PEARSON EDEXCEL A-LEVEL PHYSICS · 9PH0

PHYSICS



EXAM QUESTION PACK

TOPIC 2: MECHANICS

MOTION AND KINEMATIC QUANTITIES

SCORE	PERCENTAGE
/336	%

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Q1.

In the sport of curling, two teams of 'curlers' take turns sliding polished granite stones across an ice surface towards a circular target marked on the ice.



commons.wikimedia.org

A stone of mass 19.6 kg is accelerated uniformly for 1.25 s before being released by a curler. The stone then decelerates uniformly to rest, travelling 32.5 m in a time of 17.5 s.

Calculate the average useful power developed by the curler in accelerating the stone.

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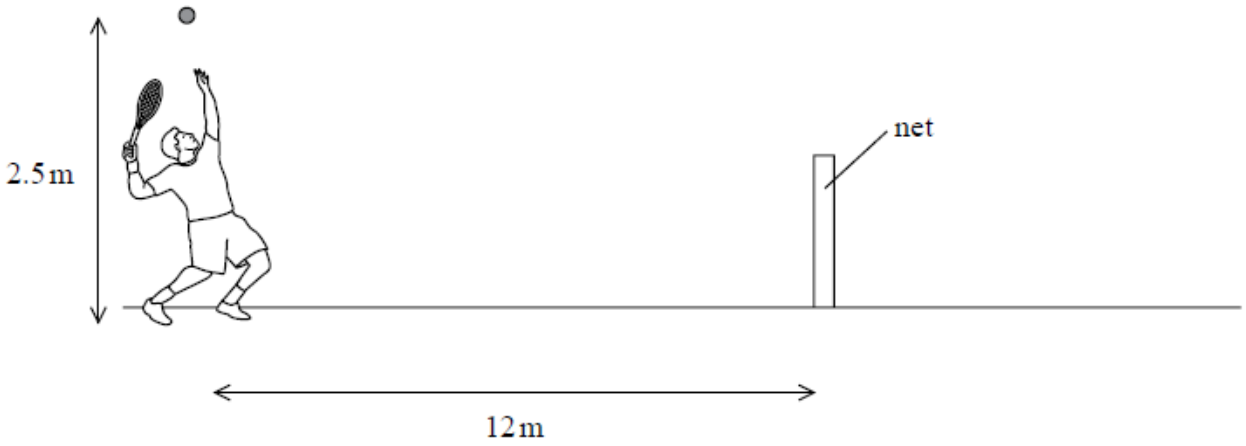
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Average power = ...

(Total for question = 4 marks)

Q2.

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 is in contact with the racket for 0.04 s.

Calculate the average force on the ball.

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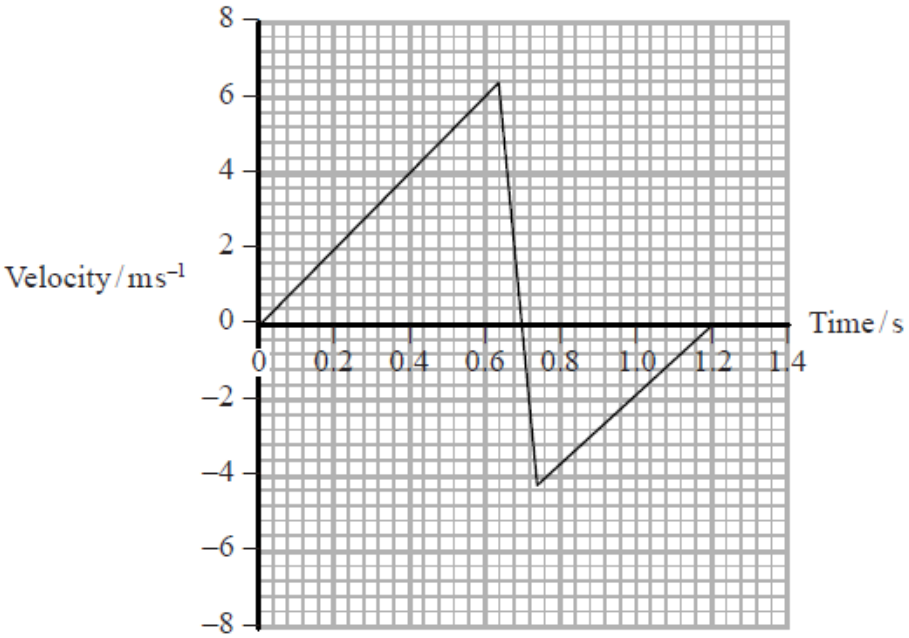
Average force = ...

(Total for question = 3 marks)

Q3.

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.

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(Total for question = 10 marks)

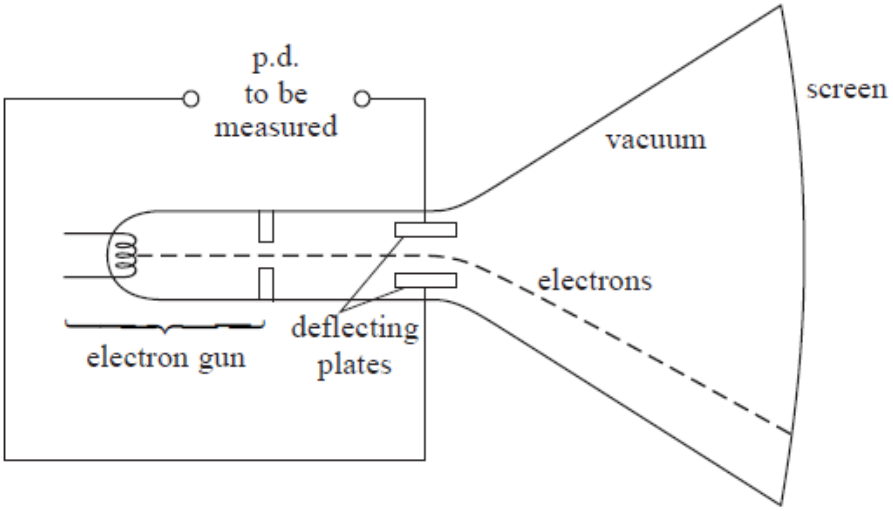
Q4.

Cathode ray tubes are used in oscilloscopes.



The diagram shows a simplified cathode ray tube that can be used to determine the magnitude and polarity of a potential difference (p.d.).

The cathode ray tube consists of an electron gun, a pair of deflecting plates and a fluorescent screen.



(a) The electron gun includes a filament. When this filament is heated, electrons are released and are accelerated by a p.d. of 1.5 kV to form an electron beam.

(i) Name the process by which electrons are released from the heated filament.

(1)

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(ii) Show that the maximum velocity of the electrons is about 2×10^7 m s^{-1}.

(2)

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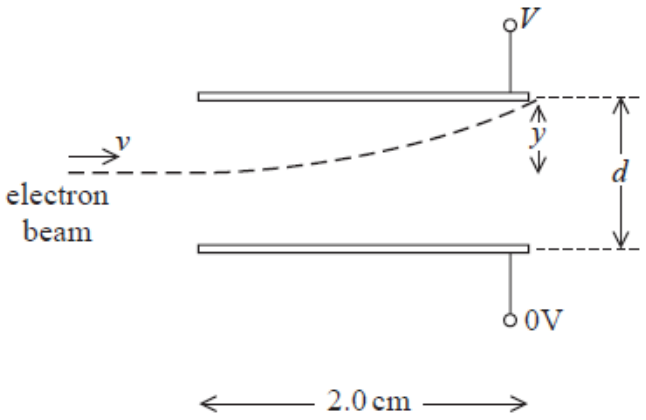
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(b) The electron beam then enters a uniform electric field between the two parallel horizontal deflecting plates. The magnitude and direction of the deflection is determined by the p.d. *V* that is applied across the plates.

The diagram shows one possible path of the electron beam as it passes between the plates.



(i) Show that the acceleration of an electron, of mass *m* and charge *Q*, is given by

$\frac{VQ}{dm}$

(2)

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(ii) Calculate the magnitude of the vertical deflection y of the beam as it leaves the plates.

V = 50 V
d = 0.01 m

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y = ...

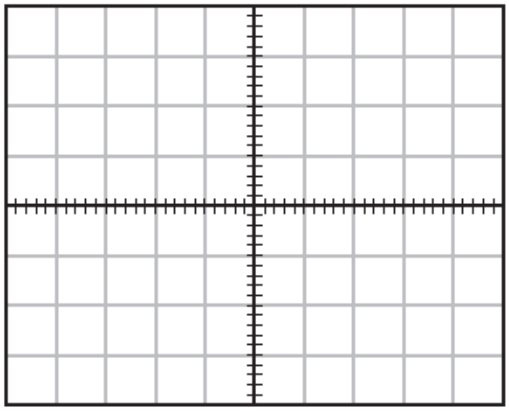
(c) A laboratory oscilloscope with the time base turned off operates in the same way as this simplified cathode ray tube. A student uses an oscilloscope in this way to monitor an alternating p.d. of 53 V_{rms}

On the grid, draw the trace that would be seen on the screen.

(4)

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1 square = 25 V

(Total for question = 14 marks)

Q5.

The photograph shows a model racing car set. The curved parts of the track are semicircular. The car makes electrical contact with the track using metal brushes underneath the car.



The following measurements are made for a car starting at rest on a straight piece of track.

distance travelled = 1.2 m

time taken = 0.77 s

(i) Show that the final velocity of the car is about 3 m s^{-1}.

Assume the acceleration is constant.

(2)

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(ii) The final velocity calculated in (i) is the maximum velocity before the car slips off the track.

Calculate the maximum horizontal force between the curved part of the track and the car.

mass of car = 0.050 kg

radius of curved part of track = 0.042 m

(2)

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Maximum horizontal force = ...

(Total for question = 4 marks)

Q6.

Scientists have been studying a type of jumping spider that can jump up to six times its body length.

The scientists photographed a spider at 0.02 s intervals, during a jump. The picture is taken from the photograph and is shown actual size.



(i) Deduce whether the images show that the motion in the *x*-direction is independent of the motion in the *y*-direction. You should take measurements using the cross marking the centre of gravity of the spider.

(4)

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(ii) Show that the initial velocity of the spider at the start of the jump is about $1\ m\ s^{-1}$. You should take measurements using the cross marking the centre of gravity of the spider.

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(iii) The spider achieves this jump by extending its two back legs by 3.0 mm.

Calculate the average force the spider exerts in each leg to achieve the jump.

mass of spider = 150 mg

(3)

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Average force = ...

(Total for question = 12 marks)

Q7.

In 2014 the Rosetta spacecraft reached the comet Churyumov-Gerasimenko.
Rosetta went into orbit around the comet.

The following table gives some data for the comet.

Mass / kg	1.0×10^{13}
Density / kg m^{-3}	470

The comet is irregular in shape but can be modelled as a spherical object.

(a) Show that a sphere with this mass and density has a radius of about 1700 m.

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(b) Calculate the gravitational field strength at the surface of the comet.

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Gravitational field strength = ...

(c) A probe was sent from the Rosetta spacecraft to land on the comet.
The probe bounced off the surface of the comet and took 1 hour and 50 minutes to return to the surface again.

Calculate the height above the surface of the comet that the probe would have reached. Assume that the acceleration of the probe is constant with the magnitude calculated in (b).

(2)

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Height = ...

(d) Explain, using gravitational field theory, how the actual height reached would compare with the value calculated in part (c).

You may assume there are no resistive forces such as air resistance.

