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EDEXCEL A LEVEL PHYSICS: QUESTIONS BY TOPIC

Further Mechanics (6)

A Level Physics Topic 6

30 questions · 218 marks · Mark schemes included

A Level only content · Pearson Edexcel 8PH0 / 9PH0 papers, 2016–2025

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HOW TO USE THIS BOOKLET

Questions are grouped by specification sub-topic and run from the lowest mark tariff to the highest within each one.

Click any row below to jump straight to that sub-topic or question.

On every question page, click ANSWER in the top-right corner to jump to its mark scheme.

Diagrams, graphs, tables and data are printed exactly as they appeared in the original papers.

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QUESTIONS

30 questions · 218 marks · 2 sub-topics



SUB-TOPIC 6.1

MOMENTUM, IMPULSE AND COLLISIONS

Sub-topic 6.1 · 15 questions · 106 marks · lowest tariff first



- 2 A trolley, mass 0.50 kg , has a speed of 2.0 m s^{-1} . A second trolley, mass 1.0 kg , has a speed of 2.0 m s^{-1} . The two trolleys are travelling in opposite directions and collide.

Which of the following could be a correct value of total momentum, in kg m s^{-1} , after the collision?

- ☐ A 0
- ☐ B 1.0
- ☐ C 2.0
- ☐ D 3.0

(Total for Question 2 = 1 mark)



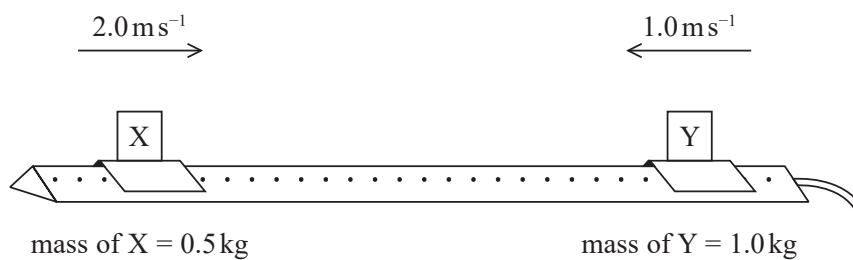
6 Which of the following are the base units for impulse?

- ☐ A kg m s^{-1}
- ☐ B kg m s^{-2}
- ☐ C Nm
- ☐ D Ns

(Total for Question 6 = 1 mark)



- 10 Two gliders, X and Y, are placed on an air track. The gliders are pushed towards each other as shown.



The gliders collide and continue to move after the collision.

Which row of the table could show the velocities of X and Y, in ms^{-1} , after the collision?

	X	Y
☐ A	-1.0	0.5
☐ B	-1.0	-0.5
☐ C	-2.0	-1.0
☐ D	-2.0	2.0

(Total for Question 10 = 1 mark)

- 2 The velocity v of a non-relativistic particle can be expressed in terms of combinations of the following quantities: kinetic energy E_k , momentum p and mass m .

Which of the following expressions is correct?

☐ A $v = \frac{p^2}{m}$

☐ B $v = \sqrt{\frac{2E_k}{m}}$

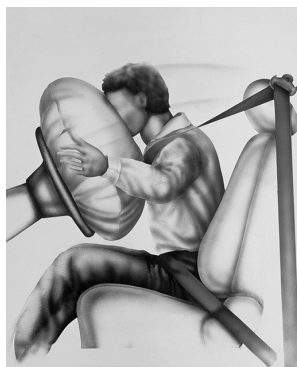
☐ C $v = \frac{E_k}{2p}$

☐ D $v = \frac{2E_k}{pm}$

(Total for Question 2 = 1 mark)



7 A car is fitted with an airbag which will inflate if the car stops very suddenly.



(Source: © KAIROS, LATIN STOCK/SCIENCE PHOTO LIBRARY)

Which of the following is increased if the airbag inflates because the car suddenly stops?

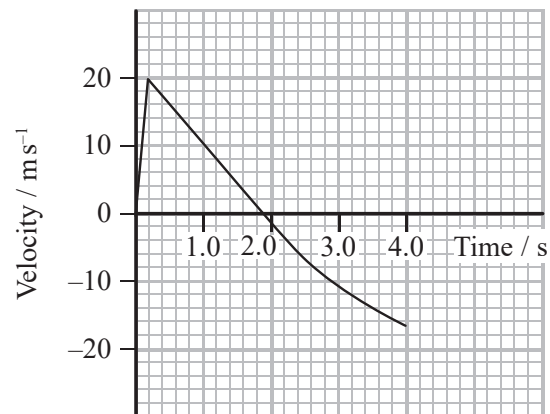
- ☐ A change in momentum of the driver
- ☐ B change in velocity of the driver
- ☐ C force on the driver
- ☐ D time that the driver takes to stop

(Total for Question 7 = 1 mark)

- 14 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.



- (a) Determine the height to which the rocket travelled.

(2)

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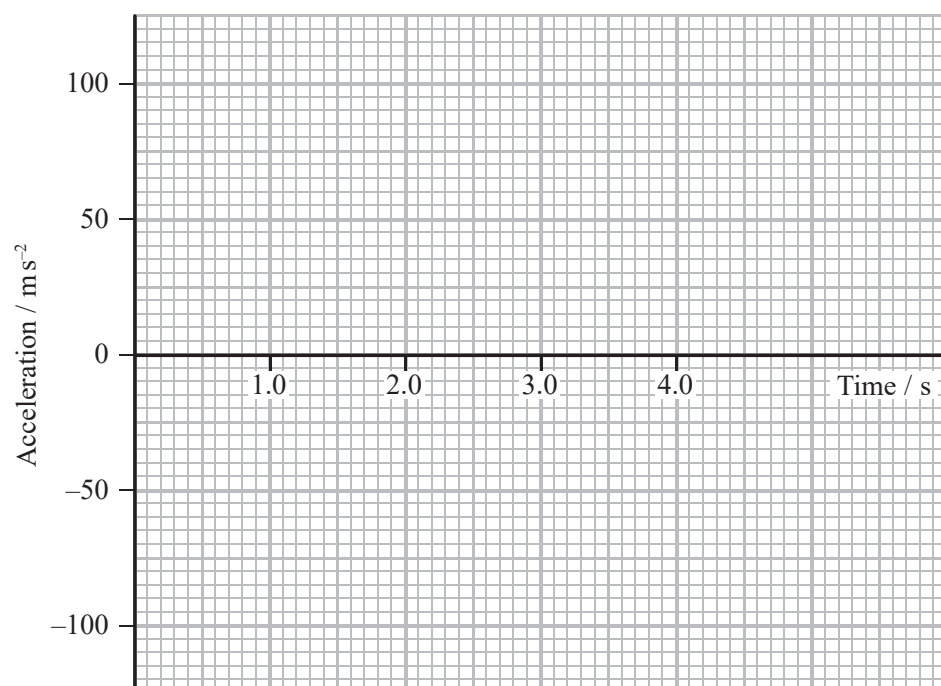
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Height = ...

(b) Sketch the corresponding acceleration-time graph on the axes below.

(5)



(Total for Question 14 = 7 marks)



- 10** Seat belts are being tested by a car manufacturer. In the test, a car moving at a steady speed of 28 m s^{-1} collides with a wall and stops.

A crash-test dummy in the driving seat is wearing a seat belt made from polyester webbing. The seat belt has a cross-sectional area of 0.85 cm^2 and a total length of 2.0 m . A student suggests that in the collision the seat belt absorbs all the kinetic energy of the dummy.

- (a) Show that the energy per unit volume that would have to be absorbed by the seat belt is about $2 \times 10^8 \text{ J m}^{-3}$.

mass of dummy = 75 kg

(3)

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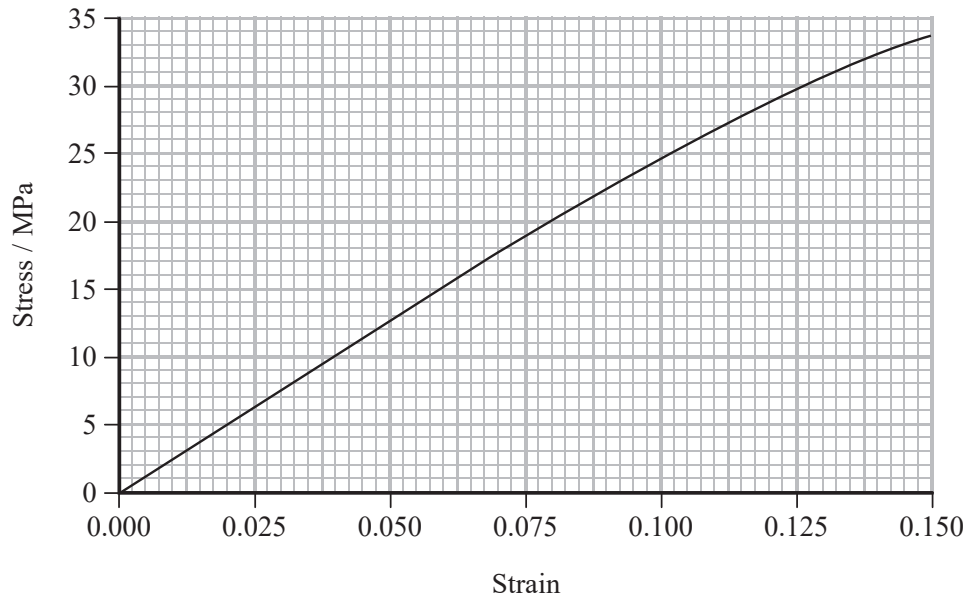
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- (b) The graph shows how stress varies with strain for the seat belt.



- (i) Show that the area under the graph represents the energy stored per unit volume in the seat belt.

(2)

- (ii) Use the graph to determine whether the seat belt absorbs all the kinetic energy of the dummy from part (a).

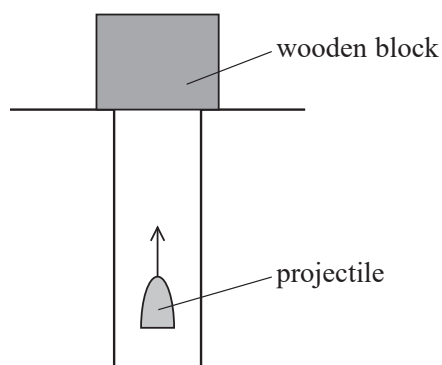
In this collision, the maximum strain of the seat belt is 0.075

(3)

(Total for Question 10 = 8 marks)



- 7 A projectile of mass 65 g is fired vertically upwards into a stationary wooden block of mass 2.400 kg, as shown.



- (a) The projectile becomes embedded in the block. They both move vertically upwards through a vertical displacement of 55 cm before momentarily coming to rest.

Calculate the energy dissipated as the projectile hits the block.

(6)

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Energy dissipated = ...

(b) Explain how the principle of conservation of energy applies to this collision.

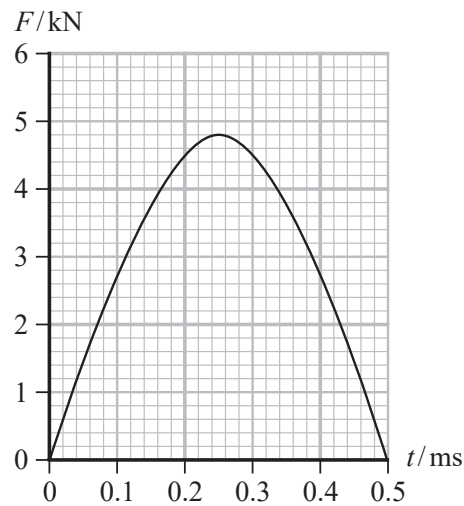
(2)

(Total for Question 7 = 8 marks)



- 12** 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.



