **Or** $v = u + at$ with $t = 1.0$ s **Or** see $u_v = 9.81\ m\ s^{-1}$ (1) • Combining of horizontal velocity and vertical velocity expressions **Or** see $\tan\theta = \left(\frac{9.81}{25}\right)$ (1) • $\theta = 21°$ (1)	Example of calculation horizontal motion: $u_h = \frac{50\ m}{2.0\ s} = 25\ m\ s^{-1}$ vertical motion: $0 = (u_v)\ (2.0\ s) + ½(-9.81\ m\ s^{-2})(2.0\ s)^2$ $u_v = 9.81\ m\ s^{-1}$ $\tan\theta = \frac{u_v}{u_h} = \frac{9.81\ m\ s^{-1}}{25\ m\ s^{-1}}$ $\theta = 21.4°$	4

Q5.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	• Use of $v = u + at$ (1) • $a = 0.81\ m\ s^{-2}$ (1)	Example of calculation $a = \frac{v-u}{t} = \frac{97\ m\ s^{-1}}{120\ s} = 0.808\ m\ s^{-2}$	2
(ii)	• Use of $s = ut + \frac{1}{2}at^2$ **Or** $v^2 = u^2 + 2as$ **Or** $s = \left(\frac{(v+u)}{2}\right)t$ (1) • Use of $v_{av} = \frac{s}{t}$ with $t = 320$ s (1) • $v_{av} = 75\ m\ s^{-1}$ (1)	Ecf acceleration from (a)(i) Example of calculation $s = ut + \frac{1}{2}at^2 = 0.5 \times 0.808\ m\ s^{-2}\ (120\ s)^2 = 5820\ m$ $s_2 = 29900\ m - 5820\ m = 24\ 080\ m$ $t = 440s - 120\ s = 320\ s$ $v_{av} = \frac{24\ 080\ m}{320\ s} = 75.3\ m\ s^{-1}$	3

Q6.

Question Number	Answer	Additional Guidance	Mark
	• Tangent drawn at t = 4.0 s (1) • Gradient of tangent determined (1) • a in the range 1.4 – 1.6 $m\ s^{-2}$ (1)	Example of calculation $a = \frac{(35.0-25.0)\ m\ s^{-1}}{(10.0-0.0)\ s} = 1.50\ m\ s^{-2}$	3

Q7.

Question Number	Answer	Additional Guidance	Mark
	• Use of displacement = area under line **(1)** • 1 square = 20 m **(1)** **Or** area divided into regular shapes • s in the range 410 – 430 m **(1)**	Example of calculation Number of squares = 42 1 square = 2 s × 5 m s^{-1} = 10 m s = 42 × 10 m = 420 m	3

Q8.

Question Number	Acceptable Answer	Additional guidance	Mark
(a)	• attempts to find area under second peak OR use of a suitable equation of motion OR equate $E = \frac{1}{2}mv^2$ and $\Delta E = mg\Delta h$ (1) • height = 0.9 - 1.0 m (1)	Example of calculation: $h = \frac{1}{2} \times 4.2\ \text{m s}^{-1} \times (1.2-0.70)\ \text{s} = 1.0\ \text{m}$	**(2)**

Question Number	Acceptable Answer	Additional guidance	Mark
(b)	• use of $\Delta E = mg\Delta h$ (1) OR use of $E = \frac{1}{2}mv^2$ • ΔE =0.59 J (1)	Example of calculation: $E = 0.060\ \text{kg} \times 9.81\ \text{m s}^{-2} \times (2.0 - 1.0)\ \text{m}$ $E = 0.59\ \text{J}$	**(2)**

Question Number	Acceptable Answer	Additional guidance	Mark
(c)	EITHER • finds gradient of middle section (1) • use of $F = ma$ (1) • $F = 64$ N (1) OR • reads two corresponding pairs of v and t from middle section of graph (1) • use of $F = \frac{m(v-u)}{\Delta t}$ (1) • $F = 64$ N (1)	Example of calculation: $F = \frac{(6.3+4.2)\ \text{m s}^{-1}}{(0.74-0.64)\ \text{s}} \times 0.060\ \text{kg} = 64\ \text{N}$	**(3)**

Question Number	Acceptable Answer	Additional guidance	Mark
(d)	Initial free-fall • gradient of both graphs is the same (1) Bounce section • the gradient of the soft ball graph is less (1) Second free-fall • gradient of the soft ball graph is the same as the first graph OR the gradient is the same as in the initial free-fall (1)	Accept the first line is the same Accept time for the bounce is longer	**(3)**

Q9.