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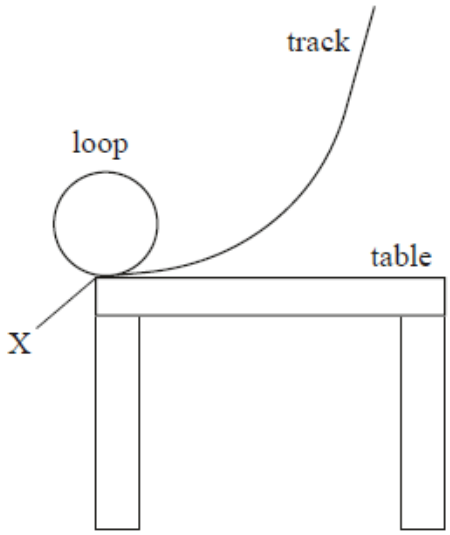
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(Total for question = 10 marks)

Q8.

A track for toy cars can be built with a circular loop as shown.



A toy car is placed on the track at various heights. It travels around the loop before leaving the track horizontally at X.

The toy car leaves the track at X with a horizontal velocity of 3.0 m s^{-1}.

X is 0.65 m above the floor.

Calculate the horizontal displacement of the car from X when it hits the floor.

(4)

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Horizontal displacement = ...

(Total for question = 4 marks)

Q9.

The photograph shows a model racing car set. The curved parts of the track are semicircular. The car makes electrical contact with the track using metal brushes underneath the car.



The cars are controlled separately and so can be raced, with one car on the inner lane and the other on the outer lane. The cars are identical. Each car is raced at its highest speed for that lane.

Explain why the outcome of the race is difficult to predict.

(3)

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(Total for question = 3 marks)

Q10.

A student is carrying out an experiment to determine a value for the acceleration due to gravity *g*. He drops a ball from various heights, which he measured with a metre rule.
The ball has a built in timer which starts when the ball is released and stops when the ball hits the ground.



The student starts by releasing the ball from a height of 1.00 m and measures the time taken for the ball to fall. He repeats this twice.

t_1 /s	t_2 /s	t_3 /s
0.45	0.51	0.43

(a) Use the student's data to calculate a value for g.

(3)

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g = ...

(b) Estimate the percentage uncertainty in your value for g.

(3)

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Percentage uncertainty = ...

(c) The student then measured the time interval for the ball to fall from a 3.00 m height. Explain how this would improve the value obtained for g.

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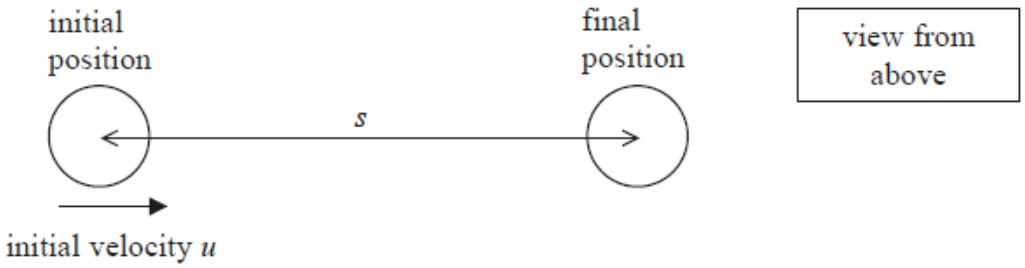
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(Total for question = 8 marks)

Q11.

A student carried out an experiment with coins.

She gave a 2p coin a sharp tap, so that it slid along a horizontal surface and came to rest as shown.



The student recorded the distance *s* moved by the coin.

She then replaced the 2p coin with a 1p coin and repeated the process.

The student read that the frictional force between an object and a surface is directly proportional to the mass of the object. She suggested that, in her experiment, *u* is directly proportional to $\sqrt{s}$ and is independent of the mass of the coin.

Discuss the validity of this suggestion.

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(Total for question = 6 marks)

Q12.

The International Space Station (ISS) is in a low Earth orbit. Astronauts in ISS have an apparent weight of zero. In order to determine their mass, the astronauts must secure themselves to a platform which is set into oscillation and moves with simple harmonic motion.





State what is meant by simple harmonic motion.

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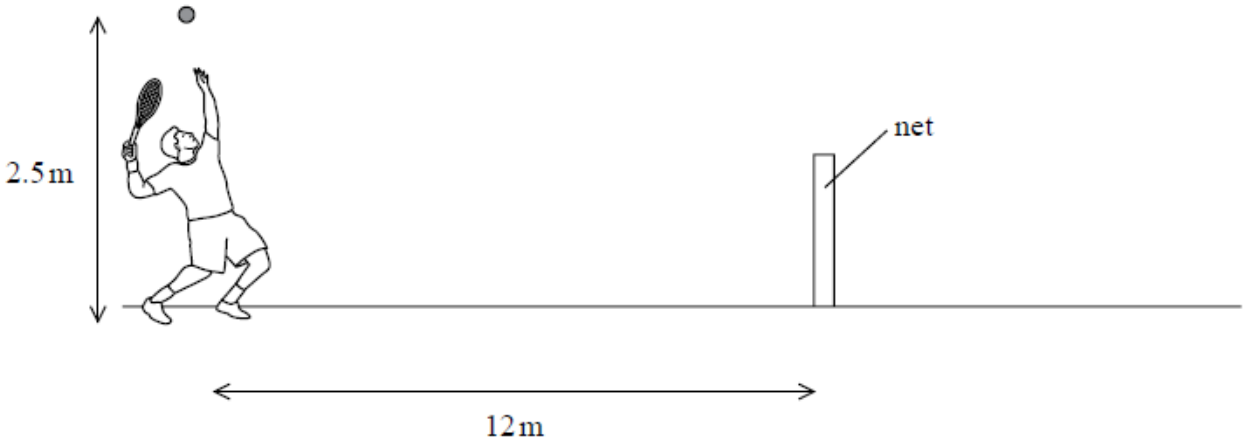
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(Total for question = 2 marks)

Q13.

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.

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(Total for question = 6 marks)

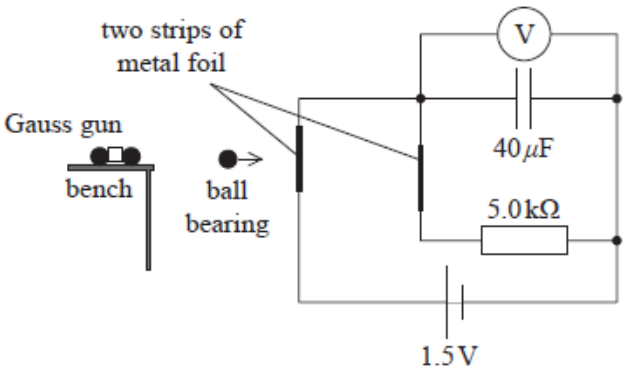
Q14.

A 'Gauss gun' can be made from five ball bearings of equal mass and two magnets, as shown.



Pairs of ball bearings are placed to the right of two strong magnets. A single ball bearing is released from the left, as shown. The ball bearing is attracted to, and collides with, the first magnet. This and all subsequent collisions can be assumed to be elastic.

A student set up the apparatus shown to measure the speed of the last ball bearing. The 'Gauss gun' was placed at the end of a bench, so that the ball bearing left the gun and broke two strips of metal foil which formed part of an electric circuit.



As the ball bearing left the gun, it broke the first foil strip at its centre so that the capacitor started to discharge. When the ball bearing broke the second foil strip the capacitor discharge stopped.

(i) Calculate the energy stored in the capacitor when it was fully charged.

(2)

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Energy stored = ...

(ii) The voltmeter reading halved in the time taken for the ball bearing to travel between the two foil strips.

Show that the time taken for the ball bearing to travel between the two foil strips was about 0.1 s.

(2)

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(iii) The two foil strips were 0.50 m apart.

Calculate the horizontal velocity of the ball bearing.

(2)

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Horizontal velocity = ...

(iv) The student positioned the second foil strip with its centre 8.0 cm lower than the centre of the first foil strip.

Deduce whether the ball bearing broke the second foil strip at its centre.

Assume the ball bearing was travelling horizontally as it broke the first foil strip.

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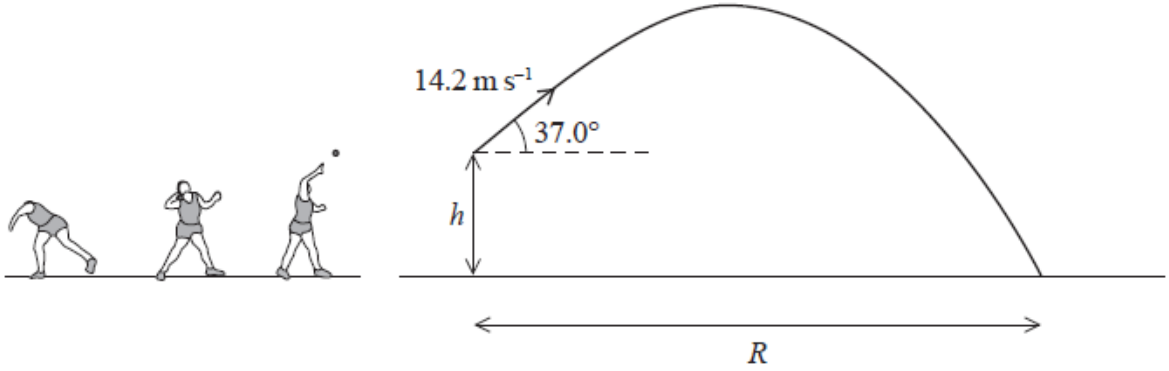
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(Total for question = 8 marks)

Q15.

The shot put is an Olympic field event. The distance for the women's world record shot put is in excess of twenty two metres.

The shot is a metal ball, which is thrown from a standing position so that it lands on the ground a horizontal distance *R* away from the thrower.



A shot is thrown from a height *h* above the ground with an initial velocity of 14.2 m s^{-1} at an angle of 37.0° to the horizontal. The time it takes for the shot to reach the ground is 1.98 *s*.

(a) Show that the vertical component of the initial velocity is about 8.6 m s^{-1}.

(2)

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(b) Calculate the height *h* above the ground from which the shot was thrown.

(3)

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h = ...

(c) Calculate the horizontal distance R for this throw.

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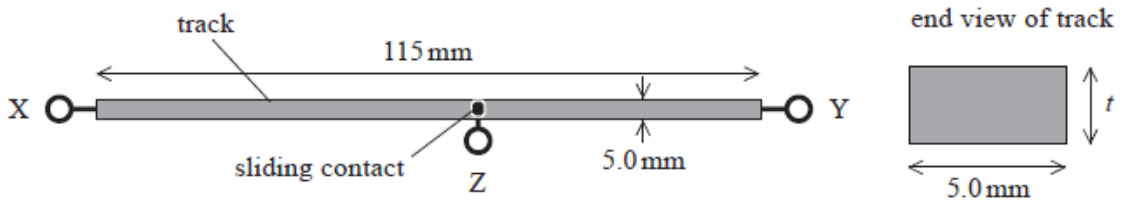
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R = ...

(Total for question = 8 marks)

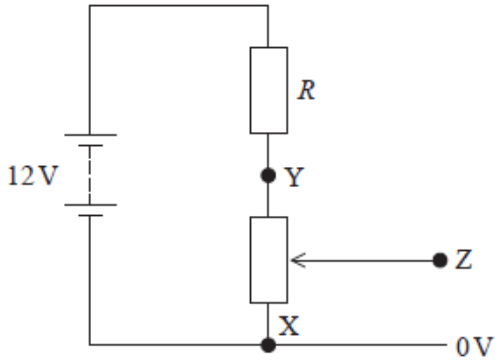
Q1.