- (a) State why the area under the graph represents impulse.

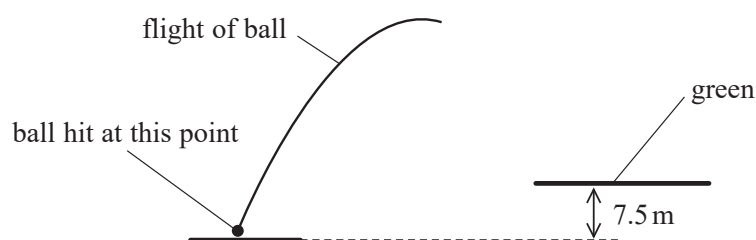
(1)

- (b) (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)

- (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)

(Total for Question 12 = 9 marks)

18 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) Explain what happens to make the last ball bearing on the right subsequently move off with a large velocity.

(3)

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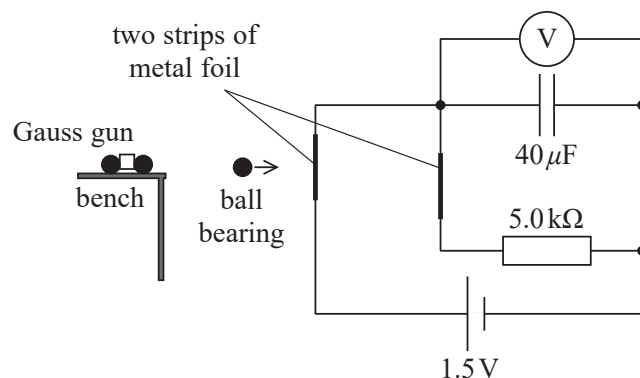
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- (b) A student set up the apparatus shown to measure the speed of the last ball bearing. The 'Gauss gun' was placed at the end of a bench, so that the ball bearing left the gun and broke two strips of metal foil which formed part of an electric circuit.



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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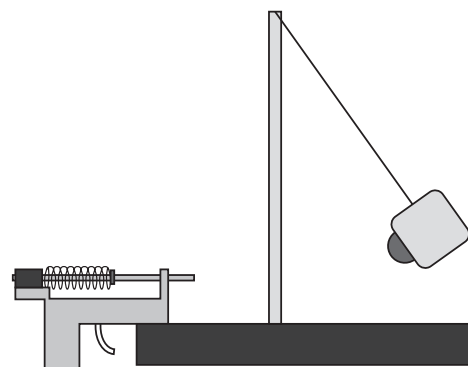
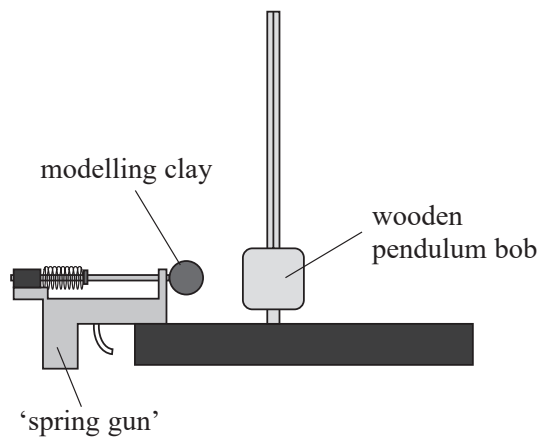
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(Total for Question 18 = 11 marks)



- 8 A student investigated the behaviour of a pendulum. The student used a ‘spring gun’ to fire a small sphere of modelling clay at the wooden pendulum bob, as shown in Figure 1. The clay stuck to the pendulum bob, which swung to one side, as shown in Figure 2.



- *(a) Describe how the principle of energy conservation and the principle of momentum conservation apply to this situation.

Consider the situation from the instant the spring gun is released to the instant the bob reaches its maximum height.

(6)

(b) When the modelling clay hits the pendulum bob, the pendulum swings to one side.

- (i) Show that the time taken for the pendulum bob to move from its lowest position to its highest position is about 0.6 s.

effective length of pendulum = 1.25 m

(3)

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- (ii) The pendulum bob was then attached to a spring of stiffness 0.12 N m^{-1} . When the bob was displaced vertically and released, it oscillated with a time period equal to that of the pendulum.

Calculate the mass of the pendulum bob.

(2)

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Mass of pendulum bob = ...

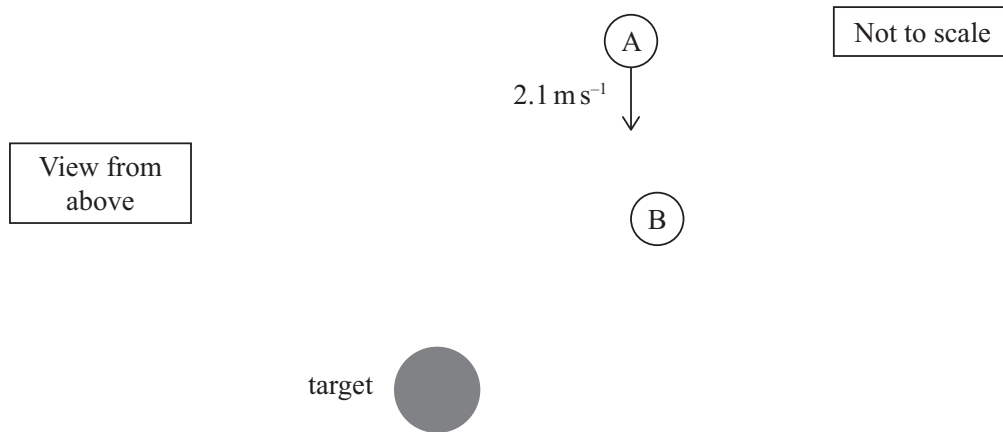
(Total for Question 8 = 11 marks)



- 16** Curling is a sport played on ice. Players slide stones made of granite along the ice. The aim of the sport is to slide a stone into a circular area called the target.

The diagram below shows two stones, A and B. Each stone has a mass of 18 kg.

Stone A is moving with a velocity of 2.1 m s^{-1} , as shown. B is initially stationary.



- (a) (i) Show that the momentum of A is about 40 N s .

(2)

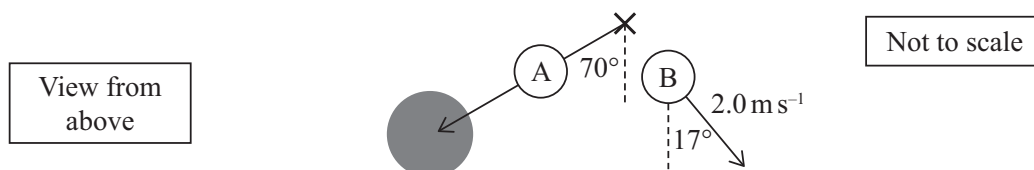
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- (ii) Stone A collides with stone B.

The diagram below shows the velocity of stone B after the collision. The point of collision is marked X.



Deduce whether stone A moves in the direction shown after the collision.

(5)

(b) Stone A comes to rest 1.9 m from X. The deceleration of the stone on the ice is 0.10 m s^{-2} .

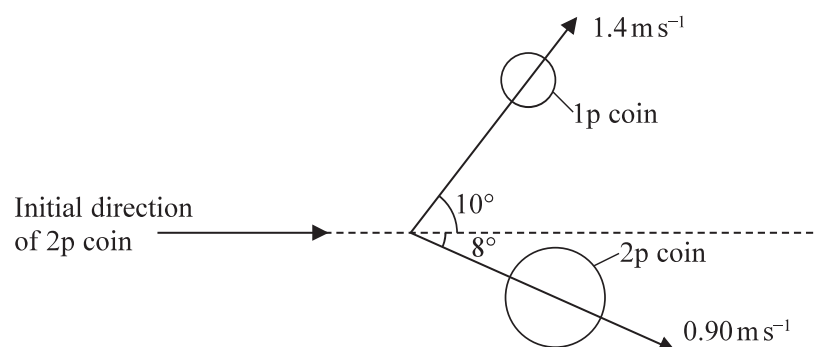
Deduce whether the collision was elastic.

(4)

(Total for Question 16 = 11 marks)



- (b) 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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(Total for Question 14 = 12 marks)

- 8 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) 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.

(4)

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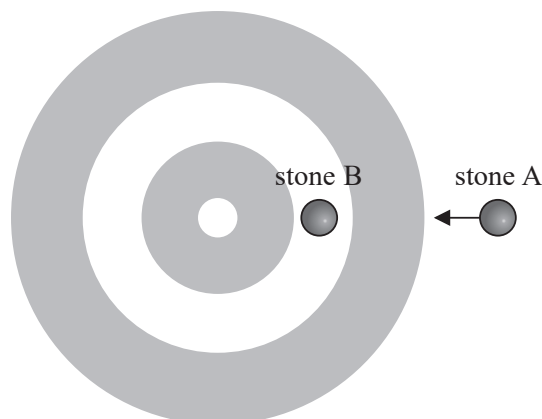
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Average power = ...

- *(b) Stone B is stationary. Stone A travels towards the target and makes a direct hit on stone B as shown. Both stones have mass m .



17 A cosmic ray, consisting of a fast-moving proton, collides with a proton within the nucleus of an atom in the upper atmosphere. Three particles, a proton, a neutron and a pion result from the collision.

(a) Write a particle equation for this collision.

(2)

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(b) The table shows the properties of two quarks.

Quark	Charge/ e
u	$+2/3$
d	$-1/3$

Give the quark structure for each of the particles produced by this collision.

(3)

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(c) The mass of a pion is $140 \text{ MeV}/c^2$.

Calculate the mass of the pion in kg.

(3)

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Mass = ... kg

- (d) The mass of a neutron is about the same as the mass of a proton. A student suggests that the minimum kinetic energy the cosmic ray proton would need to create the pion in this collision is 140 MeV.

Discuss whether this suggestion is correct. Your answer should include reference to the laws of conservation of momentum and conservation of energy.

(4)

(Total for Question 17 = 12 marks)



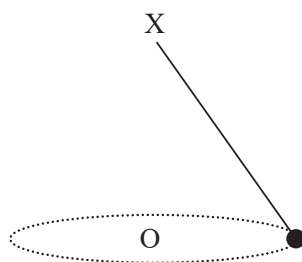
SUB-TOPIC 6.2

CIRCULAR MOTION

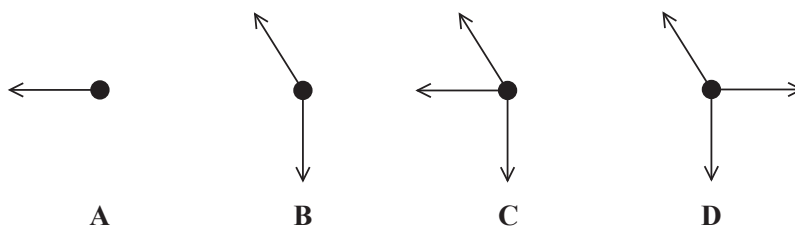
Sub-topic 6.2 · 15 questions · 112 marks · lowest tariff first



- 9 A mass is attached to a light thread which is fixed at X. The mass is moving at constant speed in a horizontal circle, centre O.



Which of the following is a correct free-body force diagram for this mass?



- ☒ A
- ☒ B
- ☒ C
- ☒ D

(Total for Question 9 = 1 mark)

9 The blade of a lawnmower rotates at a speed of 50 revolutions per second.

Which of the following is the angular speed of the blade in rads s^{-1} ?