Question Number	Acceptable Answer		Additional guidance	Mark
(a)	• Use of $v = u + at$ • Max acceleration from 0-60 time = 2.8 ($m\ s^{-2}$)	(1) (1)	Example of calculation $\frac{(60 \times 1600)\ m}{(60 \times 60)\ s} = 0 + a \times 9.5\ s$ Max acceleration = 2.8 $m\ s^{-2}$	2

Question Number	Acceptable Answer		Additional guidance	Mark
(b)	• Use of $v^2 = u^2 + 2as$ • Max speed with manufacturer's acceleration = 18 $m\ s^{-1}$ **Or** acceleration shown by police = 3.3 $m\ s^{-2}$ • Decision **and** evidence required consistent with calculated values	(1) (1) (1)	Examples for MP3: e.g. 18.3 $m\ s^{-1}$ is lower than 20 $m\ s^{-1}$ so should be challenged e.g. 18.3 $m\ s^{-1}$ is lower than the maximum speed so should be challenged e.g. The police are suggesting a greater acceleration than the manufacturers, so it should be challenged e.g. The maximum speed achievable is less than that suggested by the police, so it should be challenged MP2: maximum manufacturer's speed with show that value of acceleration = 19.0 $m\ s^{-1}$ Example of calculation $v^2 = 0^2 + 2 \times 2.8\ m\ s^{-2} \times 60\ m$ $v = 18.3\ m\ s^{-1}$	3

Question Number	Acceptable Answer		Additional guidance	Mark
(c)	• Air resistance increases with speed so acceleration decreases (at higher speeds) • The car could brake with greater negative acceleration/force than the positive acceleration/force	(1) (1)	Ignore references to the mass of the car Accept friction for air resistance	2

Q10.

Question Number	Acceptable answers	Additional guidance	Mark
	• calculation of gradient of the graph **(1)** • Use of $s = ½ at^2$ to obtain value for g **(1)** • Total uncertainty = 7 % **(1)** • Calculation of % difference **Or** Range of calculated g **(1)** • Judgment on accuracy of experiment with reason **(1)**	MP2: use of $\frac{2}{\text{gradient}}$ MP3: percentage uncertainty = 3 % + 3 % + 1 % MP5: e.g. comparison of total uncertainty with % difference **Or** comparison of calculated range with 9.81 m s^{-2} <u>Example of calculation</u> Gradient = $\frac{0.385\ s^2 - 0.06\ s^2}{1.8\ m - 0.4m} = 0.232\ s^2\ m^{-1}$ $g = \frac{2}{0.232\ s^2\ m^{-1}} = 8.67\ m\ s^{-2}$ Percentage difference = $\left(\frac{9.81\ m\ s^{-2} - 8.67\ m\ s^{-2}}{9.81\ m\ s^{-2}}\right) \times 100 =$ 12 %	**5**

Q11.

Question Number	Acceptable Answers	Additional Guidance	Mark
	• Attempts to find area under graph **(1)** • Height = 19 m **(1)** Alternative: • Use equations of motion to Height = 19 m **(2)**	Range for base of triangle between 1.8 and 2s to recognise area Example of calculation: Area = $\frac{1}{2} \times 1.9s \times 20ms^{-1}$ = 19 m	**2**

Q12.

Question Number	Acceptable answers	Additional guidance	Mark
	• Attempt to find area under the graph (1) • Length from 18 000 m to 20 000 m (1) • Comparison of calculated value to 23 km (1) e.g. The length is long enough	MP1: use of triangles or counting squares MP3: conclusion to be consistent with calculated value Example of calculation Area under the graph (counting large squares) $= 18.7 \times 100 \text{ m s}^{-1} \times 10 \text{ s} = 18\,700 \text{ m}$	3

Q13.

Question Number	Answer	Mark
	D	1
	Incorrect Answers: **A** – both sections of graph incorrect **B** – both sections of graph incorrect **C** – second section of graph incorrect	

Q14.

