Name: ____

Topic 6: Further Mechanics Part 1

Date:

Time:

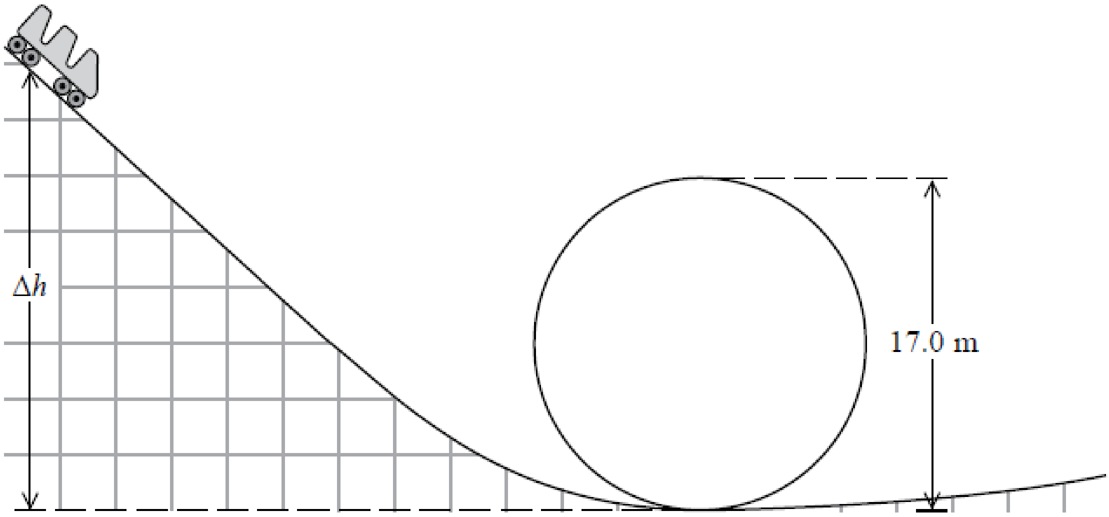
Total marks available:

Total marks achieved: ______

Questions

Q1.

The diagram shows the carriage of a rollercoaster about to enter a vertical loop of diameter 17.0 m. The carriage is initially at rest at a height Δh above the bottom of the loop.



(i) So that a passenger remains in contact with their seat at the top of the ride, show that the minimum speed of the car at the top of the loop is 9.1 m s^{-1}.

(3)

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(ii) Calculate the minimum value of Δh that will enable the passenger to remain in contact with their seat at the top of the loop.

(3)

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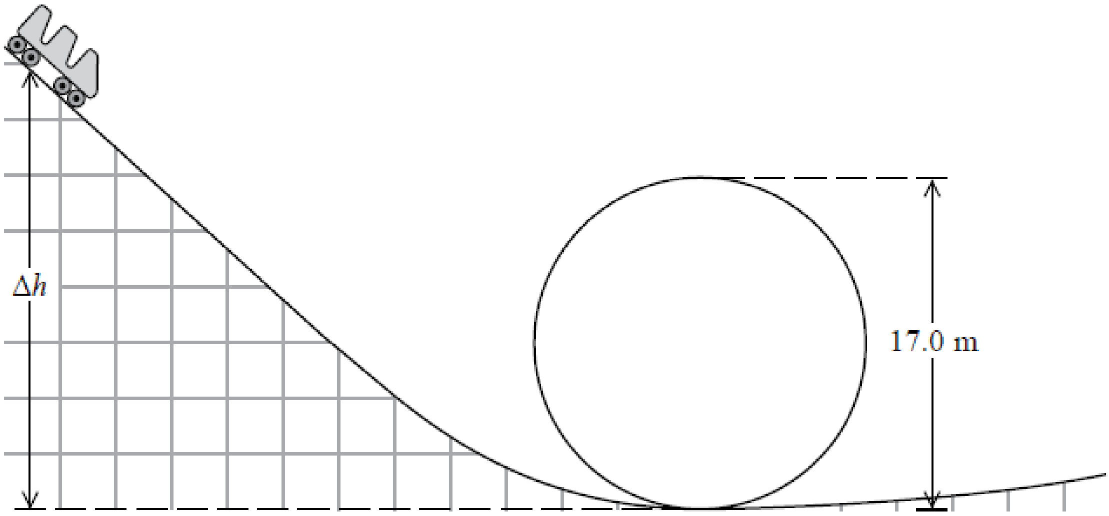
Δh = ...