☐ A 7.96

☐ B 15.9

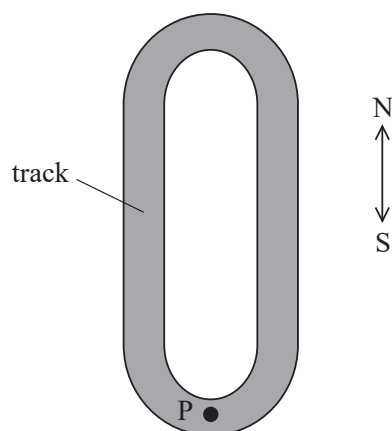
☐ C 157

☐ D 314

(Total for Question 9 = 1 mark)



- 5 The plan view of a model racing car track is shown. Friction acts between a model racing car and the track. A car is moving round the track with a constant speed and reaches point P. Arrows indicating directions North and South are also shown.



The car then slides off the track at P.

Which of the following is the reason why the car slides off the track?

- ☐ A The centripetal force is acting in the N direction.
- ☐ B The centripetal force is acting in the S direction.
- ☐ C The frictional force is equal to the centripetal force.
- ☐ D The frictional force is not large enough.

(Total for Question 5 = 1 mark)

8 A roundabout completes 5.0 revolutions in 20 s.

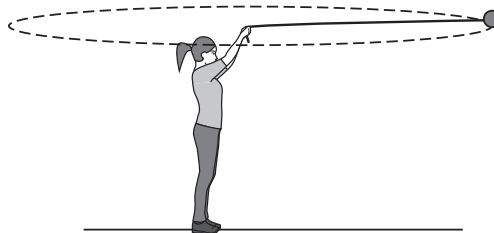
Which of the following is the angular velocity of the roundabout?

- ☐ **A** 1.6 rad s^{-1}
- ☐ **B** 16 rad s^{-1}
- ☐ **C** 25 rad s^{-1}
- ☐ **D** 630 rad s^{-1}

(Total for Question 8 = 1 mark)



- 3 A ball is tied to the end of a length of string. A person holds the other end of the string. The person spins the ball and string around in a horizontal circle, as shown.

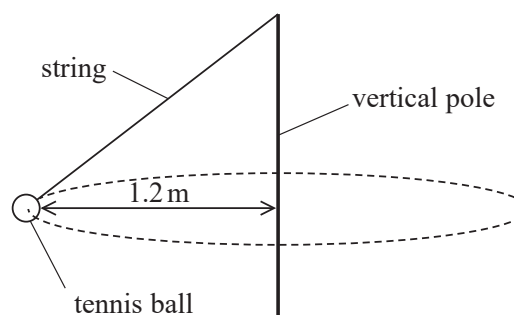


Which of the following statements best describes why the person feels a force from the string?

- ☐ A There is a centripetal force acting on the person.
- ☐ B There is a force on the person due to Newton's first law.
- ☐ C There is a force on the person due to Newton's third law.
- ☐ D There is a force on the person due to the weight of the ball.

(Total for Question 3 = 1 mark)

- 13 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.

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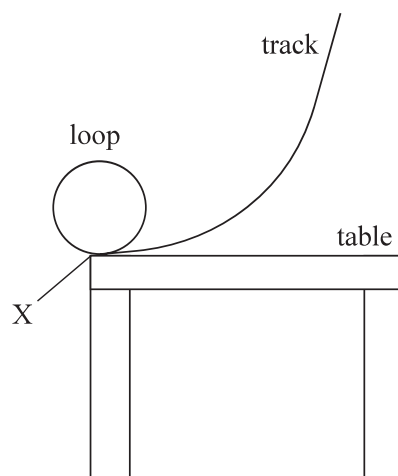
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(Total for Question 13 = 5 marks)

- 11 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.

- (a) The loop has radius r and the mass of the toy car is m . It is possible for a toy car to complete the loop without losing contact with the inside of the track.

For this to occur the minimum speed of the toy car at the top of the loop v_{top} is given by

$$v_{\text{top}} = \sqrt{gr}$$

Explain why.

(2)

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- (b) The toy car just completes the loop without losing contact with the track.

Show that the speed of the toy car at the bottom of the loop is about 3 m s^{-1} .

$$r = 0.15 \text{ m}$$

(3)

- (c) 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)

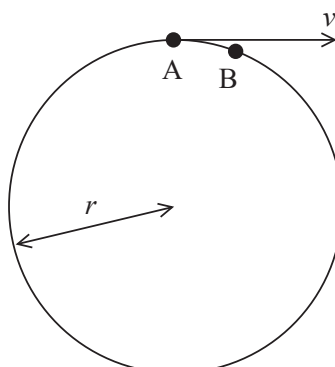
Horizontal displacement = ...

(Total for Question 11 = 9 marks)



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

(a) 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)

- (b) (i) The ISS completes one orbit in 92 minutes.

Calculate the centripetal acceleration of the ISS.

$$r = 6800 \text{ km}$$

(3)

Centripetal acceleration = ...

- (ii) Astronauts in the ISS are often described as being “weightless”.

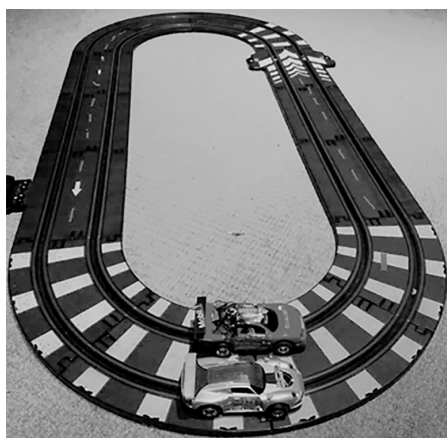
Discuss whether the astronauts are “weightless” when they are orbiting the Earth in the ISS.

(4)

(Total for Question 11 = 9 marks)



- 13 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.



- (a) There is a maximum speed for the car to stay on the curved part of the track. Explain why the car will slip off the curved part of the track if the car exceeds the maximum speed.

(3)

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- (b) 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 (b)(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 = ...

- (c) 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 13 = 10 marks)

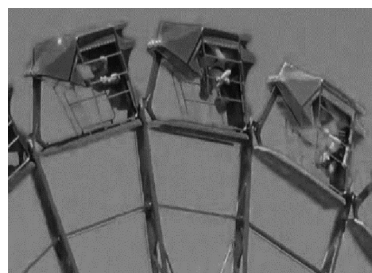


- 6 The Enterprise is an amusement park ride. Riders sit in cars that are made to rotate in a vertical circle.

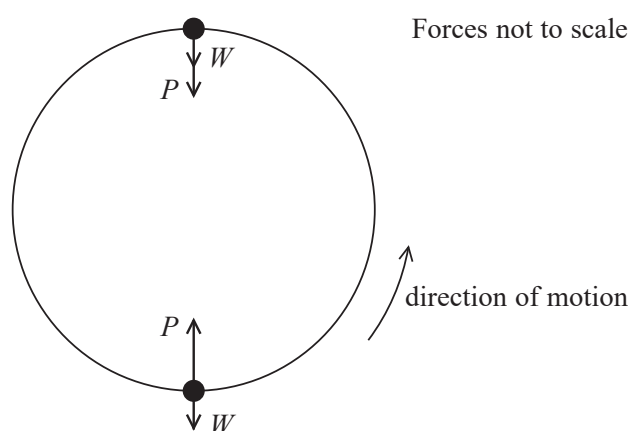
The ride starts by moving in a horizontal circle. The speed of rotation increases, and the frame tilts until the ride is rotating vertically as shown.



The photograph below shows riders at the top of the vertical circle. The riders are in contact with their seats at all times during the ride.



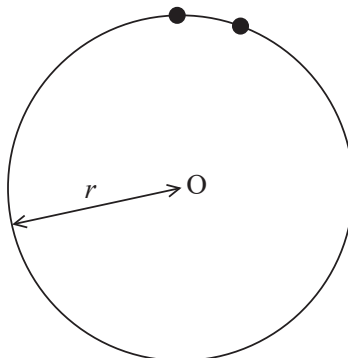
The diagram shows the weight W of a rider and the push P from the seat on the rider at the top and bottom of the circular path.



17 A centrifuge is a machine which rotates.

(a) 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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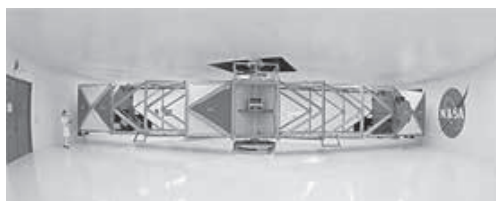
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- (b) The United States' space agency, NASA, uses a centrifuge to test whether equipment will operate when experiencing large forces. The equipment to be tested is attached to the end of the frame of the centrifuge, which rotates around a vertical axis at its centre.



The centrifuge rotates at 50 revolutions per minute with a radius of 8.8 m.

- (i) Show that the angular velocity of the centrifuge is about 5 rad s^{-1} .

(2)

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- (ii) Explain how the centrifuge applies large forces to the equipment under test.

(2)

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- (iii) The NASA website says the centrifuge can be used to test whether the equipment can withstand accelerations of up to about $25g$.

Deduce whether this claim is correct.

(2)

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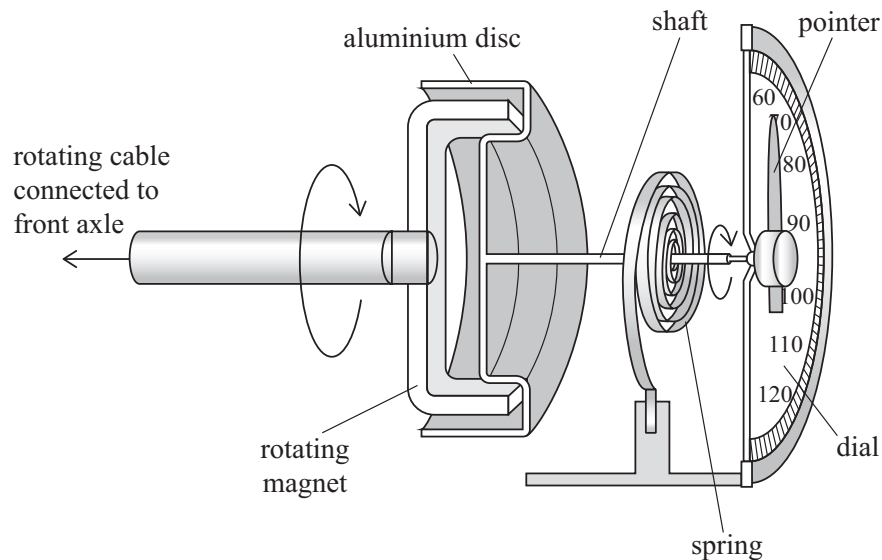
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(Total for Question 17 = 11 marks)

- 17 The diagram shows a section through the components of a speedometer for a bicycle. The front wheel axle of the bicycle is connected to a cable. The cable rotates as the bicycle wheel rotates. The other end of the cable is connected to a magnet which also rotates, as shown.



An aluminium disc is shaped so that it is close to, but not touching, the magnet. The disc is connected to a pointer by a shaft. A spring prevents the disc and shaft from freely rotating.

- *(a) Explain why the aluminium disc rotates in the same direction as the magnet.

(6)

- (b) The road speed of the bicycle should be displayed by the speedometer.

Explain why the displayed speed can **not** be accurate, as bicycles can have different wheel diameters.

(2)

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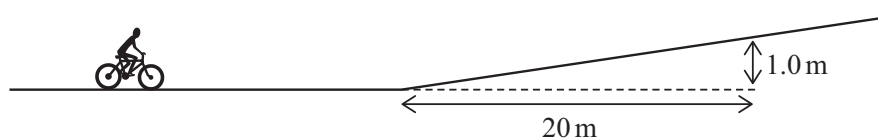
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- (c) A cyclist has a constant speed of 8.3 m s^{-1} on a flat road. The cyclist generates an average power of 190 W. The total mass of the cyclist and bicycle is 75 kg.