Question Number	Answer	Mark
	C $vt \sin 35°$	1
	Incorrect Answers: A – correct formula but initial vertical velocity and not horizontal velocity used B – incorrect formula used with initial vertical velocity D – incorrect formula used with initial horizontal velocity	

Q15.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	• Two straight lines drawn between points (0, 31) to (0.6, 31) and (0.6, 31) to (10.6, 0) **(1)**		1
(ii)	• Use of area under graph or equations of motion to determine distance **(1)** • Distance travelled = 170 m which is less than 180 m so concludes car stops without colliding **(1)**	Example of calculation distance = (0.6 s x 31 m s^{-1}) + (10 s × 31 m s^{-1}) /2 = 174 m	2

Q16.

Question Number	Acceptable Answer	Additional Guidance	Mark
(a)	**Either (Energy route)** • Use of $E_k = ½ mv^2$ **and** use of $W = Fd$ **(1)** • Use of $W = E_k$ **(1)** • Length of the road train = 194 (m) **(1)** **Or (suvat route)** • Use of $v^2 = u^2 + 2as$ with $v = 0$ to calculate the deceleration **(1)** • Use of $v^2 = u^2 + 2as$ with u = 25 m s^{-1} and calculated a **(1)** • Length of the road train = 194 or 195 (m) **(1)** (Do not award MP3 using suvat route for a substitution with u and v the wrong way round i.e. a positive value for a)	Example of calculation $E_k = ½ \times m \times (15\ m\ s^{-1})^2$ $½ \times m \times (15\ m\ s^{-1})^2 = F \times 70$ m $m = 0.62F$ $½ \times m \times (25\ m\ s^{-1})^2 = F \times d$ $½ \times 0.62F \times (25\ m\ s^{-1})^2 = F \times d$ $d = 194$ m Example of calculation $0 = (15\ m\ s^{-1})^2 + (2 \times a \times 70\ m)$ $a = -1.61\ m\ s^{-2}$ $0 = (25\ m\ s^{-1})^2 + (2 \times (-1.61\ m\ s^{-2}) \times s)$ $s = 194$ m (Reverse show that max 2 for either route)	3

Question Number	Acceptable Answer	Additional Guidance	Mark
(b)	• Use of $m\ s^{-1} = \frac{3600}{1000}$ km h^{-1} **(1)** • Use of correct equation(s) of motion to obtain the displacement **(1)** • s = 55 m **(1)**	(MP2 independent of MP1 and is for use of the equations using the speed in m s^{-1} or km h^{-1}) Example of calculation $(\frac{130\ km\ h^{-1} \times 1000\ m}{3600\ s})^2 = (30\ m\ s^{-1})^2 + (2 \times 3.7\ m\ s^{-2} \times s)$ $s = 54.6$ m	3

Q17.

Question Number	Acceptable answers	Additional guidance	Mark
	• feathers will cause turbulent air flow (1) Or feathers increase surface area • this results in (high) drag force (1) • horizontal velocities decrease (1) Or vertical acceleration is no longer g		3

Q18.

Question Number	Acceptable Answer	Additional Guidance	Mark
	D		1

Q19.

Question Number	Acceptable answers	Additional guidance	Mark
	The only correct answer is D *A is not correct because the acceleration in the vertical plane is g* *B is not correct because the horizontal component of velocity is constant* *C is not correct because of $v = 0 - at$ gives $t = v / g$*		1

Q20.

Question Number	Answer	Additional Guidance	Mark
(i)	• $v \sin\theta = 2.2$ (m s^{-1}) (1)	Example of calculation $v \sin\theta = 2.6 \text{ m s}^{-1} \times \sin 57°$ $= 2.18 \text{ m s}^{-1}$	1
(ii)	• Use of $v = u + at$ (1) • Use of $v \cos\theta$ (1) • Use of $s = ut + \frac{1}{2}at^2$ (1) • Number of body lengths = range/body length (1) • 12.7 body lengths, so not twenty lengths (1)	Example of calculation $t = \frac{(0 - 2.2)\text{m s}^{-1}}{-9.8 \text{ m s}^{-2}} = 0.224 \text{ s}$ $v \cos\theta = 2.6 \text{ m s}^{-1} \times \cos 57°$ $= 1.42 \text{ m s}^{-1}$ $s = 1.42 \text{ m s}^{-1} \times 2 \times 0.224 \text{ s}$ $= 0.636 \text{ m}$ $\text{number of lengths} = \frac{0.636 \text{ m}}{0.05 \text{ m}}$ $= 12.7$	5

Q21.