(Total for question = 4 marks)

Q2.

The diagram shows the carriage of a rollercoaster about to enter a vertical loop of diameter 17.0 m. The carriage is initially at rest at a height Δ*h* above the bottom of the loop.



During one particular ride, the speed of a car at the bottom of the loop was 22.5 m s^{-1}.

(i) Calculate the acceleration of the passenger at the bottom of the loop as a multiple of *g*, the acceleration due to gravity.

(2)

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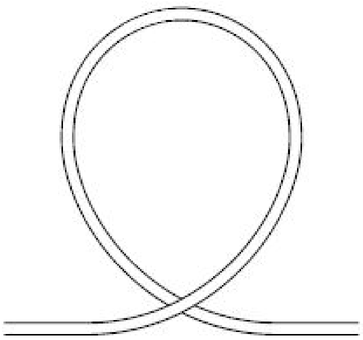
Acceleration = ...

(ii) The maximum safe acceleration recommended for passengers is 4*g*. Most loop-the-loop rollercoasters do not have a circular loop. Instead, the radius of curvature of the loop varies.



Explain why making the radius of the loop vary in this way enables the acceleration at the bottom of the loop to be less than 4*g*.

(2)

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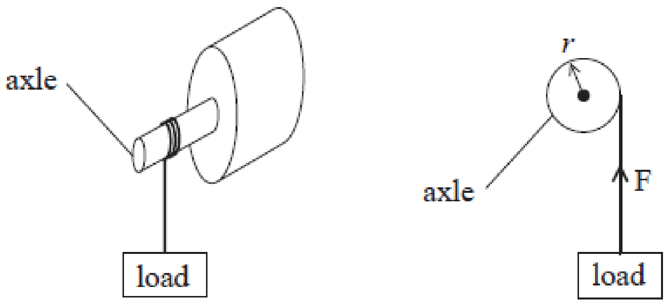
(Total for question = 10 marks)

Q3.

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 × angular velocity

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

(4)

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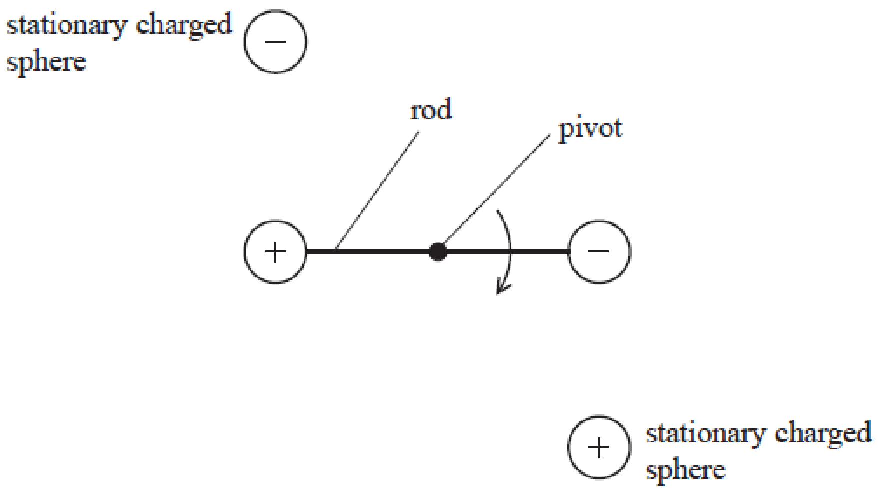
(b) An electrostatic motor was first demonstrated by Benjamin Franklin in 1750.

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.