The cyclist comes to a hill of gradient 1 in 20, as shown.



The cyclist now generates an average power of 330 W. The speed decreases to a constant value which the speedometer suggests is 5.6 m s^{-1} .

Deduce whether the speedometer is accurate.

Assume resistive forces are constant.

(4)

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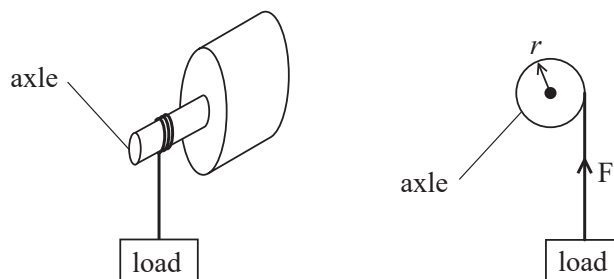
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(Total for Question 17 = 12 marks)

18 Motors usually have a rotating component which can do work W .

(a) A motor lifts a load in a time t . The axle of the motor has a radius r and exerts a force F .



The power produced by a motor can be calculated by using the following word equation.

Power = moment of the force exerted by the rotating axle $\times$ angular velocity

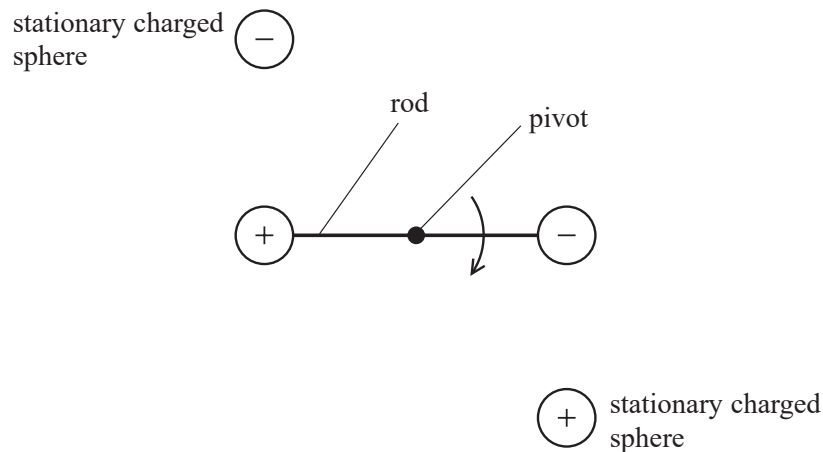
Derive this equation, starting with power $P = \frac{W}{t}$.

(4)

(b) An electrostatic motor was first demonstrated by Benjamin Franklin in 1750.

The diagram shows a simplified version of part of this motor.

This consists of a rod, with an oppositely charged sphere at either end, which rotates around a fixed pivot. Two stationary charged spheres apply a force on the spheres at either end of the rod.

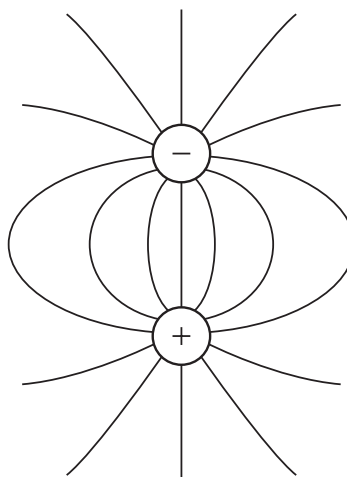


(i) In the diagram below, electric field lines have been drawn around one pair of these spheres.

Add to the diagram to show

- the directions of the field lines
- the lines of equipotential.

(3)



(ii) The distance between the centres of each charged sphere in this pair is 5.0 cm.

Show that the force between this pair of charged spheres is about 0.04 N.

charge on each sphere = 0.10 μC

(2)

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(c) The table shows the typical power and the corresponding angular velocity required for three different appliances.

	Power / W	Angular velocity / rad s^{-1}
Electric car	2.0×10^4	300
Vacuum cleaner	1.4×10^3	1000
Small pond pump	0.5	200

Deduce which of these appliances, in principle, could use the electrostatic motor in (b).

You should use the word equation in (a) and assume that the length of the rod in the electrostatic motor is 8.0 cm.

Assume that the electrostatic motor would deliver a constant force throughout one complete rotation.

(4)

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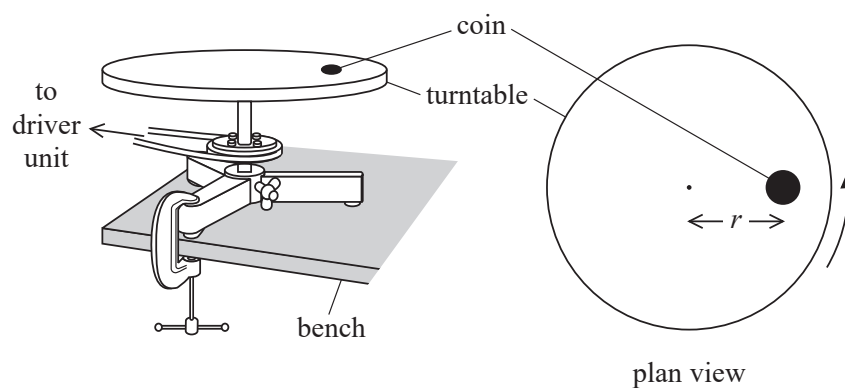
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(Total for Question 18 = 13 marks)

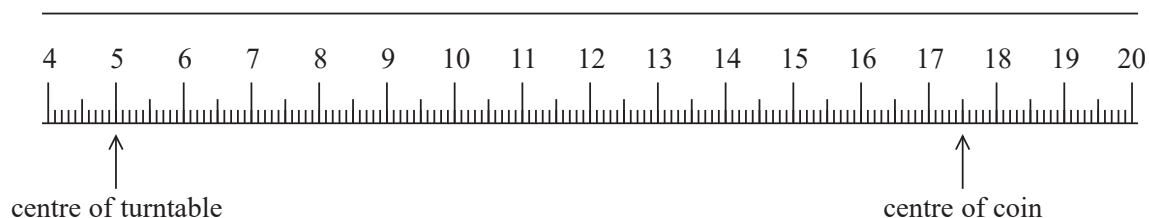


- 3 A student was investigating the forces involved in circular motion.

He placed a small coin on a horizontal turntable as shown. The turntable was connected to a driver unit so that it could be rotated at a constant rate.



- (a) The student measured the distance r between the centre of the turntable and the centre of the coin, with a metre rule as shown.



Explain why the percentage uncertainty in the value of r is about 1%.
Your answer should include a calculation.

(3)

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- (b) The student switched on the driver unit and increased the rate of rotation until the coin slid off the turntable. He read the angular velocity ω of the turntable from a digital display on the driver unit. He then replaced the coin in the original position on the turntable and repeated the procedure.

His results are shown.

$\omega / \text{rad s}^{-1}$				
0.125	0.112	0.118	0.123	0.116

- (i) The student used the results to calculate a mean value of ω .

State the purpose of calculating a mean.

(1)

- (ii) Calculate the percentage uncertainty in the mean value of ω .

(3)

Percentage uncertainty = ...

- (iii) The student used ω and r to calculate the centripetal acceleration of the coin at the instant it started to slide.

Calculate the percentage uncertainty in this centripetal acceleration.

(3)

Percentage uncertainty = ...



(c) The student repeated the procedure with different values of r .

Explain how the value of ω at which the coin started to slide varied as r increased.

(3)

(Total for Question 3 = 13 marks)



11 Particle accelerators produce beams of high speed charged particles which are used to investigate particle collisions. New particles are created during the collisions.

(a) In the Large Hadron Collider (LHC), protons are maintained in a circular path by the force exerted on the protons due to a magnetic field.

(i) The magnetic flux density required to maintain the protons in a circular path increases as the kinetic energy of the protons increases.

Explain why.

(2)

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(ii) Calculate the magnetic flux density required to maintain the protons in the LHC when the protons are travelling at a speed of $3.0 \times 10^7 \text{ m s}^{-1}$.

circumference of LHC = 27 km

(4)

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Magnetic flux density = ...



MARK SCHEMES

official mark schemes



Question Number	Acceptable answers	Additional guidance	Mark
2	B as equal to total momentum before = $1 \times 2 - 0.5 \times 2$	1.0	1
	A is the answer if each trolley had the same momentum C is the momentum of the second trolley only D is the answer if the two trolleys were travelling in the same direction		



Question Number	Acceptable answers	Additional guidance	Mark
6	The only correct answer is A <i>B is not correct because these are base units of force</i> <i>C is not correct because these are not base units</i> <i>D is not correct because these are not base units</i>	kg m s^{-1}	1



10	The only correct answer is A <table><tr><td>-1.0</td><td>0.5</td></tr></table>	-1.0	0.5	B,C and D are incorrect as for each, momentum is not conserved.	1
-1.0	0.5				

(Total for Multiple Choice Questions = 10 marks)



Question Number	Acceptable answers	Additional guidance	Mark
2	The only correct answer is B <i>A is not correct because this is not dimensionally correct</i> <i>C is not correct because $E_k/2p = v/4$</i> <i>D is not correct because this is not dimensionally correct</i>		1



7	The only correct answer is D A is not the correct answer, as change in momentum is the same. B is not the correct answer, as change in velocity is the same. C is not the correct answer, as force decreases.		1
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Question Number	Acceptable Answers	Additional Guidance	Mark
14 (a)	- Attempts to find area under graph - Height = 10 m	(1) Range for base of triangle between 1.8 and 2s to recognise area Example of calculation: (1) $\frac{1}{2} \times 1.8 \times 20 = 18$	2



Question Number	Acceptable Answer	Additional Guidance	Mark
10(a)	- Cross sectional area $\times$ length used to calculate volume (1) - Use of $E_k = \frac{1}{2}mv^2$ (1) - Energy per unit volume = $1.7 \times 10^8 \text{ J m}^{-3}$ (1)	<u>Example of calculation:</u> Volume of seatbelt, $V = 0.85 \times 10^{-4} \text{ m}^2 \times 2 \text{ m}$ $V = 1.7 \times 10^{-4} \text{ m}^3$ $E_k = \frac{1}{2} \times 75 \text{ kg} \times (28 \text{ m s}^{-1})^2 = 2.9 \times 10^4 \text{ J}$ $\therefore \frac{E}{V} = \frac{2.9 \times 10^4 \text{ J}}{1.7 \times 10^{-4} \text{ m}^3} = 1.73 \times 10^8 \text{ J m}^{-3}$	3
10(b)(i)	(For linear section of graph) area under graph = $\frac{1}{2}$ stress $\times$ strain (1) - Use of stress = F/A and strain = $\Delta x/x$ to show that area = $\frac{1}{2} \times \frac{F}{A} \times \frac{\Delta x}{x} = \frac{F_{av} \Delta x}{V} = \frac{E}{V}$ (1)	Candidates who only use the graph to show that the area has units J m^{-3} can score a maximum 1 mark Accept F_{av} for $\frac{1}{2}F$	2
10(b)(ii)	- Area under graph up to 0.075 calculated (1) - Energy per unit volume = $7.1 \times 10^5 \text{ J m}^{-3}$ (1) - This is much less than the value given in (a), and so belt does not absorb all the KE. (1) OR - Graph used to determine stress when strain is 0.075 and $\sigma = \frac{F}{A}$ used to calculate force (1) $\epsilon = \frac{\Delta x}{x}$ used to calculate extension and $W = \frac{1}{2}F\Delta x$ used to calculate energy (1) - Statement that this energy is much less than the value in (a), and so belt does not absorb all the kinetic energy (1)	Example of calculation: When strain is 0.075 Area = $\frac{1}{2} \times 19 \times 10^6 \text{ Pa} \times 0.075 = 7.13 \times 10^5 \text{ J m}^{-3}$	3