Question Number	Answer	Mark
	C 42 m	1
	Incorrect Answers: A – 141 m is ¾ of the internal circumference of the track (¾ × 2 × π × 30 = 141 m) B – 141 m is ¼ of the internal circumference of the track (¼ × 2 × π × 30 = 47 m) D – 30 m (the radius) is the displacement travelled in one direction (downwards from the start position)	

Q22.

Question Number	Answer	Mark
	D 4 mm	**1**
	Incorrect Answers: A – distance has been measured and has not been scaled. B – the displacement has not been scaled C – distance has been used	

Q23.

Question Number	Answer	Mark
	A area under an acceleration-time graph	**1**
	Incorrect Answers: B – this is equivalent to the displacement C – this is equivalent to the rate of change of acceleration D – this is equivalent to the acceleration	

Q24.

Question Number	Answers	Additional Guidance	Mark
	B	$s = ut + \frac{1}{2}at^2$	**(1)**

Q25.

Question Number	Acceptable Answer	Additional Guidance	Mark
	C Rolling up one ramp and down a second ramp.		**1**

Q26.

Question Number	Acceptable answers	Additional guidance	Mark
	C		**1**

Q27.

<table>
<tr><th>Question Number</th><th>Acceptable answers</th><th>Additional guidance</th><th>Mark</th></tr>
<tr><td>*</td><td>This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning.

Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.

The following table shows how the marks should be awarded for indicative content.
<table><tr><th>Number of indicative marking points seen in answer</th><th>Number of marks awarded for marking points</th></tr><tr><td>6</td><td>4</td></tr><tr><td>5 - 4</td><td>3</td></tr><tr><td>3 - 2</td><td>2</td></tr><tr><td>1</td><td>1</td></tr><tr><td>0</td><td>0</td></tr></table>Indicative content

• At greater speed, the drag force is greater

• Resultant force decreases Or acceleration decreases

• When the rocket is started the (resultant) force/thrust increases

• The mass/weight of the car decreases as fuel is used up

• Increasing the acceleration (for a given applied force)

• When the brakes are applied, there is a deceleration
Or when the brakes are applied the resultant force is in the opposite direction
Or deceleration (due to drag forces) decreases due to smaller drag forces acting on the car at lower speeds</td><td>The following table shows how the marks should be awarded for structure and lines of reasoning
<table><tr><th></th><th>Number of marks awarded for structure of answer and sustained line of reasoning</th></tr><tr><td>Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout</td><td>2</td></tr><tr><td>Answer is partially structured with some linkages and lines of reasoning</td><td>1</td></tr><tr><td>Answer has no linkages between points and is unstructured</td><td>0</td></tr></table></td><td>6</td></tr>
</table>

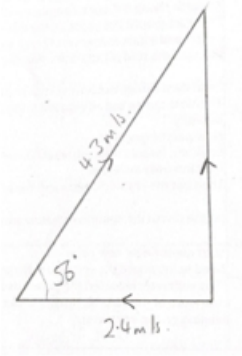
Q28.

Question Number	Acceptable answers	Additional guidance	Mark
	The only correct answer is B **energy**	A,C,D are vectors	**1**

Q29.

Question Number	Acceptable Answer	Additional Guidance	Mark
	B Average speed		**1**

Q30.

Question Number	Acceptable answers	Additional guidance	Mark
	• Correct combination of vectors drawn **(1)** • Both vectors drawn to scale **(1)** • Angle = 56° (range 55° - 58°) **(1)**		**3**

Q31.

Question Number	Answer		Mark
	• Angle θ will need to decrease **Or** (Component of boat) velocity along river must increase **(1)** • There is further to travel (relative to the water) **(1)** **Or** **(1)** (Component of boat) velocity across river decreases • time increases (Dependent on either MP1 or MP2)		**3**

Q32.

Question Number	Answer		Mark
(i)	Distance = 75 km	**(1)**	**1**
(ii)	Use of Pythagoras **Or** correctly constructed scale drawing (labels not required) Displacement = 54 km Direction = 34° East of North (accept angle indicated on diagram) (there is only 1 unit error for km in (i)and (ii)) Example of calculation Displacement$^2 = 45^2 + 30^2$ Displacement = $\sqrt{2925}$ km Displacement = 54.1 km Direction = 33.7° (east of north) **Or** 56° (north of east)	**(1)** **(1)** **(1)**	**3**

Q33.