A potential divider circuit may contain a component known as a potentiometer. One type of potentiometer consists of a track with terminals X and Y at either end. There is a sliding contact that can move along the track connected to a terminal Z as shown.



The length of the track is 115 mm and the width is 5.0 mm.

The potentiometer is used to monitor the displacement of a moving tool on a machine in a production line. The tool is attached to the sliding contact. The potentiometer is connected to a resistor of resistance *R* and a potential difference is applied as shown. The tool moves through a maximum displacement of 60 mm from end X, producing a maximum potential difference of 5.0 V between Z and X.



(i) Show that the potential difference between X and Y is about 10 V.

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(ii) Calculate the value of *R*.

(3)

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R = ...

(iii) When the circuit is assembled, using the correctly calculated resistance value and a battery of e.m.f. 12 V, it is found that the maximum output from the potentiometer is slightly less than 5.0 V.

Explain why the maximum output is slightly less than predicted.

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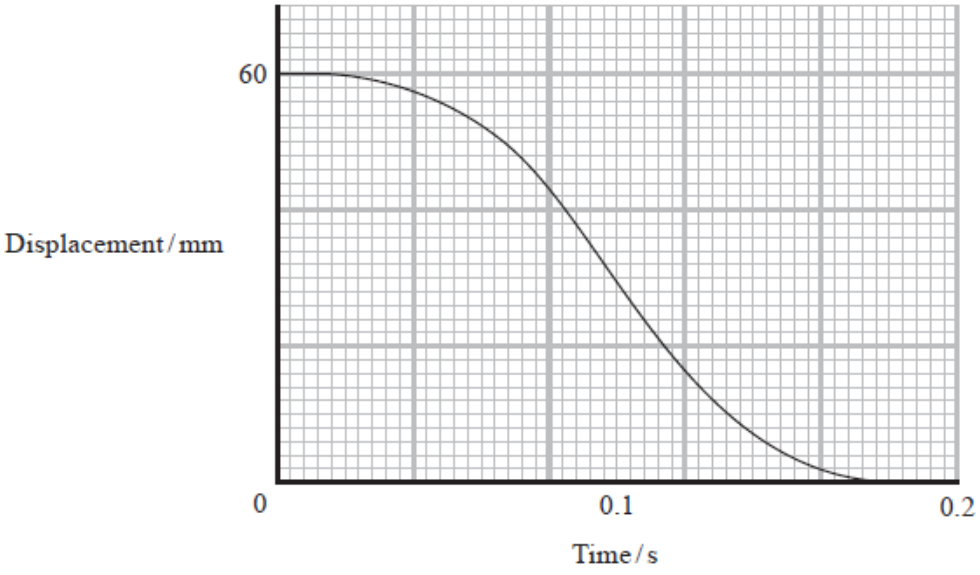
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(iv) The tool on the machine should not travel with a speed any larger than 0.8 m s^{-1} .

The graph shows how the displacement varies with time for the downward stroke of the moving tool.



Deduce whether this speed is exceeded by the moving tool.

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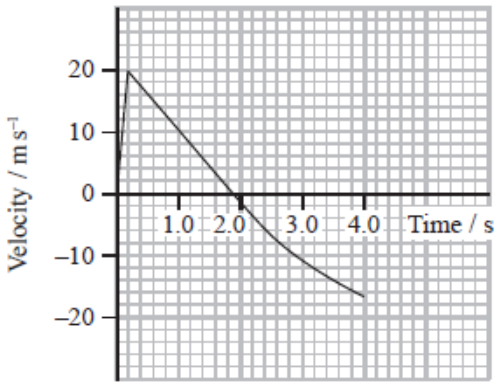
(Total for question = 12 marks)

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.

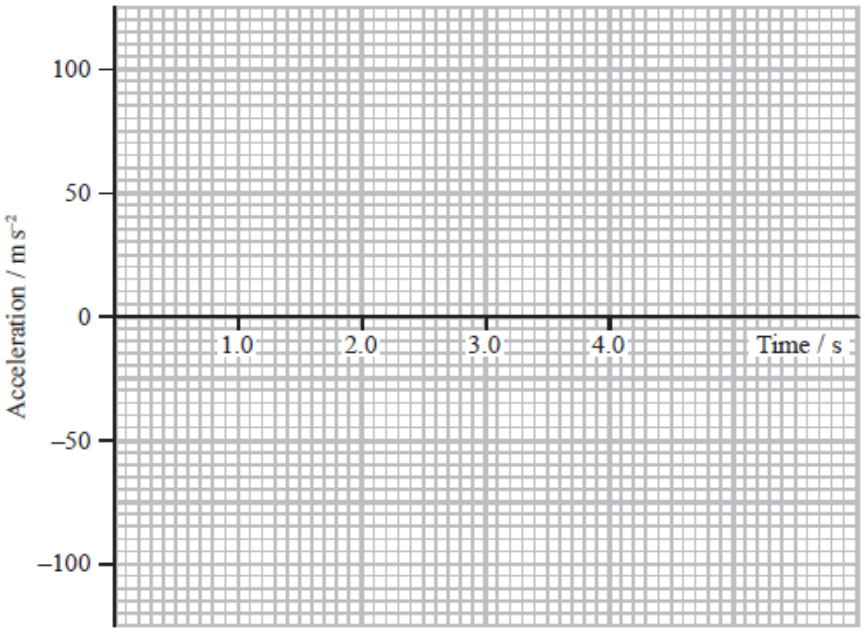


A velocity-time graph for the bottle for the first 4 s after take-off is shown.



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

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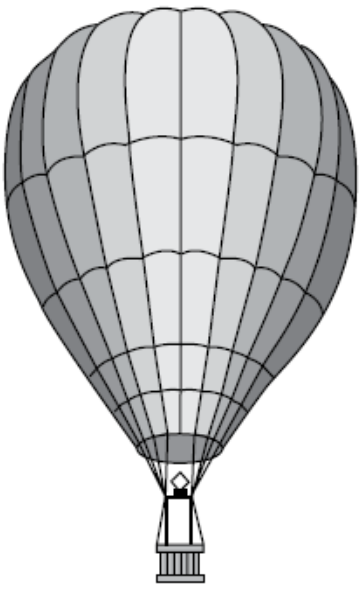


(Total for question = 5 marks)

Q3.

Newton's laws relate the changes in motion of an object to the forces acting on the object.

A hot-air balloon is made of an envelope, containing hot air, with a wicker basket suspended from it. The balloon rises upwards because the heated air in the envelope is less dense than the surrounding air.



The total volume of the hot-air balloon is 2880 m^3. The total mass of the hot-air balloon, including the envelope, is 3400 kg. The density of the surrounding air is 1.20 kg m^{-3}.

Calculate the initial upward acceleration of the balloon.

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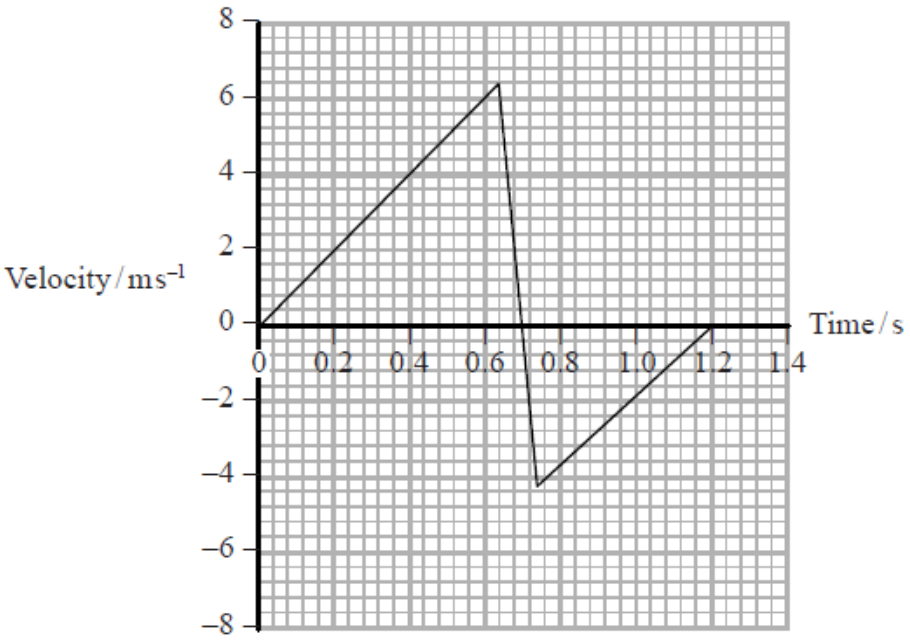
Initial acceleration = ...

(Total for question = 4 marks)

Q4.

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)

Q5.

Photograph 1 shows a toy known as a popper. It is a hollow hemisphere made of rubber.



Photograph 1

When the top of the popper is pushed down, it changes shape as in Photograph 2.



Photograph 2

It remains in this shape for two to three seconds. It then returns to its original shape and is launched from the surface, rising nearly a metre.

The initial speed of the popper can be determined using only a metre rule to measure the maximum height reached by the popper.

(i) Describe how the maximum height measurement can be used to determine the launch

speed.

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(ii) Comment on using the maximum height measurement as a means of determining an accurate value for the launch speed.

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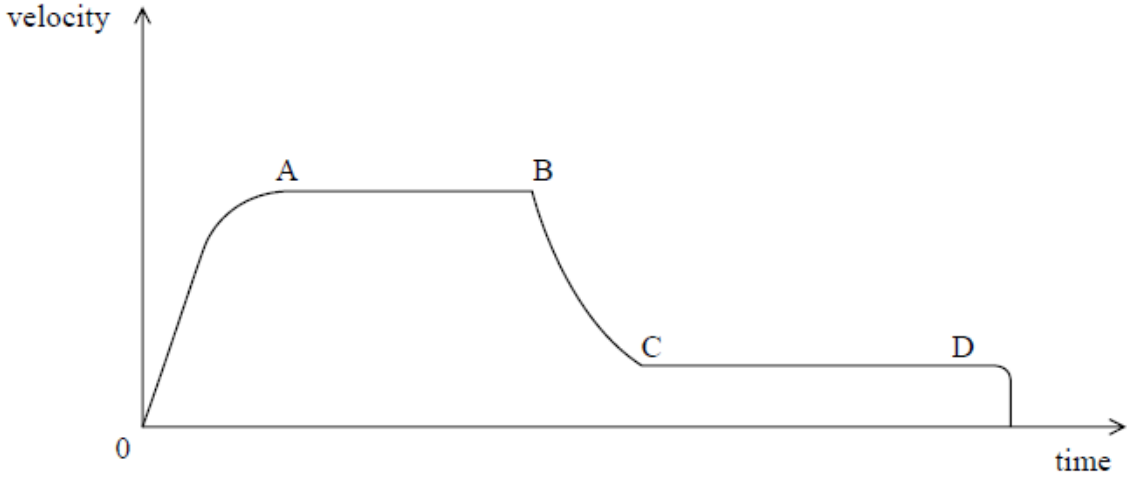
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(Total for question = 6 marks)

Q6.

* The graph shows the velocity of a skydiver from the moment that she begins her freefall jump, until she lands on the ground.



Explain, in terms of the force acting, the shape of the graph from the point when the parachute opens until point D.

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(Total for question = 6 marks)

Q7.

The photograph shows a cyclist cycling at a constant velocity on horizontal ground.