(Total for Question 10 = 8 marks)



Question Number	Acceptable Answer	Additional Guidance	Mark
7(a)	- Use of $E_{\text{grav}} = mg\Delta h$ (1) - Use of $E_K = \frac{1}{2}mv^2$ for block and projectile (1) - Use of $p = mv$ (1) - Use of conservation of momentum (1) - Use of $E_K = \frac{1}{2}mu^2$ for projectile (1) $\Delta E = 490 \text{ J}$ (1)	MP1: Use of suvat equation to calculate u MP2: Use of $E_K = \frac{1}{2}mv^2$ for block and projectile Or use of $E_{\text{grav}} = mg\Delta h$ <u>Example of calculation</u> $E_{\text{grav}} = (2.4 + 0.065)\text{kg} \times 9.81 \text{ m s}^{-2} \times 0.55 \text{ m} = 13.3 \text{ J}$ (of block and projectile) $13.3 \text{ J} = \frac{1}{2} \times (2.4 + 0.065)\text{kg} \times v^2$ $\therefore v = \sqrt{\frac{13.3 \text{ J}}{0.5 \times 2.465 \text{ kg}}} = 3.28 \text{ m s}^{-1}$ $0.065 \text{ kg} \times u = 2.465 \text{ kg} \times 3.28 \text{ m s}^{-1}$ $\therefore u = \frac{8.10 \text{ kg m s}^{-1}}{0.065 \text{ kg}} = 124.6 \text{ m s}^{-1}$ $E_K = \frac{1}{2} \times 0.065 \text{ kg} \times (125 \text{ m s}^{-1})^2 = 504 \text{ J}$ $\therefore \Delta E = (504 - 13.3) \text{ J} = 491 \text{ J}$	6
7(b)	- Total energy is constant, but kinetic energy decreases Or reference to an inelastic collision (1) - Projectile does work on block Or internal energy of block increases (1)		2

(Total for Question 7 = 8 marks)



Question Number	Acceptable answers	Additional guidance	Mark
12(a)	Impulse is the product Ft which is area under this graph (1)		1
12(b)(i)	- Attempt to determine an area (1) - Uses area = change of momentum (1) - velocity in range 28 – 33 (m s^{-1}) (1)	eg markings on the graph <u>Example of calculation:</u> Approximates area = triangle = $(0.0005 \text{ s} \times 5500 \text{ N}) / 2$ Area = 1.375 Ns Velocity = $1.375 \text{ Ns} / 0.046 \text{ kg} = 29.1 \text{ ms}^{-1}$	3
12(b)(ii)	- Use of $ss = uuuu + \frac{1}{2}auu^2$ in vertical direction 2 (1) - if $s +$ then $ut +$ and at^2 negative (1) Or if $s -$ then $ut -$ and at^2 positive - Use of velocity = distance / time in horizontal direction (1) - Correct component of velocity in each direction (1) - Distance = 76 m and comment such as yes it reaches the green. (1) (ECF from bi) Range of distance 70.5 m for b(i) $v = 28 \text{ m s}^{-1}$ to 93.6 m for $v = 33 \text{ m s}^{-1}$	Alt: Use of pythagorus to find resultant velocity Also accept conclusion based on a comparison of velocity values from (i) and (ii) <u>Example of calculation:</u> $7.5\text{m} = 29\text{m s}^{-1}\sin\theta 3.5\text{s} - \frac{1}{2}9.81\text{m s}^{-2}3.5^2\text{s}^2$ $7.5\text{m} = 101.5 \sin\theta - 60.1$ $\sin\theta = 67.6 / 101.5 \theta = 41.8^\circ$ $29 \text{ ms}^{-1} \cos 41.8 = x / 3.5 \text{ s}$ $x = 75.7 \text{ m}$	5



		Using the “show that” value:	
		$7.5\text{m} = 30\text{m s}^{-1}\sin\theta \cdot 3.5\text{s} - \frac{1}{2} \cdot 9.81\text{m s}^{-2} \cdot 3.5^2\text{s}^2$ $7.5\text{m} = 105 \sin\theta - 60.1$ $\sin\theta = 67.6 / 105 \Rightarrow \theta = 40.1^\circ$ $30 \text{ ms}^{-1} \cos 40.1 = x / 3.5 \text{ s}$ $x = 80.3 \text{ m}$	

(Total for Question 12 = 9 marks)



18a	- Magnet accelerates ball Or magnet increases ball's KE (1) - Momentum is conserved in the collision(s) (1) (Since collisions are elastic) KE conserved so third ball moves off with the same velocity/KE as incoming ball hit magnet with (1)	Marks can be gained by discussing either set of balls	3
18bi	- Use of $W = \frac{1}{2} CV^2$ (1) $W = 45 \mu\text{J}$ (1)	<u>Example of calculation</u> $W = \frac{1}{2} 40\mu\text{F} \times (1.5 \text{ V})^2$ $W = 45 \mu\text{J}$ Alt: Use $Q = CV$ then $E = QV/2$ for MP1	2
18bii	- Use of $V = V_0 e^{-t/RC}$ (1) - Time = 0.14 (s) (1)	<u>Example of calculation</u> $0.5 = e^{-t/5000 \times 40 \times 10^{-6}}$ $\ln 0.5 = -t/0.2$ $t = 0.14\text{s}$	2
18biii	- Use of speed = d/t (1) - Speed = 3.6 ms^{-1} (1) Allow ecf from ii	Show that value gives 5.0 ms^{-1} <u>Example of calculation</u> $v = 0.5\text{m} / 0.14\text{s}$ $= 3.6 \text{ ms}^{-1}$	2
18biv	- use of $s = \frac{at^2}{2}$ (1) $s = 9 \text{ cm}$ + comment that foil is not broken at its centre (comment consistent with calculation) Allow ecf from ii (1)	Show that value gives 0.049 m <u>Example of calculation</u> $s = \frac{9.81 \text{ ms}^{-2} \times 0.14^2 \text{ s}}{2} = 0.094 \text{ m}$	2

(Total for Question 18 = 11 marks)



Question Number	Acceptable Answer	Additional Guidance	Mark																																																				
*8(a)	This question assesses a student’s ability to show a coherent and logical structured answer with linkage and fully-sustained reasoning. Indicative content: IC1 Elastic P.E. (of the spring) is transferred to K.E. of the modelling clay IC2 Clay has momentum before hitting the bob IC3 Momentum is conserved when clay hits the bob IC4 K.E. is transferred from the clay to the bob IC5 Collision is inelastic Or K.E. is not conserved Or In the collision (some) energy is transferred to thermal energy IC6 At the maximum height/displacement of the bob all the K.E. (after the collision) has been transferred to gravitational P.E.	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 indicative 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> <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> Total marks awarded is the sum of marks for indicative content and the marks for structure and lines of reasoning <table><tr><th>IC points</th><th>IC mark</th><th>Max linkage mark</th><th>Max final mark</th></tr><tr><td>6</td><td>4</td><td>2</td><td>6</td></tr><tr><td>5</td><td>3</td><td>2</td><td>5</td></tr><tr><td>4</td><td>3</td><td>1</td><td>4</td></tr><tr><td>3</td><td>2</td><td>1</td><td>3</td></tr><tr><td>2</td><td>2</td><td>0</td><td>2</td></tr><tr><td>1</td><td>1</td><td>0</td><td>1</td></tr><tr><td>0</td><td>0</td><td>0</td><td>0</td></tr></table> (Accept responses in terms of energy stores model)	Number of indicative marking points seen in answer	Number of marks awarded for indicative marking points	6	4	5–4	3	3–2	2	1	1	0	0		Number of marks awarded for structure of answer and sustained line of reasoning	Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout	2	Answer is partially structured with some linkages and lines of reasoning	1	Answer has no linkages between points and is unstructured	0	IC points	IC mark	Max linkage mark	Max final mark	6	4	2	6	5	3	2	5	4	3	1	4	3	2	1	3	2	2	0	2	1	1	0	1	0	0	0	0	
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6



8(b)(i)	• Use of $T = 2\pi\sqrt{\frac{l}{g}}$ (1) • Time to reach maximum height = $T/4$ (1) • Time to reach maximum height = 0.56 (s) (1)	<u>Example of calculation</u> $T = 2\pi\sqrt{\frac{1.25 \text{ m}}{9.81 \text{ m s}^{-2}}} = 2.24 \text{ s}$ $t = \frac{T}{4} = \frac{2.24 \text{ s}}{4} = 0.56 \text{ s}$	3
8(b)(ii)	• Use of $T = 2\pi\sqrt{\frac{m}{k}}$ (1) • $m = 0.015 \text{ kg}$ (ecf from (b)(i)) (1) [show that value gives 0.018 kg]	<u>Example of calculation</u> $2.24 \text{ s} = 2\pi\sqrt{\frac{m}{0.12 \text{ N m}^{-1}}}$ $\therefore m = \left(\frac{2.24 \text{ s}}{2\pi}\right)^2 \times 0.12 \text{ N m}^{-1} = 0.0153 \text{ kg}$	2

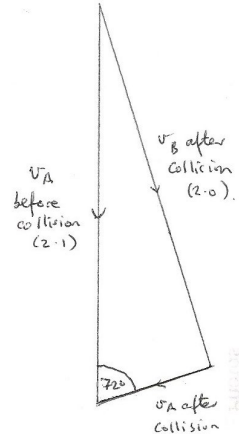
(Total for Question 8 = 11 marks)



Question Number	Acceptable Answer	Additional Guidance	Mark
16(a)(i)	- Use of $p = mv$ $p = 38 \text{ (Ns)}$	(1) <u>Example of calculation</u> $p = 18 \text{ kg} \times 2.1 \text{ m s}^{-1}$ (1) $p = 37.8 \text{ Ns}$	2
16(a)(ii)	- Expression for component of p_B East - Expression for component of p_B South - Uses momentum conservation along line South - Uses $\tan \theta = \frac{\text{component } x}{\text{component } y}$ $\theta = 72^\circ$ and so stone A moves in the direction shown Or $\theta = 72^\circ$ and so stone A doesn't move in the direction shown [if using show that value $\theta = 62^\circ$ and this is not in the right direction]	(1) <u>Example of calculation</u> p_B in east direction $= 18 \text{ kg} \times 2 \text{ m s}^{-1} \times \sin 17^\circ$ $= 10.53 \text{ Ns}$ (1) p_B in south direction $= 18 \text{ kg} \times 2 \text{ m s}^{-1} \times \cos 17^\circ$ $= 34.43 \text{ Ns}$ Momentum conservation in South direction $37.8 \text{ Ns} = 34.43 \text{ Ns} + p_A$ in South direction Or p_A in south direction after collision $= 37.8 - 34.43 = 3.37 \text{ Ns}$ [If show that value used $= 5.57 \text{ Ns}$] (1) p_A in west direction $= p_B$ in east direction $= 10.53 \text{ Ns}$ $\tan \theta = \frac{10.53}{3.37}$ (1) $\theta = 72^\circ$ to south direction [Note this could all be done using velocity values as the mass of each stone is the same]	5