Question number	Acceptable answers	Additional guidance	Mark
	• Use of $s = ut + \frac{1}{2}at^2$ **(1)** • Use of $s = \frac{1}{2}at^2$ with vertical components to find t **(1)** • Use of $s = ut$ with horizontal components to find s **(1)** • Subtract 12 from their answer for horizontal distance **(1)** • Distance from net = 6 m **(1)** • Makes conclusion whether the ball is within the required range of the net **(1)**	Answer consistent with calculated value. Example of calculation: $t = \sqrt{\frac{2 \times 2.5}{9.81}} = 0.714$ s $s = 25 \times 0.714 = 17.85$ m Distance from net = 17.85 – 12 = 5.9 m	**6**

Q34.

Question Number	Acceptable answers		Additional guidance	Mark
(i)	• calculate difference in positions on y axis	(1)	might show this with a calculation:	
	• use velocity = distance/0.1s	(1)	v = (3.0 - 2.0) m / 0.1 s = 10 m s^{-1}	2
(ii)	• this velocity is an average	(1)		1
(iii)	• the horizontal distances between the points vary	(1)	2 max from MP1,2,3	
	• the graph is not symmetrical around the vertical **Or** the graph is not parabolic	(1)	1 max from MP4,5	
	• velocity-time graph is not straight line **Or** gradient of velocity-time graph is not constant	(1)		
	• horizontal component of velocity should be constant	(1)		
	• Acceleration in vertical direction should equal *g*	(1)		3Max
(iv)	• attempt to find an area under graph	(1)	Example of calculation	
	• finds area up to *v* = 0	(1)	area of approximate triangle = ½ 0.5 × 11.5	
	• height in range 2.80 - 2.95 m	(1)	= 2.88 m	3

Q35.

Question Number	Answer	Mark
	B momentum	1
	Incorrect Answers: **A** – scalar quantity **C** – scalar quantity **D** – scalar quantity	

Q36.

Question Number	Answer	Mark
	B distance	1
	Incorrect Answers: A – acceleration is a vector quantity C – momentum is a vector quantity D – velocity is a vector quantity	

Q37.

Question Number	Acceptable Answer	Additional Guidance	Mark
	D		**1**

Q38.

Question Number	Acceptable Answer	Additional guidance	Mark
	• Use of trig to determine the vertical or horizontal component of the initial velocity **(1)** • Use of equation(s) of motion to determine the time of flight **(1)** • Use of s=ut for horizontal motion **(1)** • s = 150 m	Example Calculation $u_V = 41.5\ ms^{-1} \sin 30 = 20.8\ ms^{-1}$ $u_H = 41.5\ ms^{-1} \cos 30 = 35.9\ ms^{-1}$ $v = u + at$ $0\ ms^{-1} = 20.8\ ms^{-1} - 9.81 ms^{-2}\ t$ t (to max height) = 2.12s $s = 35.9\ ms^{-1} \times 2 \times 2.12s$ s = 152 m	**4**

Q39.

Question Number	Acceptable Answers	Additional guidance	Mark
	• Uses Pythagoras (1) • Speed = 15 m s^{-1} (1) • Uses trigonometry (1) • Angle to N-S line = 53° **Or** Angle to E-W line = 37° (1)	Example of Calculation $v = \sqrt{12^2 + 9^2} = 15\ m\ s^{-1}$ $\tan\theta = \frac{12}{9} = 53°$ to N-S line	**4**

Q40.

Question Number	Answer	Mark
	C	**1**

Q41.

Question Number	Acceptable answers	Additional guidance	Mark
	The only correct answer is A B is not correct as the rebound velocity wil be about $0.7 \times v_{initial}$ C is not correct as the velocity must switch sign on rebound D is not correct as the velocity must switch sign on rebound		**1**

Q42.

Question Number	Acceptable answers		Additional guidance	Mark
	• Initial acceleration due to a resultant force	(1)		3
	• Decreasing acceleration as resistive forces increase **Or** Decreasing acceleration as resultant force decreases	(1)	Accept reference to gradient of graph for acceleration for MP2 & MP3.	
	• No acceleration as resultant force is zero **Or** constant velocity as resultant force is zero	(1)	Accept terminal velocity for constant velocity	