The cyclist stops pedalling and comes to rest in a time of 5.2 s.

(i) Sketch a graph to show how the cyclist's velocity changes during this time.

Assume the deceleration is constant.

(2)



(ii) The cyclist travels 7.80 m while coming to rest.

Calculate the average resistive force on the cyclist and bicycle.

mass of cyclist and bicycle = 28.0 kg

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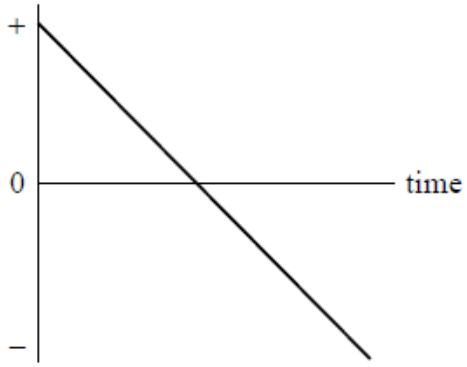
Average resistive force = ...

(Total for question = 6 marks)

Q8.

A ball is thrown upwards, allowed to fall and is caught.

The graph represents its motion.



What quantity is plotted on the *y*-axis?

☒ **A** acceleration

☒ **B** displacement

☒ **C** momentum

☒ **D** velocity

(Total for question = 1 mark)

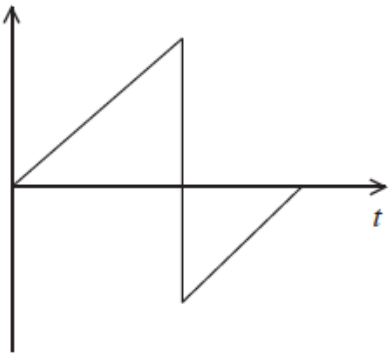
Q9.

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 ☒.

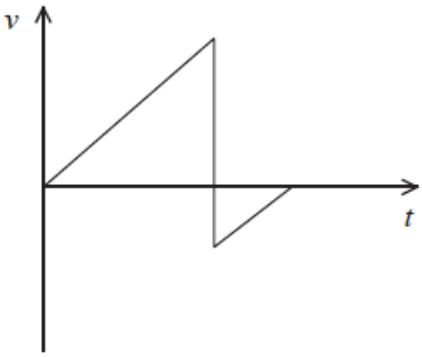
A ball was dropped from rest, from a height above the ground. The ball bounced back up to about half its initial height.

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

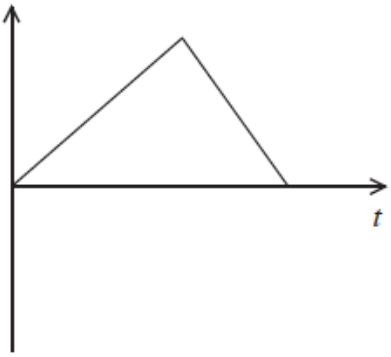
A



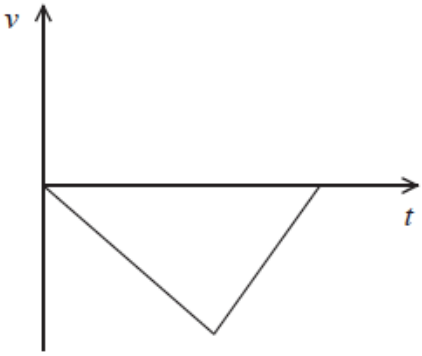
B



C



D



☒ **A**

☒ **B**

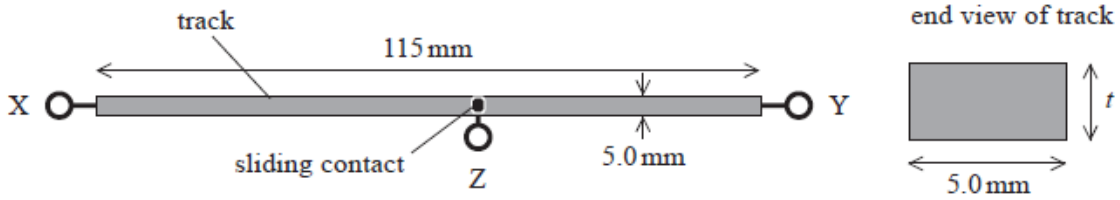
☒ **C**

☒ **D**

(Total for question = 1 mark)

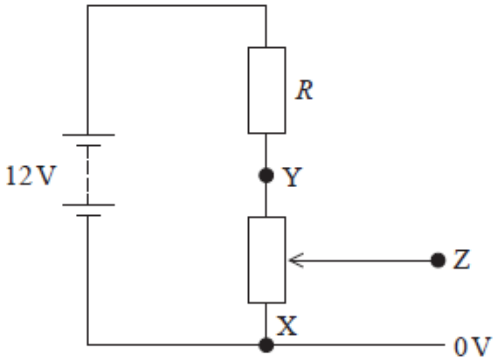
Q1.

A potential divider circuit may contain a component known as a potentiometer. One type of potentiometer consists of a track with terminals X and Y at either end. There is a sliding contact that can move along the track connected to a terminal Z as shown.



The length of the track is 115 mm and the width is 5.0 mm.

The potentiometer is used to monitor the displacement of a moving tool on a machine in a production line. The tool is attached to the sliding contact. The potentiometer is connected to a resistor of resistance *R* and a potential difference is applied as shown. The tool moves through a maximum displacement of 60 mm from end X, producing a maximum potential difference of 5.0 V between Z and X.



(i) Show that the potential difference between X and Y is about 10 V.

(2)

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(ii) Calculate the value of *R*.

(3)

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R = ...

(iii) When the circuit is assembled, using the correctly calculated resistance value and a battery of e.m.f. 12 V, it is found that the maximum output from the potentiometer is slightly less than 5.0 V.

Explain why the maximum output is slightly less than predicted.

(3)

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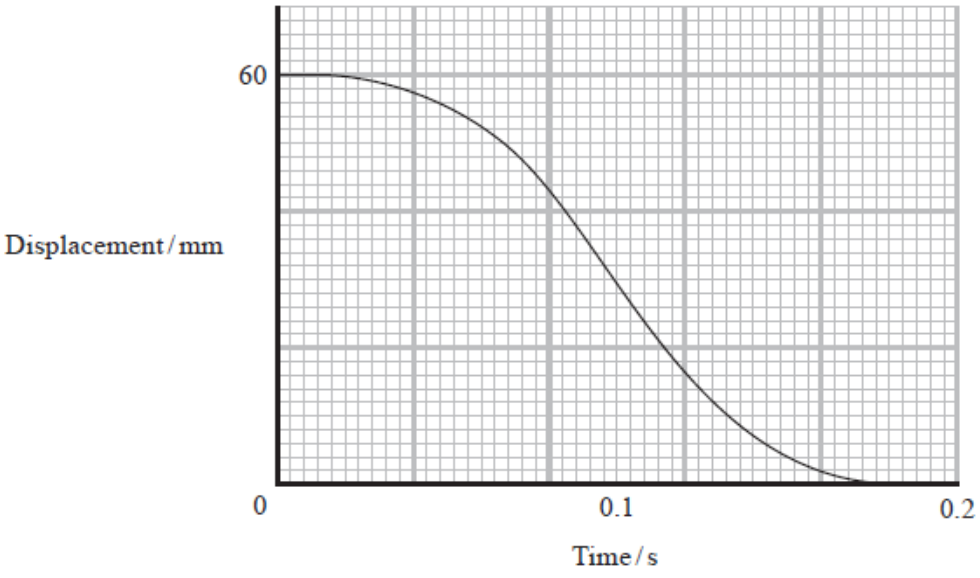
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(iv) The tool on the machine should not travel with a speed any larger than 0.8 m s^{-1} .

The graph shows how the displacement varies with time for the downward stroke of the moving tool.



Deduce whether this speed is exceeded by the moving tool.

(4)

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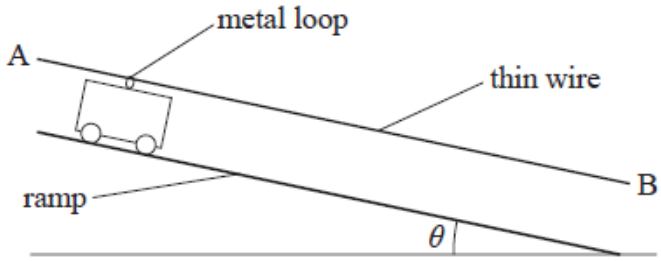
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(Total for question = 12 marks)

Q2.

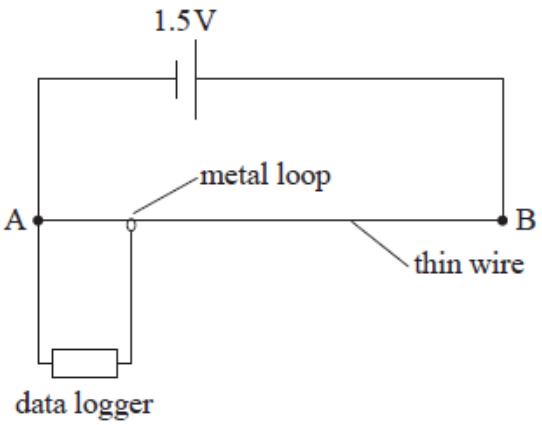
A student investigates the motion of a friction-free trolley down a ramp. On the top of the trolley there is a metal loop which makes contact with a length of thin resistance wire, AB, fixed above the ramp. The resistance wire has a uniform diameter.

The trolley accelerates down the ramp and the metal loop stays in contact with the wire along the full length of the ramp.



The student uses a protractor to measure the angle θ between the ramp and the horizontal and records a value of 4° with an uncertainty of ±1°.

(a) The two ends of the wire are connected to a 1.5 V cell. A data logger, set to measure potential difference, is connected to the metal loop and to the negative terminal of the cell.



Explain how the potential difference recorded by the data logger will vary as the loop moves along the length of the
wire AB.

(3)

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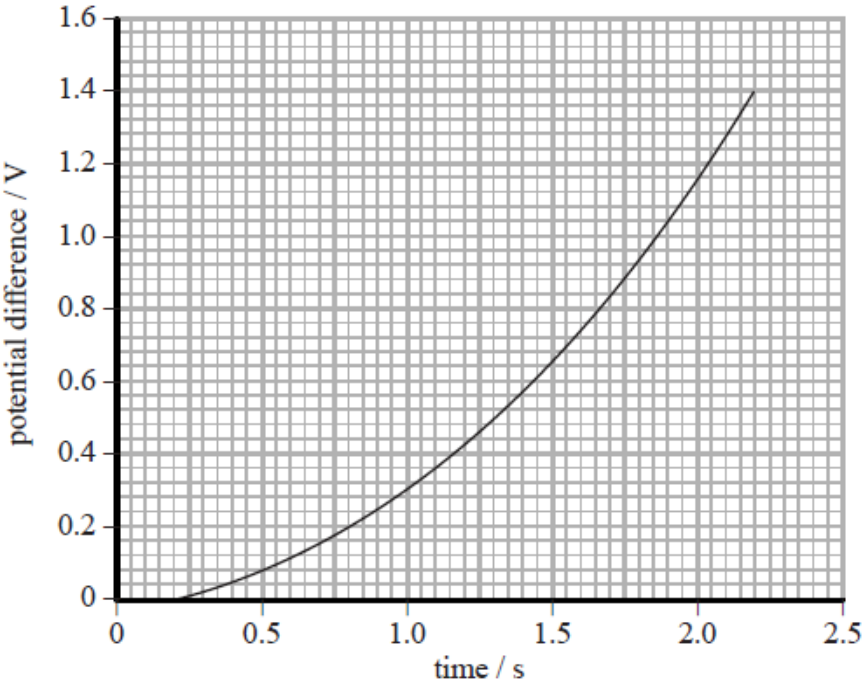
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(b) The graph shows the data obtained from the data logger.