	Alternative making use of angle of 70° to determine the velocity of A by considering momentum conservation in two directions and comparing the two results • Expression for component of v_B South (1) • Uses conservation along line South (1) • Expression for component of v_B East (1) • Uses conservation East West (1) • Gives two correct values of velocity/momenta for stone A <i>eg</i> $0.56 \text{ (ms}^{-1}\text{)}$ and $0.62 \text{ (ms}^{-1}\text{)}$ after the collision with a comparison of the two values and sensible conclusion such as the two values are not consistent so the stone does not move in this direction (1) [If momenta used the two values for momenta of A after the collision are 10.1 (Ns) and 11.2 (Ns)]	The alternative is shown using velocity values but could be done using momentum values as above. v_B in south direction $= 2 \text{ ms}^{-1} \times \cos 17^\circ$ $= 1.91 \text{ ms}^{-1}$ Conservation in South direction $2.1 \text{ ms}^{-1} = 1.91 \text{ ms}^{-1} + v_A$ in south direction after collision Or v_A in south direction after collision $= 2.1 \text{ ms}^{-1} - 1.91 \text{ ms}^{-1}$ $0.19 \text{ ms}^{-1} = v_A \cos 70$ Gives $v_A = 0.56 \text{ ms}^{-1}$ v_B in east direction $= 2 \text{ ms}^{-1} \times \sin 17^\circ$ $= 0.585 \text{ ms}^{-1}$ Momentum conservation in East west direction $v_A \sin 70 = v_B$ in east direction $= 0.585$ Gives $v_A = 0.62 \text{ ms}^{-1}$ MP5 Note: can compare the components of A and B in the East -west direction after the collision	
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	If using a Vector diagram • Labelled line representing p_A / v_A before collision (1) • Uses or states sensible (more than half the space) scale (1) • Line representing p_B / v_B after collision starting at one end of p_A / v_A before collision line (1) • Line representing p_A / v_A after collision and completes triangle (1) • Measures angle: $\theta = 70^\circ$ and this is the required angle so stone A moves towards the button after the collision (1)	<u>Example of vector diagram</u> Note this could be done using momenta or velocities as masses are the same. 	
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16(b)	• Use of $v^2 = u^2 + 2as$ • Use of $E_k = \frac{1}{2}mv^2$ • Determines E_k of A before collision = 40 J Or Determines E_k of A after collision = 3.5 J • Total kinetic energy after = 39.5 J and suggests elastic / inelastic	(1) <u>Example of calculation</u> $0 = u^2 + 2 \times 0.10 \text{ m s}^{-1} \times 1.9 \text{ m}$ $u = 0.62 \text{ m s}^{-1}$ (1) Note that the velocity of A could be taken from a(ii) if so award MP1 for the extra work already done as long as it is correct (range between 0.55 and 0.62 depending on rounding) (1) E_k of A before collision = $\frac{1}{2} 18 \text{ kg} \times 2.1^2 (\text{m s}^{-1})^2$ $= 39.7 \text{ J}$ E_k of B after collision = $\frac{1}{2} 18 \text{ kg} \times 2.0^2 (\text{m s}^{-1})^2$ $= 36.0 \text{ J}$ E_k of A after collision = $\frac{1}{2} 18 \text{ kg} \times 0.62^2 (\text{m s}^{-1})^2$ $= 3.5 \text{ J}$ Total E_k after collision = $36.0 + 3.5 = 39.5 \text{ J}$ [Note this could all be done using velocity values as the mass of each stone is the same then unit $\text{m}^2 \text{s}^{-2}$]	4
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(Total for Question 16 = 11 marks)



Question Number	Acceptable answers	Additional guidance	Mark
14(a)	• Use of $v^2 = u^2 + 2as$ (1) • $v = 0$ so $u = \sqrt{-2as}$ (1) • a is a deceleration caused by friction (with surface) (1) • States $F = ma$ where F is friction (1) • As $F = km = ma$ so a must be constant Or $F = ma$ if F proportional to m then a must be constant (1) • so acceleration a the same (as 1 p coin) so statement correct (1)	ignore whether minus sign included or not Alternative: • Work done by friction (with surface) • States $W = Fs$ • States $E_k = \frac{1}{2} mu^2$ • So $Fs = \frac{1}{2} mu^2$ • As $F = km$ • m's cancel so statement correct	(6)
14(b)(i)	• Use of momentum = mv (1) • See component(s) in x direction (1) • Uses momentum conservation (1) • $u = 1.6 \text{ (m s}^{-1}\text{)}$ (1)	Example of calculation: $7.1(\text{g})u = 7.1(\text{g}) \times 0.9(\text{ms}^{-1}) \times \cos 8 + 3.6(\text{g}) \times 1.4(\text{ms}^{-1}) \times \cos 10$ $u = \frac{(6.33 + 4.96)}{7.1}$ $u = 1.59 \text{ ms}^{-1}$	(4)

14(b)(ii)	• Use of $E_k = \frac{1}{2} mv^2$ (1) • Value of Initial $E_k = 9.0 \times 10^{-3}$ (J) and (1) Final $E_k = 6.4 \times 10^{-3}$ (J) (Show that value gives Initial $E_k = 1.42 \times 10^{-2}$ (J) allow ecf from (b)(i))	Allow ecf from b(i) Example of calculation: Initial $E_k = \frac{1}{2} \times 7.1 \times 10^{-3} (\text{kg}) \times 1.59^2 (\text{ms}^{-1})^2 = 9.0 \times 10^{-3} \text{ J}$ Final $E_k = \frac{1}{2} \times 7.1 \times 10^{-3} \times 0.9^2 + \frac{1}{2} \times 3.6 \times 10^{-3} \times 1.4^2 = 6.4 \times 10^{-3} \text{ J}$	(2)
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(Total for Question 14 = 12 marks)

Question Number	Acceptable Answer	Additional Guidance																																									
8(a)	• Use of $s = \frac{(u+v)}{2} \cdot t$ • Use of $E_k = \frac{1}{2}mv^2$ • Use of $P = \frac{\Delta W}{\Delta t}$ • $P = 110 \text{ W}$ (1) (1) (1) (1)	Example of calculation: $32.5 \text{ m} = \frac{(u+0)}{2} \times 17.5 \text{ s}$ $\therefore u = \frac{32.5 \text{ m} \times 2}{17.5 \text{ s}} = 3.71 \text{ m s}^{-1}$ $P = \frac{\Delta E_k}{\Delta t} = \frac{\frac{1}{2} \times 19.6 \text{ kg} \times (3.7 \text{ m s}^{-2})^2}{1.25 \text{ s}} = 107 \text{ W}$	4																																								
8(b)	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 table shows how the marks should be awarded for indicative content and lines of reasoning. <table><tr><th>IC points</th><th>IC mark</th><th>Max linkage mark available</th><th>Max final mark</th></tr><tr><td>6</td><td>4</td><td>2</td><td>6</td></tr><tr><td>5</td><td>3</td><td>2</td><td>5</td></tr><tr><td>4</td><td>3</td><td>1</td><td>4</td></tr><tr><td>3</td><td>2</td><td>1</td><td>3</td></tr><tr><td>2</td><td>2</td><td>0</td><td>2</td></tr><tr><td>1</td><td>1</td><td>0</td><td>1</td></tr><tr><td>0</td><td>0</td><td>0</td><td>0</td></tr></table>	IC points	IC mark	Max linkage mark available	Max final mark	6	4	2	6	5	3	2	5	4	3	1	4	3	2	1	3	2	2	0	2	1	1	0	1	0	0	0	0	<table><tr><td></td><td>Number of marks awarded for structure of answer and sustained line of reasoning</td></tr><tr><td>Answer shows a coherent and logical structure with linkage 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 its points and is unstructured</td><td>0</td></tr></table>		Number of marks awarded for structure of answer and sustained line of reasoning	Answer shows a coherent and logical structure with linkage and fully sustained lines of reasoning demonstrated throughout	2	Answer is partially structured with some linkages and lines of reasoning	1	Answer has no linkages between its points and is unstructured	0	
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	Indicative content: • (Collision takes place on an ice surface so) there is minimal friction Or External forces are negligible • Momentum is conserved in the collision • The momentum of stone A before the collision equals the momentum of (A and) B after the collision • Stone A must be at rest after the collision • All of the kinetic energy of stone A must have been transferred to stone B • Kinetic energy is conserved in an elastic collision		6
8(c)	An explanation that makes reference to the following points: • Sweeping the ice smooths out the surface Or Sweeping the ice melts the surface of the ice. (1) • So frictional forces are reduced (and the deceleration of the stone is reduced) (1)	For MP2 accept references to a lower rate of working against friction Or less work done against friction for a given displacement	2

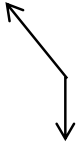
(Total for Question 8 = 12 marks)



Question Number	Acceptable answers	Additional guidance	Mark
17 (a)	- Correct equation ignoring charges (1) - Charge on pion + (1)	$p + p \rightarrow p + n + \pi^+$	2
17 (b)	- p : u u d (1) - n : u d d (1) π^- : u $\bar{d}$ (1)	Accept labelled π^- : $\bar{u}$ d	3
17(c)	- Convert eV to J (1) - Convert J to kg (1) - mass = 2.5×10^{-28} (kg) (1)	<u>Example of calculation:</u> $m = \frac{140 (\text{MeV}/c^2) \times 1.6 \times 10^{-13} \text{ J MeV}^{-1}}{(3 \times 10^8)^2 (\text{m s}^{-1})^2}$ $m = 2.49 \times 10^{-28} (\text{kg})$	3
17(d)	- extra mass after collision is the mass of pion Or energy must be conserved so E_k is required for pion (1) - According to $\Delta E = c^2 \Delta m$ (if extra mass is pion) then ΔE required is 140 MeV Or extra mass is 140 MeV/c^2 so E required is 140 MeV (1) - Momentum conservation means that the (three) resulting particles after the collision must have some momentum/E_k (1) - The incoming proton needs 140 MeV plus the E_k of the product particles so statement is inaccurate (1)		4

(Total for Question 17 = 12 marks)



9	B The two forces acting on the mass are its weight (vertically down) and a tension in the thread.		1
	A assumes there is a centripetal force only C assumes there is an additional centripetal force D assumes the additional centripetal force acts away from the centre of the circle		



9	The only correct answer is D 314	A, B and C all contain numerical errors	1
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Question Number	Acceptable answers	Additional guidance	Mark
5	The only correct answer is D A is not the correct answer, as centripetal force keeps car moving with circular motion B is not the correct answer, as centripetal force keeps car moving with circular motion C is not the correct answer, as this would keep car moving with circular motion		1



Question Number	Acceptable answers	Additional guidance	Mark
8	The only correct answer is A B is not the correct answer, as angular velocity = $5 \times 2\pi/20$ C is not the correct answer, as angular velocity = $5 \times 2\pi/20$		1
	D is not the correct answer, as angular velocity = $5 \times 2\pi/20$		



Question Number	Acceptable Answer	Additional Guidance	Mark
3	The only correct answer is C (There is a force on the person due to Newton's third law.) A is not the correct answer, as a centripetal force acts on the ball B is not the correct answer, as Newton's first law describes the force on the ball D is not the correct answer, as weight does not act in the horizontal plane		1



Question Number	Acceptable answers	Additional guidance	Mark
13	- Measures angle at $52^\circ \pm 2^\circ$ (1) - Uses $F = ma$ horizontally (1) - Resolves forces vertically (1) - Uses $a = v^2 / r$ Or $a = r\omega^2$ (1) - Calculates the 51° and reaches a consistent conclusion (1)	Accept angle calculate from measured dimensions and trigonometry. <u>Example of calculation</u> $T \sin \theta = \frac{mv^2}{r}$ $T \cos \theta = mg$ $\tan \theta = \frac{v^2}{rg}$ $\tan \theta = (3.8)^2 (\text{m s}^{-1})^2 / 1.2 \text{ m} \times 9.81 \text{ m s}^{-2}$ $\theta = 50.8^\circ$	5

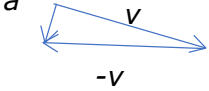
(Total for Question 13 = 5 marks)