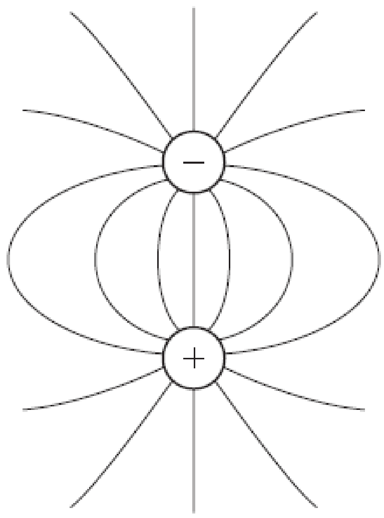


(i) In the diagram below, electric field lines have been drawn around one pair of these spheres.

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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(Total for question = 13 marks)

Q4.

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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(Total for question = 5 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 ☒.

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 = 1 mark)

Q6.

A particle moving in a circular path completes 8.0 revolutions in 5.0 s.
Its angular velocity in rad s^{-1} is

☐ **A** 1.6

☐ **B** 10

☐ **C** 40

☐ **D** 250

(Total for question = 1 mark)

Q7. A fairground roundabout makes 8 revolutions in 1 minute. The angular velocity of the roundabout is

☒ **A** 0.10 rad s^{-1}

☒ **B** 0.42 rad s^{-1}

☒ **C** 0.84 rad s^{-1}

☒ **D** 0.94 rad s^{-1}

(Total for Question = 1 mark)

Q8. The drum of a washing machine rotates with an angular velocity of 8.5 rad s^{-1}.

The time to complete 10 revolutions is

☒ **A** 0.85 s

☒ **B** 1.3 s

☒ **C** 3.7 s

☒ **D** 7.4 s

(Total for Question = 1 mark)

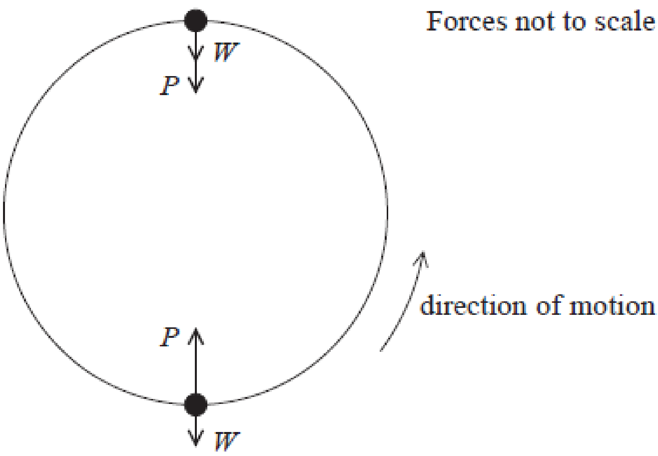
Q9.

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.



* The rider moves from the bottom to the top of the circular path.

Explain how the apparent weight experienced by the rider would change.

(6)

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(Total for question = 6 marks)

Q10.

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

Which of the following are the base units for impulse?

☐ **A** kg m s^{-1}

☐ **B** kg m s^{-2}

☐ **C** N m

☐ **D** N s

(Total for question = 1 mark)

Q11.

Astronomers observing stars at the centre of our galaxy have suggested that many of them are orbiting a supermassive black hole. The mass of this black hole is 9.2×10^{36} kg.

Calculate the orbital period for a star in a circular orbit at a distance of 1.9×10^{14} m from a black hole of this mass.

(3)

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Orbital period = ...

(Total for question = 3 marks)

Q12.

In 1990, the Hubble Space Telescope (HST) was launched into a low Earth orbit above the Earth's atmosphere.

HST orbits the Earth in a circular orbit with a speed of 7.59 km s^{-1}.

mass of Earth = 5.97×10^{24} kg
radius of Earth = 6.37×10^{6} m

(i) Show that the height of HST above the surface of the Earth is about 6×10^{5} m.

(3)

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(ii) Calculate the increase in the gravitational potential energy as HST is raised, from its initial position at the Earth's surface, to its orbital height.

mass of HST = 11 600 kg

(2)

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Increase in gravitational potential energy = ...

(iii) A student suggests that giving HST more energy than that required in (ii) would result in the satellite orbiting at a greater height and with a greater speed.

Assess the validity of the student's suggestion.