Determine the velocity of the trolley at 1.5 s.

1.5 V represents a distance of 2.00 m.

(4)

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Velocity = ...

(c) The student calculated the velocity of the trolley at 2.0 s to be 1.5 m s^{-1}.

By considering the acceleration of the trolley, determine whether the student's measurement of θ was within the uncertainty quoted.

(4)

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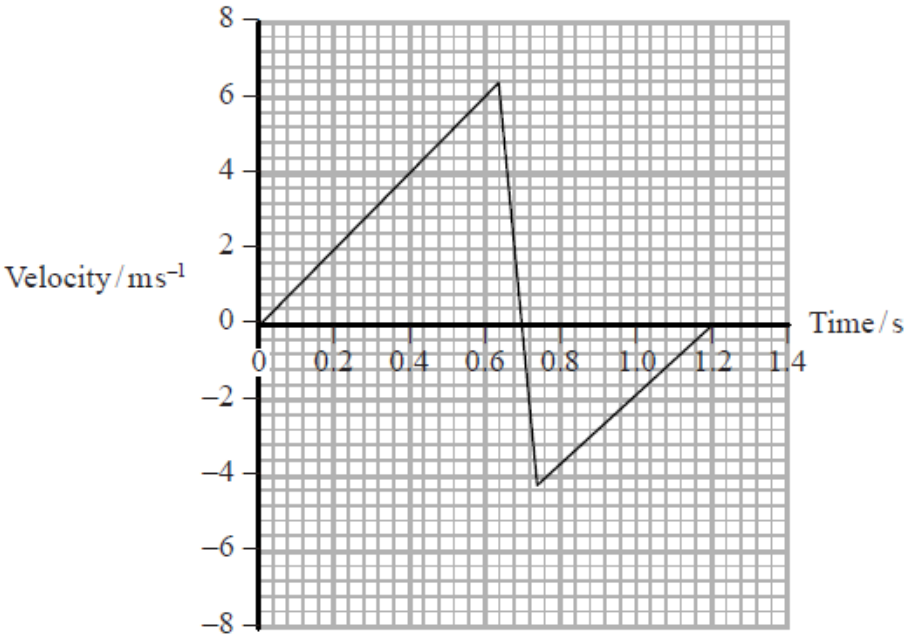
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(Total for question = 11 marks)

Q3.

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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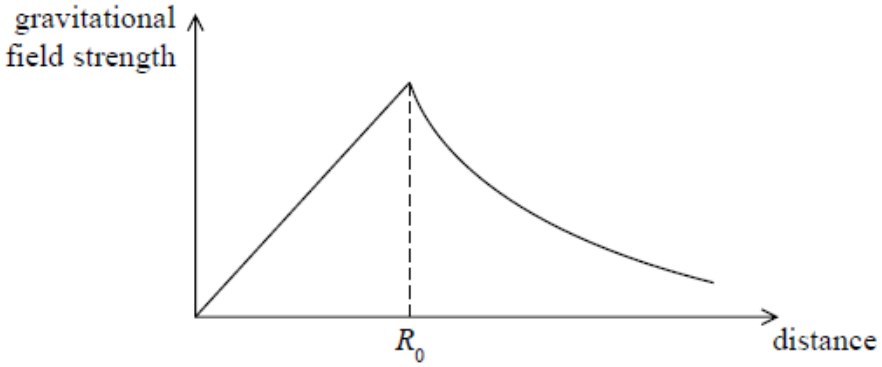
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(Total for question = 10 marks)

Q4.

The graph shows the variation of the gravitational field strength with distance from the centre of the Earth. R_0 is the radius of the Earth.



Describe how gravitational field strength varies with distance from the centre of the Earth

- for distances between 0 and R_0
- for distances greater than R_0

(3)

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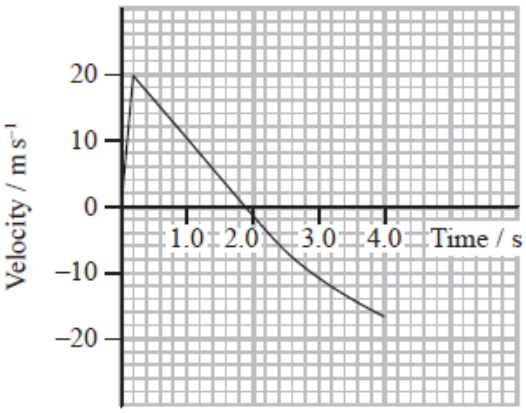
(Total for question = 3 marks)

Q5.

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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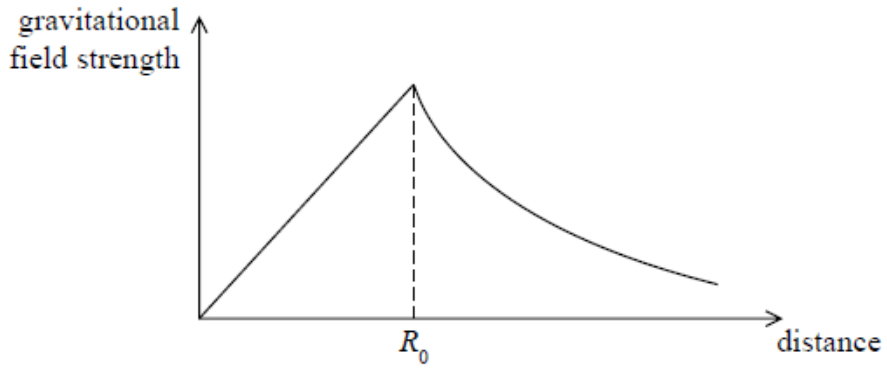
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Height = ...

(Total for question = 2 marks)

Q6.

The graph shows the variation of the gravitational field strength with distance from the centre of the Earth. R_0 is the radius of the Earth.



A scientist suggests the following:

"If a tunnel were made through the centre of the Earth, an object dropped at one end would accelerate downwards until it reached the centre. It would then decrease in speed until it reached the other end of the tunnel with a speed of zero. The object would then return the other way, undergoing simple harmonic motion."

Using the graph between 0 and R_0, determine whether simple harmonic motion would occur.

(4)

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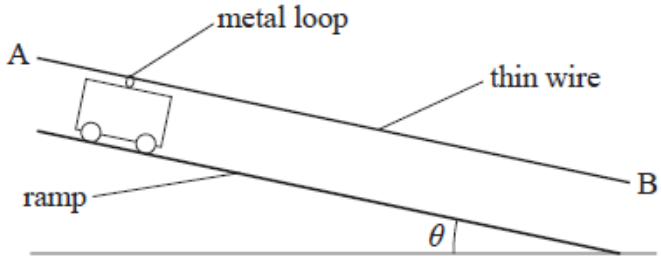
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(Total for question = 4 marks)

Q1.

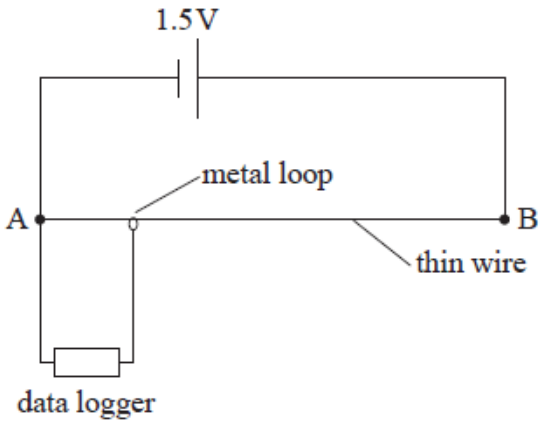
A student investigates the motion of a friction-free trolley down a ramp. On the top of the trolley there is a metal loop which makes contact with a length of thin resistance wire, AB, fixed above the ramp. The resistance wire has a uniform diameter.

The trolley accelerates down the ramp and the metal loop stays in contact with the wire along the full length of the ramp.



The student uses a protractor to measure the angle θ between the ramp and the horizontal and records a value of 4° with an uncertainty of ±1°.

(a) The two ends of the wire are connected to a 1.5 V cell. A data logger, set to measure potential difference, is connected to the metal loop and to the negative terminal of the cell.



Explain how the potential difference recorded by the data logger will vary as the loop moves along the length of the
wire AB.

(3)

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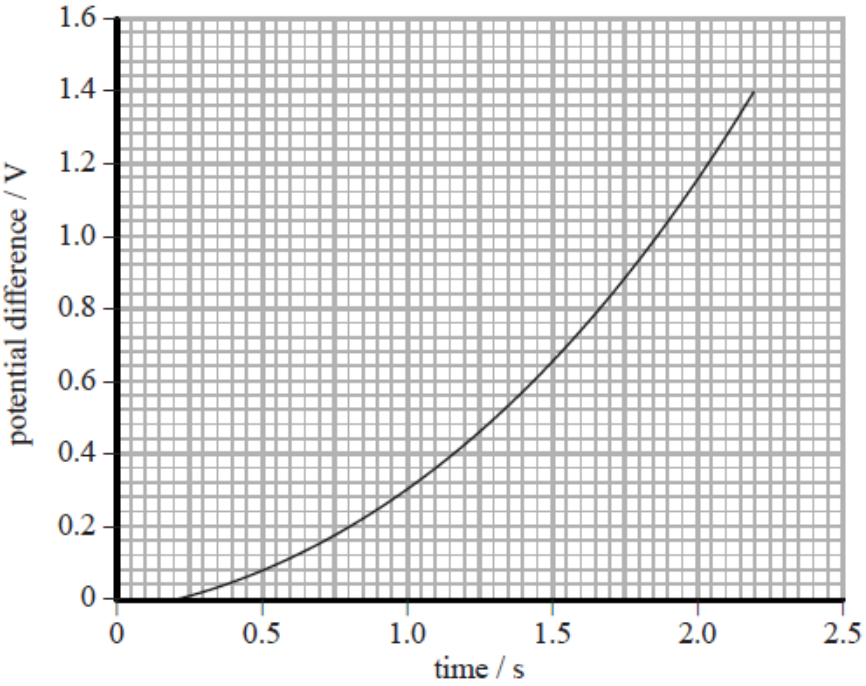
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(b) The graph shows the data obtained from the data logger.



Determine the velocity of the trolley at 1.5 s.

1.5 V represents a distance of 2.00 m.

(4)

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Velocity = ...

(c) The student calculated the velocity of the trolley at 2.0 s to be 1.5 m s^{-1}.

By considering the acceleration of the trolley, determine whether the student's measurement of θ was within the uncertainty quoted.

(4)

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(Total for question = 11 marks)

Q2.

The Starflyer is a fairground ride which operates 60 m above the ground. As it begins to spin, the chairs in which the riders sit move outwards.



Consider the chair and rider as a single object. By drawing a free-body force diagram and considering the forces acting, explain the following observations.

The angle to the vertical of the supporting ropes depends on the speed of rotation, but does not depend on the mass of the rider.