Question Number	Acceptable answers	Additional guidance	Mark
11(a)	- Use of $F = \frac{mv^2}{r}$ (1) - States that $F = mg$ only as reaction force is zero (1)	Example of derivation: $mg = \frac{mv^2}{r}$ $v = \sqrt{gr}$	(2)
11(b)	- Use of energy conservation (1) - Substitution of $v^2 = rg$ (1) $V_{\text{bottom}} = 2.7 \text{ m s}^{-1}$ (1)	Example of calculation: $\frac{1}{2}mv^2_{\text{top}} + mgh = \frac{1}{2}mv^2_{\text{bottom}}$ $g(\text{ms}^{-2})r(\text{m}) + 2g(\text{ms}^{-2})0.30(\text{m}) = v^2(\text{ms}^{-1})^2$ $v^2 = 0.75g$ $v = 2.71\text{ms}^{-1}$	(3)
11(c)	- Use of $s = ut + \frac{1}{2}at^2$ (1) - Recognise $u = 0$ (1) - Use of $v = d/t$ in horizontal direction (1) - Displacement = 1.1 m (1)	Example of calculation: $0.65 \text{ m} = \frac{1}{2}9.81 \text{ ms}^{-2}t^2$ $t = 0.364 \text{ s}$ $s = 3.0 \text{ ms}^{-1} \times 0.364 \text{ s}$ $s = 1.09 \text{ m}$	(4)

(Total for Question 11 = 9 marks)



Question Number	Acceptable answers	Additional guidance	Mark
11(a)	- vector velocities of same length with arrows as shown to indicate a difference. The “minus” v line should be approximately horizontal. - third side identified as Δv/acceleration in direction approximately towards centre of circle	(1) (1) Example of diagram  Accept “-v” line as arrow to right and labelled “v”	2
11(b)(i)	- Use of $v = \frac{2\pi r}{T}$ or $\omega = \frac{2\pi}{T}$ - Use of $a = \frac{v^2}{r}$ or $r\omega^2$ $a = 8.8 \text{ m s}^{-2}$	(1) (1) (1) <u>Example of calculation</u> $v = \frac{2\pi \times 6800000 \text{ m}}{92 \times 60 \text{ s}} = 7740 \text{ m s}^{-1}$ $a = \frac{7740^2}{6800000} = 8.81 \text{ m s}^{-2}$ or $\omega = \frac{2\pi}{92 \times 60 \text{ s}} = 1.14 \times 10^{-3} \text{ rad s}^{-1}$ $a = 6800000 \text{ m} \times (1.14 \times 10^{-3} \text{ rad s}^{-1})^2$ $a = 8.81 \text{ m s}^{-2}$	3



11(b)(ii)	- The astronauts have weight or not weightless (1) - Or Earth's gravitational field = 8.8 N kg^{-1} on ISS (ECF from (b)(i)) - Earth's gravitational field keeps astronauts/ISS in circular motion (1) - Or Weight provides the centripetal force (1) - Our notion of "weight" is reaction force acting on us from the ground/floor (1) - There are no reaction forces from the ISS on the astronauts so they "feel" weightless (1)		4
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(Total for Question 11 = 9 marks)



Question Number	Acceptable answers	Additional guidance	Mark
13a	- A (resultant) force F is required to maintain circular motion (1) - This force is friction (between car/slider and track) (1) - As v increased F required increased until it exceeds friction and car slides off track (1)	alt: A (resultant) force acts to the centre of the circle.	3
13bi	- use of $s = \frac{(u+v)}{2} \times t$ (1) $v = 3.1 \text{ (m s}^{-1}\text{)}$ (1)	Example of calculation: $1.1 \quad m = \frac{(0+v)}{2} \times 0.77 \text{ s}$ $v = 3.1 \text{ m s}^{-1}$	2
13bii	- use of $F = mv^2/r$ (1) $F = 11 \text{ N}$ (allow ecf from (i)) (1)	Example of calculation: $F = \frac{0.050 \text{ kg} \times 3.1^2 \text{ (m s}^{-1}\text{)}^2}{0.042 \text{ m}}$ $F = 11.4 \text{ N}$ “show that value” gives $F = 10.7 \text{ N}$	2
13c	- inner lane covers a smaller distance (1) - inner lane has a smaller radius of curvature (1) (maximum horizontal force is the same for both cars) therefore maximum speed is greater for the car on the outside lane (so outcome unclear) (1)		3

(Total for Question 13 = 10 marks)



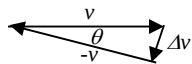
Question Number	Acceptable Answer	Additional Guidance	Mark																																																				
*6(a)	This question assesses a student’s ability to show a coherent and logically structured answer with linkages and fully sustained reasoning. Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning. The table shows how the marks should be awarded for indicative content and structure and lines of reasoning. <table><tr><th>Number of indicative marking points seen in answer</th><th>Number of marks awarded for indicative 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> <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> Indicative content: IC1 The rider experiences a resultant force acting towards the centre (of the circular path) IC2 This (resultant) force is constant, as the rider has a constant (angular) velocity Or the weight W is constant IC3 At the bottom of the circle P and W act in opposite directions, so P must be greater than W IC4 At the top of the circle P and W act in the same direction, and so P must be less (than at the bottom of the circle) IC5 P is the weight the rider appears to have IC6 The rider would feel heavier at the bottom of the circle Or the rider would feel lighter at the top of the circle	Number of indicative marking points seen in answer	Number of marks awarded for indicative marking points	6	4	5–4	3	3–2	2	1	1	0	0		Number of marks awarded for structure of answer and sustained line of reasoning	Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout	2	Answer is partially structured with some linkages and lines of reasoning	1	Answer has no linkages between points and is unstructured	0	Total marks awarded is the sum of marks for indicative content and the marks for structure and lines of reasoning <table><tr><th>IC points</th><th>IC mark</th><th>Max linkage mark</th><th>Max final mark</th></tr><tr><td>6</td><td>4</td><td>2</td><td>6</td></tr><tr><td>5</td><td>3</td><td>2</td><td>5</td></tr><tr><td>4</td><td>3</td><td>1</td><td>4</td></tr><tr><td>3</td><td>2</td><td>1</td><td>3</td></tr><tr><td>2</td><td>2</td><td>0</td><td>2</td></tr><tr><td>1</td><td>1</td><td>0</td><td>1</td></tr><tr><td>0</td><td>0</td><td>0</td><td>0</td></tr></table> Accept “the rider experiences a centripetal force”	IC points	IC mark	Max linkage mark	Max final mark	6	4	2	6	5	3	2	5	4	3	1	4	3	2	1	3	2	2	0	2	1	1	0	1	0	0	0	0	6
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6(b)	MAX 4 • The riders are most at risk of falling out of their seats when they are at the top of the circular path. (1) • But, as long as the contact/reaction force from the seat (P) is always greater than zero the riders will not fall out of their seats. (1) • The faster the ride rotates the larger the value of the contact/reaction force from the seat (P) needed to maintain the rider in a circular path (1) • So there is a minimum speed for the ride (when it is in vertical mode) Or the safety harness will be needed if the ride slows down or stops (1) • It is the need for centripetal not centrifugal force that “keeps the riders in their seats” (1)	Accept “there is no centrifugal force”	4
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(Total for Question 6 = 10 marks)



17a	- vector velocities at two positions as part of a triangle and third side identified as Δv (1) - Acceleration $a = \Delta v/t$ (i) (1) - Use of trigonometry: $\Delta v/v \approx \sin\theta \approx \theta$ for small angles (ii) (1) - Use of $v = r\theta/t$ (iii) (1) - Combine i, ii, iii to final equation (1) OR - Diagram shows components of v with angle turned through (1) - Acceleration $= 2v\sin\theta/t$ (1) - Use of trigonometry: $\Delta v/v \approx \sin\theta \approx \theta$ for small angles (1) $t = r2\theta/v$ and 2s cancel (1) - Simplify to final equation (1)	<u>Example of diagram</u>  Ignore arrow directions Combine (i) and (ii) $a = v\theta/t$ Substitute for θ using (iii) $a = \frac{v}{t} \times \frac{vt}{r}$ then “t”s cancel Allow other fully correct methods	5
17b(i)	- Correct conversion to angle in radians (1) $\omega = 5.2 \text{ (rads}^{-1}\text{)}$ (1)	<u>Example of calculation</u> $\omega = 50 \times 2\pi / 60 \text{ s}$ $= 5.24 \text{ rads}^{-1}$	2
17b(ii)	- Reference to $F = mr\omega^2$ (1) - appreciation that r is large (1) Or (the equipment) has a high (linear) velocity	Alt: mass (of equipment) could be large	2
17b(iii)	- use of $r\omega^2$ (1) $a = 25g$ and appropriate comment (1)	Show that value gives $22.5g$ Allow reverse argument starting with $25g$ to $\omega = 5.28 \text{ rads}^{-1}$ <u>Example of calculation</u> $a = 8.8 \text{ (m)} \times 5.24^2 \text{ (rads}^{-1}\text{)}^2$ $a = 238 \text{ (ms}^{-2}\text{)} \div 9.81 \text{ (ms}^{-2}\text{)}$ $= 24.6 \times g$	2

(Total for Question 17 = 11 marks)