(4)

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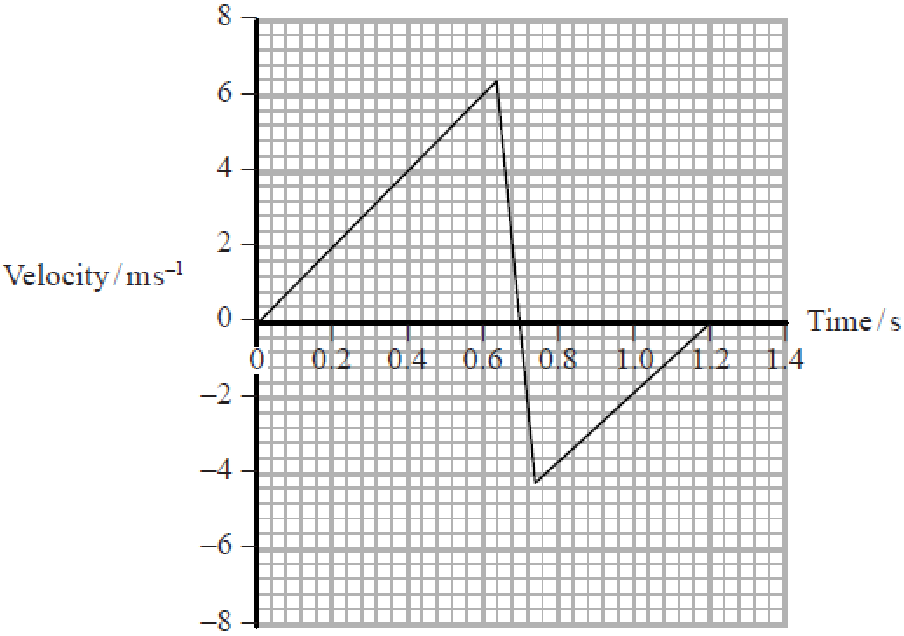
(Total for question = 9 marks)

Q13.

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)

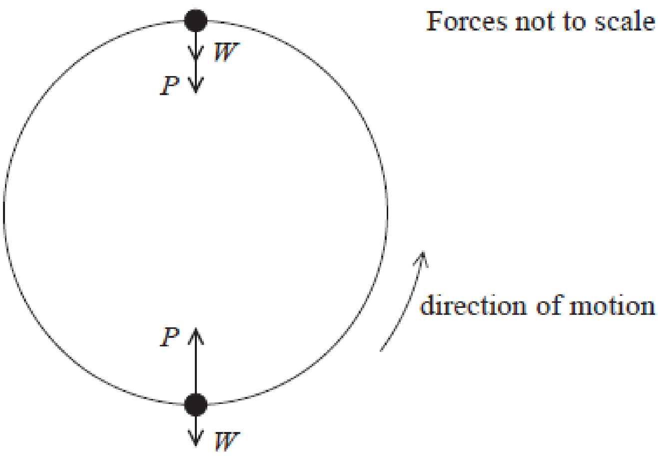
Q14.

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.



On the website of the amusement park it states

"The ride is perfectly safe without the need for safety harnesses for the riders. Centrifugal force ensures that the riders remain in their seats at all stages in the ride."

Assess the validity of this statement.

(4)

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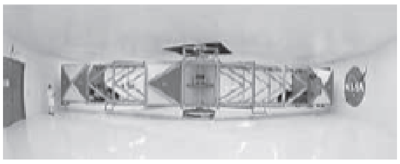
(Total for question = 4 marks)

Q15.

A centrifuge is a machine which rotates.

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.



(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 25*g*.

Deduce whether this claim is correct.

(2)

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(Total for question = 6 marks)

Q16.

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

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

Calculate the centripetal acceleration of the ISS.

r = 6800 km

(3)

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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)

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(Total for question = 7 marks)

Q17. A racing car of mass 1200 kg travels at 0.63 rad s^{-1} around a bend of radius 50 m. The force on the car necessary for this motion is

☒ **A** 2.4×10^4 N away from the centre of the circle.

☒ **B** 2.4×10^4 N towards the centre of the circle.

☒ **C** 3.8×10^4 N away from the centre of the circle.