(5)

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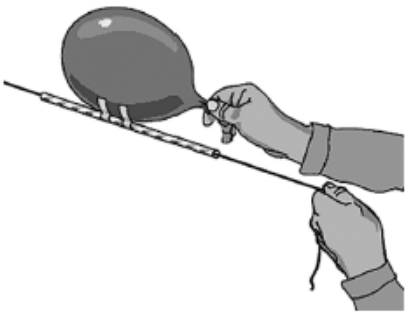
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(Total for question = 5 marks)

Q3.

A length of string is threaded through a drinking straw. The string is fixed at one end and held at the other so that it is at 30° to the horizontal. A balloon is inflated and attached to the straw. When the balloon is released, the air escapes from the balloon and the balloon and straw start to move up the string.



Calculate the minimum force on the balloon due to the escaping air if the balloon is to move in this way.

mass of straw and balloon = 11 g

(3)

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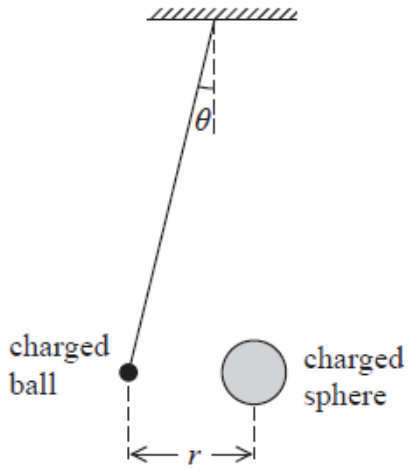
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Minimum force = ...

Q4.

A student carries out an experiment to investigate the force acting between two charged objects. A lightweight negatively-charged ball is freely suspended from the ceiling by an insulating thread. The ball is repelled by a negatively-charged sphere that is placed near it on an insulated support.
The angle of deflection is θ and r is the distance between the centres of the ball and the sphere.



(a) (i) Draw a free-body force diagram for the suspended ball.

(2)

(ii) The weight of the suspended ball is W.

Show that the force of repulsion F on the suspended ball is given by

$F = W \tan \theta$

(2)

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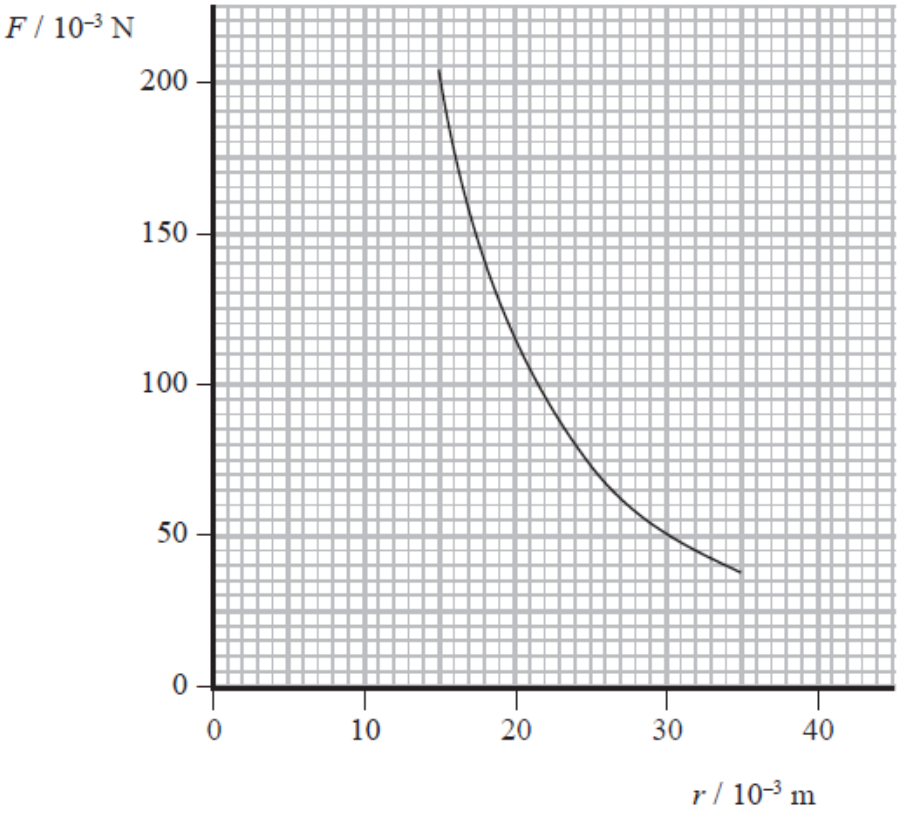
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(b) (i) The student can increase the magnitude of the force by moving the sphere towards the suspended ball.
She takes pairs of measurements of r and θ and calculates the magnitude of the force F. She then plots a graph of F against r.



Use readings from the graph to demonstrate that the relationship between F and r obeys an inverse square law.

(4)

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(ii) The charge on the sphere is 100 times greater than the charge on the ball.

Calculate the charge on the ball.

(3)

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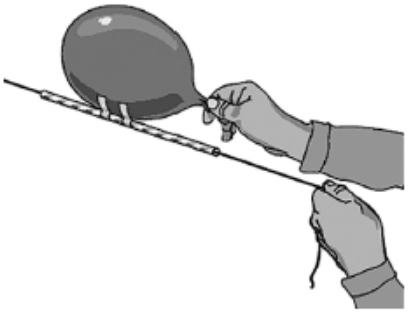
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Charge = ...

(Total for question = 11 marks)

Q5.

A length of string is threaded through a drinking straw. The string is fixed at one end and held at the other so that it is at 30° to the horizontal. A balloon is inflated and attached to the straw. When the balloon is released, the air escapes from the balloon and the balloon and straw start to move up the string.



With reference to Newton's laws of motion, explain why the balloon starts to move.

(3)

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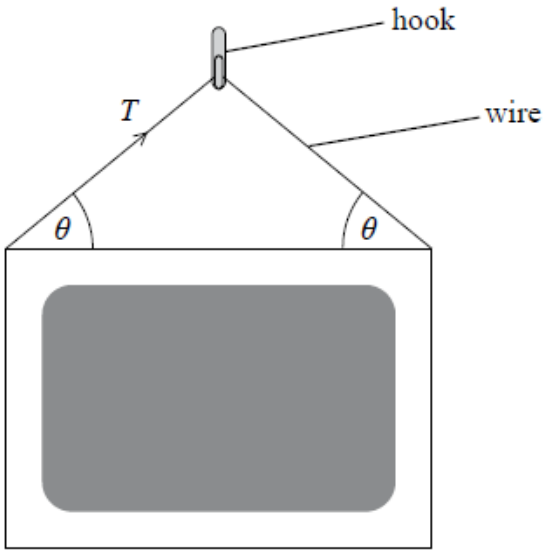
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Q6.

A picture with mass m hangs from a hook by a single length of wire. The hook is at the midpoint of the wire.



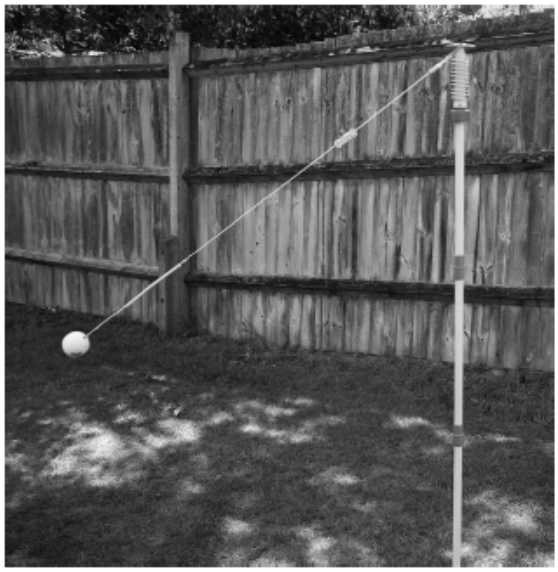
The tension T in the wire is given by

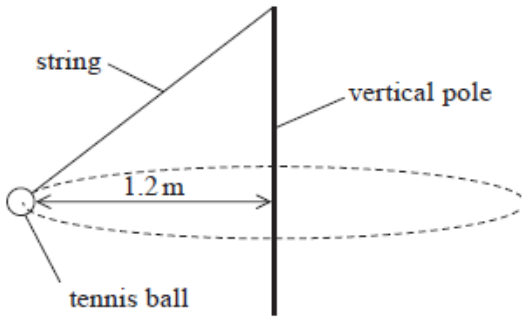
- ☐ **A** $\frac{mg}{2\sin\theta}$
- ☐ **B** $\frac{mg}{2\cos\theta}$
- ☐ **C** $\frac{mg}{\sin\theta}$
- ☐ **D** $\frac{mg}{\cos\theta}$

(Total for question = 1 mark)

Q7.

A 'tennis trainer' consists of a tennis ball suspended by a string from the top of a vertical pole. When the ball is hit it travels in a horizontal circle around the pole, as shown in both the photograph and the diagram.





The radius of the path of the ball is 1.2 m and the speed of the ball is 3.8 m s^{-1}.

Deduce whether these values are consistent with the angle between the string and the vertical pole shown in the photograph.

(5)

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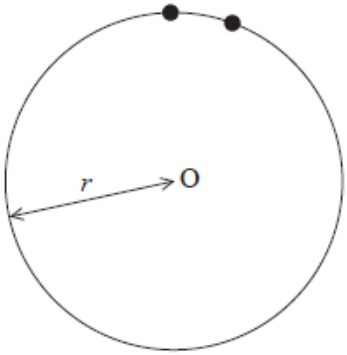
(Total for question = 5 marks)

Q8.

A centrifuge is a machine which rotates.

A particle in a centrifuge moves in a circle of radius *r*, centre O, with a constant speed *v*.

The diagram represents two positions of the particle.



Derive the equation for centripetal acceleration $a = \frac{v^2}{r}$ by considering the velocity at these two positions.

Your answer should include a vector diagram.

(5)

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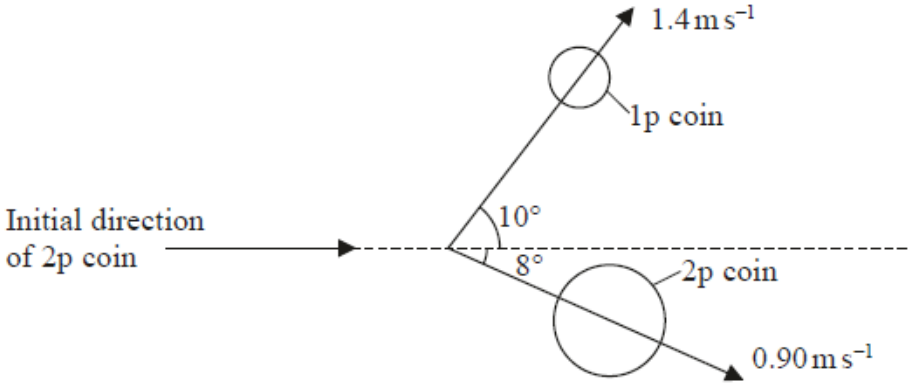
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(Total for question = 5 marks)

Q9.

A student carried out an experiment with coins.

She arranged a collision between a 2p coin and a stationary 1p coin. She noted the directions in which the coins moved after the collision and determined their velocities.



(i) Show that the velocity of the 2p coin just before the collision was about 2 m s^{-1}.

mass of 2p coin = 7.1 g

mass of 1p coin = 3.6 g

(4)

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(ii) Show that the collision was inelastic.