Question Marks	Acceptable Answers	Additional guidance	Mark
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Question Number	Acceptable Answer	Additional Guidance	Mark																																																				
*17(a)	This question assesses a student’s ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning. Total marks awarded is the sum of marks for indicative content and the marks for structure and lines of reasoning. <table><tr><th>IC points</th><th>IC mark</th><th>Max linkage mark</th><th>Max final mark</th></tr><tr><td>6</td><td>4</td><td>2</td><td>6</td></tr><tr><td>5</td><td>3</td><td>2</td><td>5</td></tr><tr><td>4</td><td>3</td><td>1</td><td>4</td></tr><tr><td>3</td><td>2</td><td>1</td><td>3</td></tr><tr><td>2</td><td>2</td><td>0</td><td>2</td></tr><tr><td>1</td><td>1</td><td>0</td><td>1</td></tr><tr><td>0</td><td>0</td><td>0</td><td>0</td></tr></table> Indicative content: IC1 There is a change in the (magnetic) field/flux (linkage with aluminium disc) Or (disc is) cutting (magnetic) field/flux IC2 So an <u>e.m.f.</u> is <u>induced</u> IC3 There is a current (in the disc) IC4 Force acts on the disc, as there is a current in a magnetic field Or Field due to current in disc interacting with field due to magnet to cause force on disc IC5 The disc moves to reduce the change in field/flux IC6 According to Lenz’s law	IC points	IC mark	Max linkage mark	Max final mark	6	4	2	6	5	3	2	5	4	3	1	4	3	2	1	3	2	2	0	2	1	1	0	1	0	0	0	0	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 points seen in answer</th><th>Number of marks awarded for indicative 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> <table><tr><th></th><th>Number of marks awarded for structure and lines of reasoning</th></tr><tr><td>Answer shows a coherent and logical structure with linkage 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 linkage between points and is unstructured</td><td>0</td></tr></table> IC4 Accept reference to $F = BIl$ if current in disc has been mentioned IC6 dependent on IC5	Number of indicative points seen in answer	Number of marks awarded for indicative points	6	4	5-4	3	3-2	2	1	1	0	0		Number of marks awarded for structure and lines of reasoning	Answer shows a coherent and logical structure with linkage and fully sustained lines of reasoning demonstrated throughout	2	Answer is partially structured with some linkages and lines of reasoning	1	Answer has no linkage between points and is unstructured	0	6
IC points	IC mark	Max linkage mark	Max final mark																																																				
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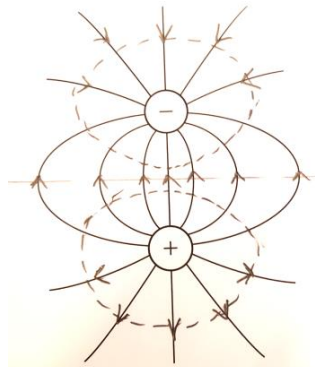
17(b)	(The speedometer reading is proportional / related to) angular velocity of axle/cable (1) - As $v = r\omega$ different radii / r will lead to different (road) speeds (1) Or (different diameter) therefore circumference of wheels are different Or one rotation leads to a different distance travelled Or different number of rotations over a set distance (1) - So the angular velocity is different for the same speed Or the velocity is different for the same angular velocity (1)	Accept angular frequency Or frequency of rotations Accept angular frequency Or frequency of rotations	2
17(c)	- Use of $P = W/t$ and $\Delta W = F\Delta s$ (1) - Use of $\Delta E_{\text{grav}} = mg\Delta h$ (1) - Use of principle of conservation of energy [MP3 dependent on MP2] (1) - Velocity = $5.5 \text{ (m s}^{-1}\text{)}$ so speedometer reading slightly inaccurate Or Velocity = $5.5 \text{ (m s}^{-1}\text{)}$ so speedometer reading is quite accurate Or Total power = 334 (W) so speedometer reading must have been correct (1)	<u>Example of calculation</u> $190 \text{ W} = F \times 8.3 \text{ m s}^{-1}$ $F = 22.9 \text{ N}$ Power loss due to friction and air resistance = $22.9 \text{ N} \times v$ Gain in G.P.E. / second = $75 \text{ kg} \times 9.81 \text{ m s}^{-2} \times \frac{v}{20}$ $330 \text{ W} = 22.9 \text{ N} \times v + 75 \text{ kg} \times 9.81 \text{ m s}^{-2} \times \frac{v}{20}$ $330 \text{ W} = 22.9v + 36.79v = 59.7v$ $v = 5.53 \text{ m s}^{-1}$ Alternative resulting on comparison of power: $190 \text{ W} = F \times 8.3 \text{ m s}^{-1}$ $F = 22.9 \text{ N}$ Gain in G.P.E. / second = $75 \text{ kg} \times 9.81 \text{ m s}^{-2} \times \frac{5.6}{20} \text{ m s}^{-1}$ Gain in G.P.E. / second = 206 W Power loss due to friction and air resistance = $22.9 \text{ N} \times 5.6 \text{ m s}^{-1} = 128 \text{ W}$ Total power = 334 W	4



	Alternative based on resolving forces: • Use of $P = W/t$ and $\Delta W = F\Delta s$ • Determines a component of force • Determines total force along the slope • Velocity = 5.5 m s^{-1} so (speedometer reading) slightly inaccurate Or Velocity = 5.5 m s^{-1} so (speedometer reading) is accurate Or Total power = 334 (W) so (speedometer reading) must be correct	Alternative based on resolving forces: $190 \text{ W} = F \times 8.3 \text{ m s}^{-1}$ $F = 22.9 \text{ N}$ Component of weight along slope = $75 \text{ kg} \times 9.81 \text{ m s}^{-2} \times \frac{1}{20}$ as $\sin \theta \sim \tan \theta = 1/20$ Force up slope from cyclist = $22.9 \text{ N} + 75 \text{ kg} \times 9.81 \text{ m s}^{-2} \times \frac{1}{20} = 59.7 \text{ N}$ So velocity of cyclist = $\frac{330 \text{ W}}{59.7 \text{ N}} = 5.53 \text{ m s}^{-1}$ Or Cyclist Power = $59.7 \text{ N} \times 5.6 \text{ m s}^{-1} = 334 \text{ W}$	
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(Total for Question 17 = 12 marks)



Question Number	Acceptable answers	Additional guidance	Mark
18(a)	- Replace Work W by force $\times$ distance (1) - Replace distance $\div$ time by velocity v (1) - Use $v = r \times$ Angular velocity (1) - Recognise $F \times r$ is the moment of F (1)	Alternative method: Consider one revolution of axle , Load rises $2\pi r$ Work done = $2\pi r F$ Time taken = $2\pi \div \omega$ Power = Work $\div$ time = $2\pi r F \div 2\pi/\omega$ to give reqd eq	4
18(b)(i)	- Arrow away from + charge Or arrow towards – charge (1) - At least 3 Equipotential lines, perpendicular to field lines (1) - Symmetrical about vertical/horizontal axis and not touching/crossing (1)	MP3 dependent on lines being perpendicular in MP2 	3

18(b)(ii)	- Use of $F = \frac{Q_1 Q_2}{4\pi\epsilon_0 r^2}$ (1) $F = 0.036 \text{ (N)}$ (1)	<u>Example of calculation:</u> $F = 8.99 \times 10^9 \text{ Nm}^2 \text{C}^{-2} \frac{(0.1 \times 10^{-6} \text{ C})^2}{(0.05 \text{ m})^2}$ $F = 0.036 \text{ N}$	2
18(c)	- Use of moment = $F \times$ (1) - Expression for correct moment (1) - Use of power = moment of force $\times$ angular velocity (1) - Only realistic possibility is pond pump and $P = 0.6 \text{ W}$ (calculated answer could also be force and then comparison with b(i)) (1)	Show that value gives $3.2 \times 10^{-3} \text{ Nm}$ and 0.64 W <u>Example of calculation:</u> $\text{Moment} = 0.036 \text{ N} \times 0.04 \text{ m} \times 2 = 2.89 \times 10^{-3} \text{ Nm}$ $\text{Power} = 2.89 \times 10^{-3} \text{ N m} \times 200 \text{ s}^{-1} = 0.58 \text{ W}$	4

(Total for Question 18 = 13 marks)



Question Number	Acceptable Answer	Additional Guidance	Mark
3(a)	An explanation that makes reference to the following points: - Uncertainty in each reading = 0.05 cm - Uncertainty in r is $2 \times$ uncertainty in each reading (1) - Hence percentage uncertainty = 0.8 % (1)	<u>Example of calculation:</u> $\% \text{ uncertainty} = \frac{0.1 \text{ cm}}{(17.5-5.0) \text{ cm}} \times 100 \% = 0.8 \%$ Accept statement that uncertainty in $r = 0.1 \text{ cm}$ for MP2	3
3(b)(i)	To reduce the effect of random errors (1)		1
3(b)(ii)	- Use of data to calculate mean value (1) - Use of half range (1) Or Use of greatest deviation from mean % uncertainty in range 5 % to 6% consistent with student's working (1 or 2 SF) (1)	Example of calculation: $\omega_{av} = \frac{(0.112+0.116+0.118+0.123+0.125)}{5} = 0.119 \text{ rad s}^{-1}$ Half range value = $\frac{0.125 \text{ mm} - 0.112 \text{ mm}}{2} = 0.0065$ $\therefore \% \text{ uncertainty} = \frac{0.0065 \text{ mm}}{0.119 \text{ mm}} \times 100 \% = 5.5 \%$ Use of greatest deviation from mean gives 5.9 %	3
3(b)(iii)	% uncertainty in ω is doubled (1) - Add % uncertainty in r (1) % uncertainty = 11 % to 13% consistent with student's working (2 or 3 SF)(ecf from (b)(ii)) (1)	Don't penalise sf in both (ii) and (iii) Example of calculation: % uncertainty = 5% + 5% + 1% = 11%	3
3(c)	An explanation that makes reference to the following points: - The centripetal force is provided by friction (1) - There is a max (frictional) force Or (frictional) force is the same when coin starts to slide (1) $F = m\omega^2 r$ so as r increased ω decreased (1)	For MP3 accept ω^2 for ω	3

(Total for Question 3 = 13 marks)



Question Number	Acceptable Answer	Additional Guidance	Mark
11(a)(i)	An explanation that makes reference to the following points: - The velocity/momentum increases as the energy of the protons increases (1) $r = \frac{p}{Bq}$ and $p=mv$ so the magnetic flux density must increase (to keep r constant). - Or $r = \frac{p}{Bq}$ and $E_k = \frac{p^2}{2m}$ so the magnetic flux density must increase (to keep r constant). - Or $F = \frac{mv^2}{r}$ and $F = Bqv$ so the magnetic flux density must increase (to keep r constant) (1)		2



11(a)(ii)	- Radius calculated - Use of $F = \frac{mv^2}{r}$ - Use of $F = Bqv$ $B = 7.3 \times 10^{-5} \text{ T}$	(1) (1) Allow use of $p = mv$ for MP2 (1) and use of $r = \frac{p}{Bq}$ for MP3 (1) <u>Example of calculation</u> $r = \frac{\text{circumference}}{2\pi} = \frac{27 \times 10^3 \text{ m}}{2\pi} = 4.30 \times 10^3 \text{ m}$ $F = \frac{1.67 \times 10^{-27} \text{ kg} \times (3.0 \times 10^7 \text{ m s}^{-1})^2}{4.30 \times 10^3 \text{ m}} = 3.50 \times 10^{-16} \text{ N}$ $B = \frac{3.50 \times 10^{-16} \text{ N}}{1.6 \times 10^{-19} \text{ C} \times 3.0 \times 10^7 \text{ m s}^{-1}} = 7.28 \times 10^{-5} \text{ T}$	4
11(a)(iii)	- Conversion to joule - Use of $\Delta E = c^2 \Delta m$ $m = 2.4 \times 10^{-23} \text{ (kg)}$	(1) <u>Example of calculation</u> (1) $E = 13\,600 \times 10^9 \text{ eV} \times 1.6 \times 10^{-19} \text{ J eV}^{-1} = 2.18 \times 10^{-6} \text{ J}$ (1) $m = \frac{2.18 \times 10^{-6} \text{ J}}{(3.0 \times 10^8 \text{ m s}^{-1})^2} = 2.42 \times 10^{-23} \text{ kg}$	3



*11(b)	This question assesses a student’s ability to show a coherent and logical structured answer with linkage and fully-sustained reasoning Indicative content: IC1 In a fixed target collision there is momentum before the collision so there is momentum after the collision IC2 So particle(s) created must have some kinetic energy IC3 So not all kinetic energy converted to mass IC4 In a colliding beam experiment total initial momentum is zero (if the colliding particles have the same mass and speed) IC5 Momentum after the collision will be zero IC6 So (almost) all of the kinetic energy is converted to mass	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 indicative 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> <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> Total marks awarded is the sum of marks for indicative content and the marks for structure and lines of reasoning. <table><tr><th>IC points</th><th>IC mark</th><th>Max linkage mark</th><th>Max final mark</th></tr><tr><td>6</td><td>4</td><td>2</td><td>6</td></tr><tr><td>5</td><td>3</td><td>2</td><td>5</td></tr><tr><td>4</td><td>3</td><td>1</td><td>4</td></tr><tr><td>3</td><td>2</td><td>1</td><td>3</td></tr><tr><td>2</td><td>2</td><td>0</td><td>2</td></tr><tr><td>1</td><td>1</td><td>0</td><td>1</td></tr><tr><td>0</td><td>0</td><td>0</td><td>0</td></tr></table>	Number of indicative marking points seen in answer	Number of marks awarded for indicative marking points	6	4	5–4	3	3–2	2	1	1	0	0		Number of marks awarded for structure of answer and sustained line of reasoning	Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout	2	Answer is partially structured with some linkages and lines of reasoning	1	Answer has no linkages between points and is unstructured	0	IC points	IC mark	Max linkage mark	Max final mark	6	4	2	6	5	3	2	5	4	3	1	4	3	2	1	3	2	2	0	2	1	1	0	1	0	0	0	0	6
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(Total for Question 11 = 15 marks)