(2)

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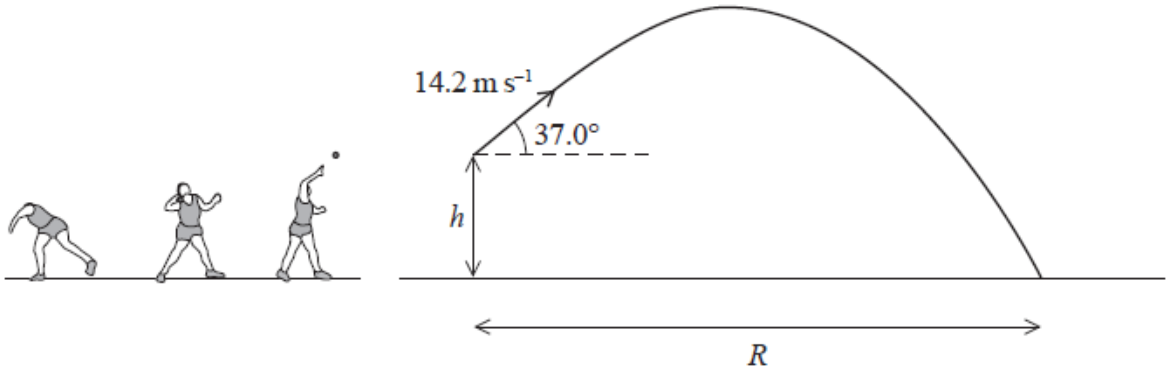
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(Total for question = 6 marks)

Q10.

The shot put is an Olympic field event. The distance for the women's world record shot put is in excess of twenty two metres.

The shot is a metal ball, which is thrown from a standing position so that it lands on the ground a horizontal distance *R* away from the thrower.



A shot is thrown from a height *h* above the ground with an initial velocity of 14.2 m s^{-1} at an angle of 37.0° to the horizontal. The time it takes for the shot to reach the ground is 1.98 *s*.

(a) Show that the vertical component of the initial velocity is about 8.6 m s^{-1}.

(2)

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(b) Calculate the height *h* above the ground from which the shot was thrown.

(3)

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h = ...

(c) Calculate the horizontal distance R for this throw.

(3)

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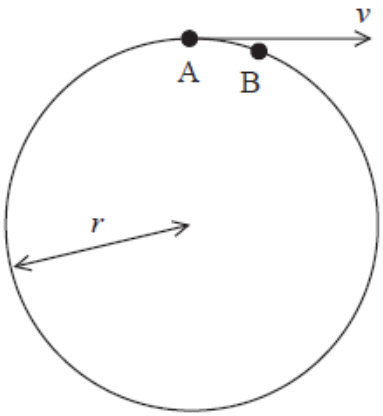
R = ...

(Total for question = 8 marks)

Q1.

The International Space Station (ISS) orbits the Earth with a constant speed *v*. The orbit is circular and of radius *r*.

The diagram represents two positions, A and B, of ISS during its orbit.



Draw a labelled vector diagram, in the space below, of the velocities at the two positions that shows the acceleration is directed towards the centre of the orbit.

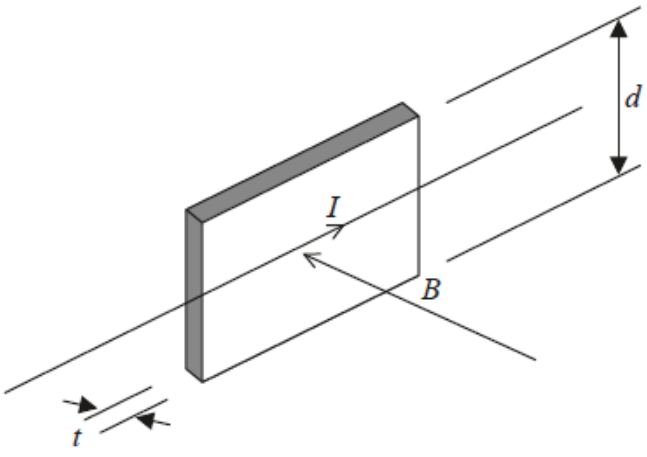
(2)

(Total for question = 2 marks)

Q2.

Tiny sensors in smartphones could be used to determine the position of the phone on the Earth's surface by measuring the Earth's magnetic flux density.

A current *I* and a magnetic field of flux density *B* are applied to a slice of semiconductor as shown. The slice has thickness *t* and depth *d*.



Electrons collect at the top edge of the slice and the bottom edge becomes positively charged.

As a result a potential difference known as a Hall voltage V_{HALL} develops.

Two sensors in the smartphone were used to determine the horizontal component B_H and the vertical component B_V of the Earth's magnetic flux density.

Calculate the angle of the Earth's magnetic field to the horizontal.

B_H = 19.0 μT

B_V = 49.0 μT

(2)

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Angle = ...

(Total for question = 2 marks)

Q3.

Scientists have been studying a type of jumping spider that can jump up to six times its body length.

The scientists photographed a spider at 0.02 s intervals, during a jump. The picture is taken from the photograph and is shown actual size.



(i) Deduce whether the images show that the motion in the *x*-direction is independent of the motion in the *y*-direction. You should take measurements using the cross marking the centre of gravity of the spider.

(4)

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(ii) Show that the initial velocity of the spider at the start of the jump is about 1 m s^{-1}. You should take measurements using the cross marking the centre of gravity of the spider.

(5)

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(iii) The spider achieves this jump by extending its two back legs by 3.0 mm.

Calculate the average force the spider exerts in each leg to achieve the jump.

mass of spider = 150 mg

(3)

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Average force = ...

(Total for question = 12 marks)

Q4.

A simple model of the hydrogen atom consists of an electron moving in a circular path around a proton.

(i) In this simple model it is the electrostatic force, rather than the gravitational force, that is responsible for keeping the electron in a circular path.

By means of calculations justify this statement.

radius r of the hydrogen atom = 5.3×10^{-11} m

(4)

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(ii) Ignoring the gravitational force, calculate the velocity of the electron in this simple model of the hydrogen atom.

(3)

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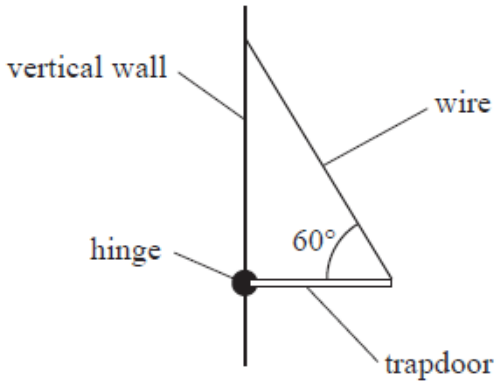
Velocity = ...

(Total for question = 7 marks)

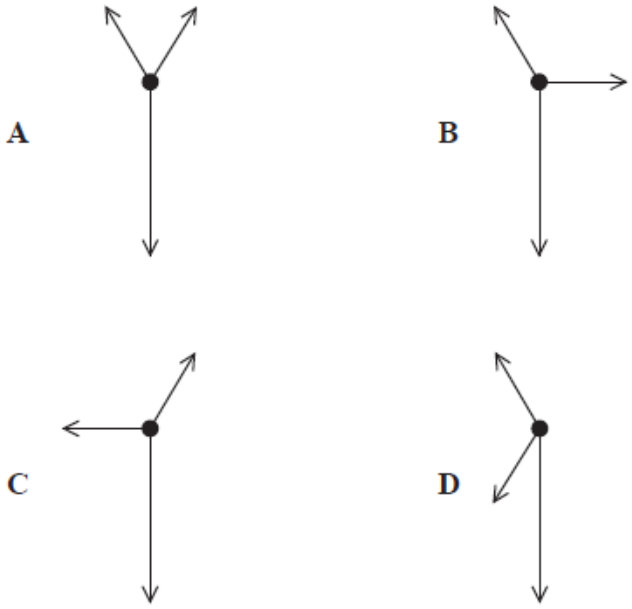
Q5.

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 ☒.

A trapdoor is fixed to a vertical wall with a hinge. A wire is attached to the other end of the trapdoor and inclined at an angle of 60°, as shown. The wire holds the trapdoor horizontal.



Which of the following shows the free-body force diagram for the trapdoor?



☒ **A**

☒ **B**

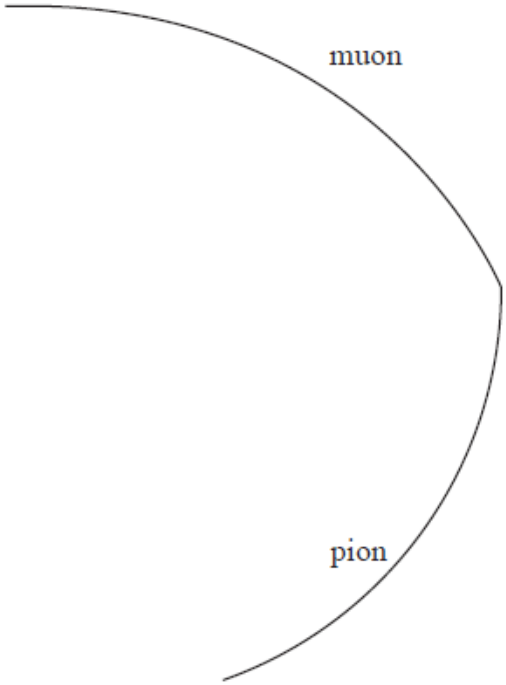
☒ **C**

☒ **D**

(Total for question = 1 mark)

Q6.

A negatively charged pion decays into a muon and an antineutrino. The diagram shows tracks in a particle detector formed in such an event.



Use a vector diagram to determine the momentum of the antineutrino.

The initial momentum of the muon is 1.59×10^{-19} N s.

(5)

Momentum of antineutrino = ...

Direction of antineutrino = ...

(Total for question = 5 marks)

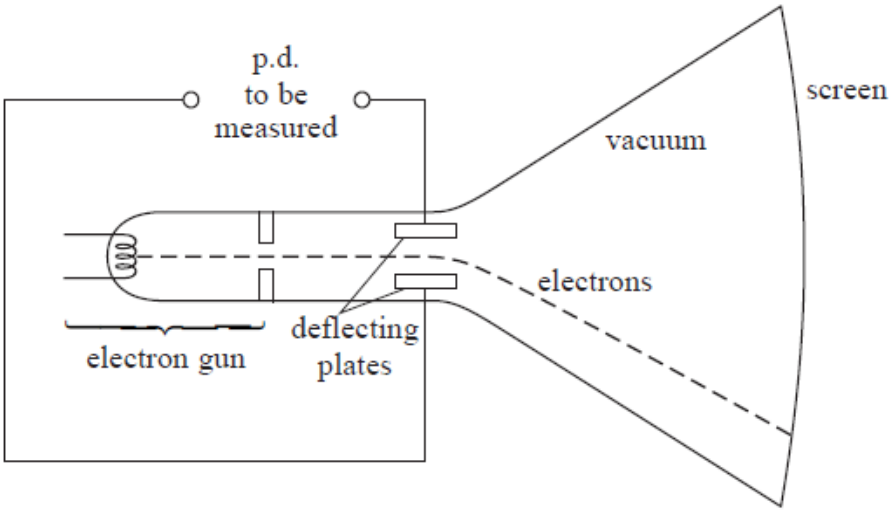
Q1.

Cathode ray tubes are used in oscilloscopes.



The diagram shows a simplified cathode ray tube that can be used to determine the magnitude and polarity of a potential difference (p.d.).

The cathode ray tube consists of an electron gun, a pair of deflecting plates and a fluorescent screen.



(a) The electron gun includes a filament. When this filament is heated, electrons are released and are accelerated by a p.d. of 1.5 kV to form an electron beam.

(i) Name the process by which electrons are released from the heated filament.

(1)

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(ii) Show that the maximum velocity of the electrons is about 2×10^7 m s^{-1}.

(2)

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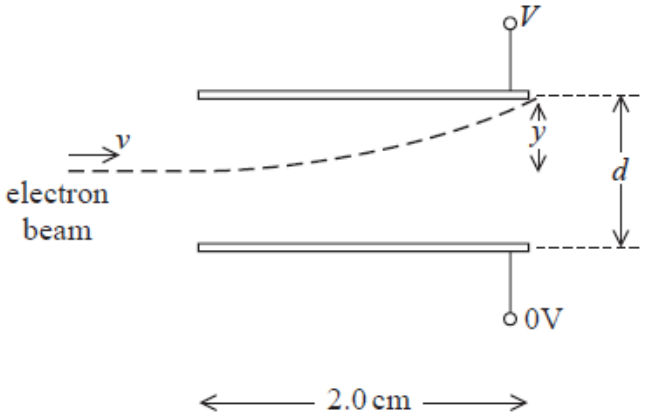
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(b) The electron beam then enters a uniform electric field between the two parallel horizontal deflecting plates. The magnitude and direction of the deflection is determined by the p.d. *V* that

is applied across the plates.

The diagram shows one possible path of the electron beam as it passes between the plates.



(i) Show that the acceleration of an electron, of mass m and charge Q, is given by

$$\frac{VQ}{dm}$$

(2)

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(ii) Calculate the magnitude of the vertical deflection y of the beam as it leaves the plates.

$V = 50$ V
$d = 0.01$ m

(5)

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y = ...

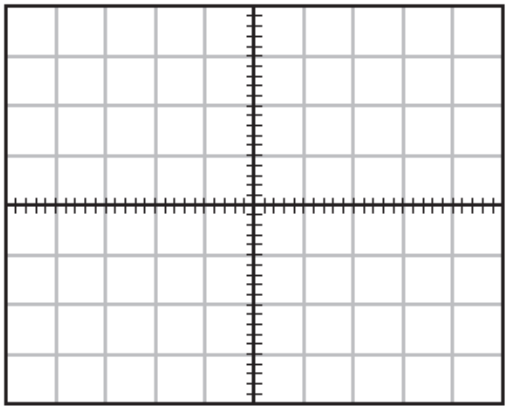
(c) A laboratory oscilloscope with the time base turned off operates in the same way as this simplified cathode ray tube. A student uses an oscilloscope in this way to monitor an alternating p.d. of 53 V_{rms}

On the grid, draw the trace that would be seen on the screen.

(4)

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1 square = 25 V

(Total for question = 14 marks)

Q2.

Scientists have been studying a type of jumping spider that can jump up to six times its body length.

The scientists photographed a spider at 0.02 s intervals, during a jump. The picture is taken from the photograph and is shown actual size.



(i) Deduce whether the images show that the motion in the *x*-direction is independent of the motion in the *y*-direction. You should take measurements using the cross marking the centre of gravity of the spider.

(4)

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(ii) Show that the initial velocity of the spider at the start of the jump is about $1\,m\,s^{-1}$. You should take measurements using the cross marking the centre of gravity of the spider.

(5)

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(iii) The spider achieves this jump by extending its two back legs by 3.0 mm.

Calculate the average force the spider exerts in each leg to achieve the jump.

mass of spider = 150 mg

(3)

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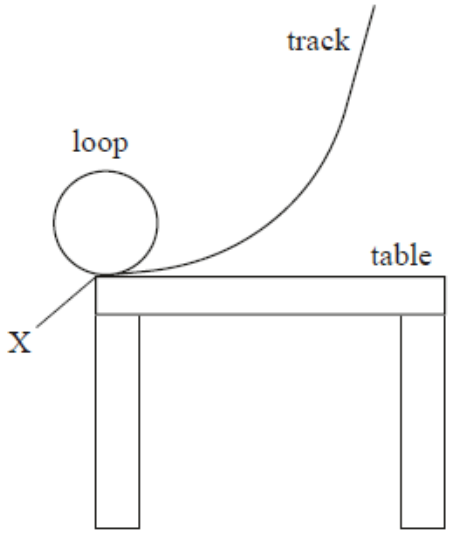
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Average force = ...

(Total for question = 12 marks)

Q3.

A track for toy cars can be built with a circular loop as shown.



A toy car is placed on the track at various heights. It travels around the loop before leaving the track horizontally at X.

The toy car leaves the track at X with a horizontal velocity of 3.0 m s^{-1}.

X is 0.65 m above the floor.

Calculate the horizontal displacement of the car from X when it hits the floor.

(4)

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Horizontal displacement = ...

(Total for question = 4 marks)

Q4.

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 ☒.

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)

Q5.

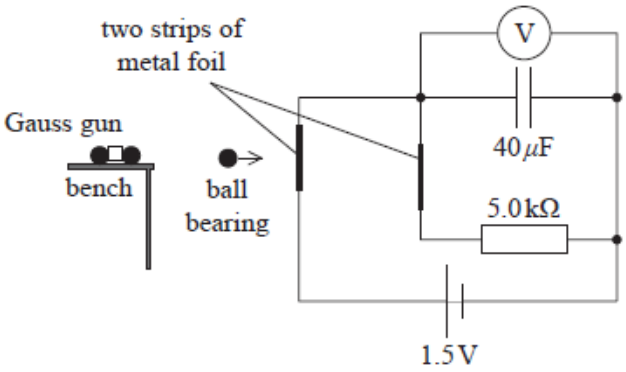
A 'Gauss gun' can be made from five ball bearings of equal mass and two magnets, as shown.



Pairs of ball bearings are placed to the right of two strong magnets. A single ball bearing is released from the left, as shown. The ball bearing is attracted to, and collides with, the first

magnet. This and all subsequent collisions can be assumed to be elastic.

A student set up the apparatus shown to measure the speed of the last ball bearing. The 'Gauss gun' was placed at the end of a bench, so that the ball bearing left the gun and broke two strips of metal foil which formed part of an electric circuit.



As the ball bearing left the gun, it broke the first foil strip at its centre so that the capacitor started to discharge. When the ball bearing broke the second foil strip the capacitor discharge stopped.

(i) Calculate the energy stored in the capacitor when it was fully charged.

(2)

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Energy stored = ...

(ii) The voltmeter reading halved in the time taken for the ball bearing to travel between the two foil strips.

Show that the time taken for the ball bearing to travel between the two foil strips was about 0.1 s.

(2)

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(iii) The two foil strips were 0.50 m apart.

Calculate the horizontal velocity of the ball bearing.

(2)

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Horizontal velocity = ...

(iv) The student positioned the second foil strip with its centre 8.0 cm lower than the centre of the first foil strip.

Deduce whether the ball bearing broke the second foil strip at its centre.

Assume the ball bearing was travelling horizontally as it broke the first foil strip.

(2)

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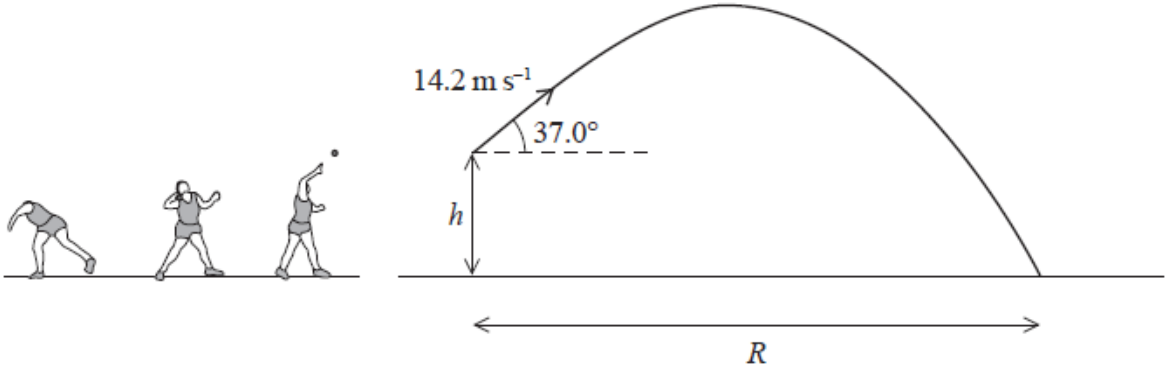
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(Total for question = 8 marks)

Q6.

The shot put is an Olympic field event. The distance for the women's world record shot put is in excess of twenty two metres.

The shot is a metal ball, which is thrown from a standing position so that it lands on the ground a horizontal distance *R* away from the thrower.



A shot is thrown from a height *h* above the ground with an initial velocity of 14.2 m s^{-1} at an angle of 37.0° to the horizontal. The time it takes for the shot to reach the ground is 1.98 *s*.

(a) Show that the vertical component of the initial velocity is about 8.6 m s^{-1}.

(2)

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(b) Calculate the height *h* above the ground from which the shot was thrown.

(3)

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h = ...

(c) Calculate the horizontal distance *R* for this throw.

(3)

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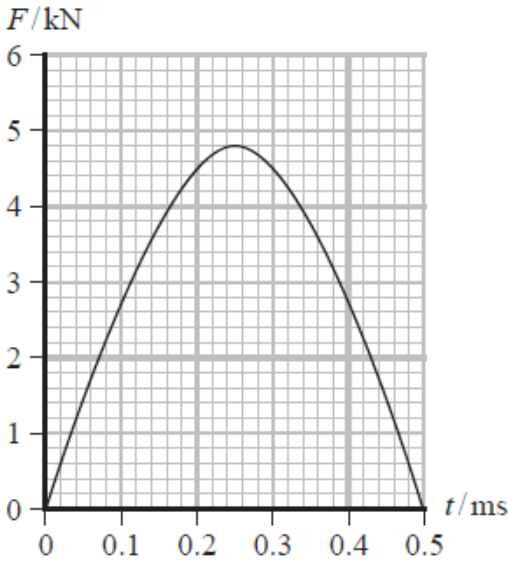
R = ...

(Total for question = 8 marks)

Q7.

In the game of golf a stationary ball is hit by a club. One of the aims of the game is to land the ball on a patch of ground called the green.

The graph shows how the force F exerted by the club on the ball varies with time t as the ball is hit.



(i) Show that the velocity of the ball is about 30 m s^{-1} immediately after it is hit by the club.

mass of ball = 0.046 kg

(3)

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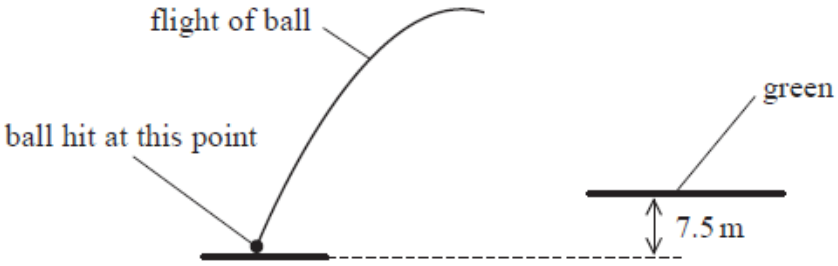
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(ii) The ball has a time of flight of 3.5 s before landing. The green is a vertical distance of 7.5 m above the point at which the ball was hit, as shown. The green is about seventy metres away from where the ball is hit.



Deduce whether, if air resistance is ignored, the ball could land on the green after a flight time of 3.5 s.

(5)

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(Total for question = 8 marks)