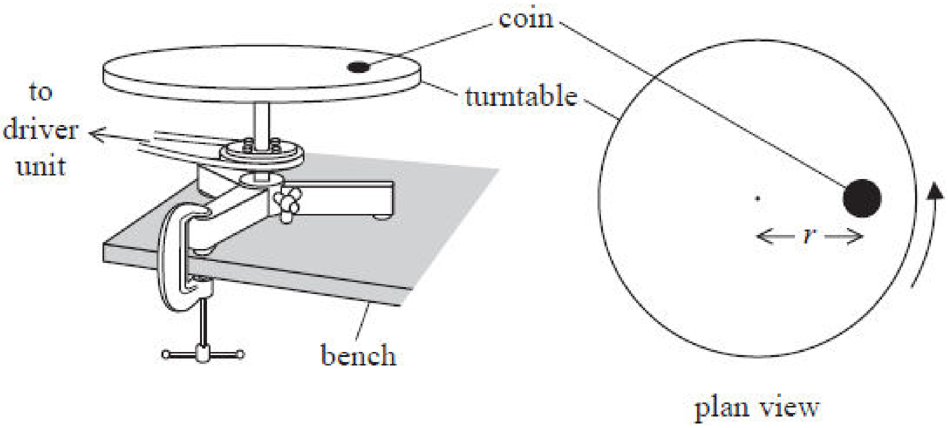
☒ **D** 3.8×10^4 N towards the centre of the circle.

(Total for Question = 1 mark)

Q18.

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.



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)

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(Total for question = 3 marks)

Q19.

The London Eye consists of a large vertical circle with 32 equally-spaced passenger cabins attached to it. The wheel rotates so that each cabin has a constant speed of 0.26 m s^{-1} and moves around a circle of radius 61 m.

(a) Calculate the time taken for each cabin to make one complete revolution.

(2)

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Time = ...

(b) Calculate the centripetal force acting on each cabin.

mass of cabin = 9.7×10^3 kg

(2)

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Centripetal force = ...

(c) (i) The diagram shows just the circle and the cabins. Draw arrows to show the direction of the centripetal force acting on a person in a cabin when the person is at each of positions **A**, **B** and **C**.

(3)

*(ii) As the person in a cabin moves around the circle, the normal contact force between the person and the cabin varies.

State the position at which this force will be a maximum and the position at which it will be a minimum. Explain your answers.

(4)

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(Total for question = 9 marks)

Q20. In order to make an object move around a circular path at a constant speed a resultant force must act on it.

(a) Explain why a resultant force is required and state the direction of this force.

(2)

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(b) When vehicles move around a bend on a level road, the resultant force is provided by friction between the tyres and the road. For a given vehicle and road surface there is a maximum value for this sideways frictional force.

Explain why roads designed for high-speed travel, such as motorways, do not have any sharp bends.

(2)

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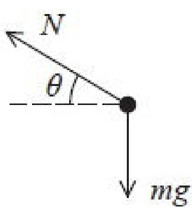
(c) Some cycling tracks are banked. When cornering, a cyclist moves up the track until the sideways frictional force is zero.

The free-body force diagram for a cyclist and bicycle is shown. The normal contact force exerted by the track is *N* and the weight of cyclist and bicycle is *mg*.



(i) By considering the vertical and horizontal motion, show that

$$\tan \theta = gr/v^2$$

where *r* is the radius of the cyclist's path and *v* is the cyclist's speed.

(3)

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(ii) Calculate the value of θ for a cyclist travelling at 11.0 m s^{-1} around a bend of radius 18.7 m.

(2)

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θ = ...

(Total for Question = 9 marks)

Q21.

The photograph is of a roundabout in a children's playground.

A child of mass 20 kg sits on the roundabout without holding the bars.

The distance from the centre of the roundabout to the centre of gravity of the child is 0.80 m. The maximum frictional force between the roundabout and the child is 0.35 × the weight of the child.

(a) Calculate the minimum time taken for one revolution of the roundabout if the child is not to slide off.

(4)

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Minimum time = ...

(b) State and explain how this time would change if a child of larger mass sat at the same place on the roundabout.

(2)

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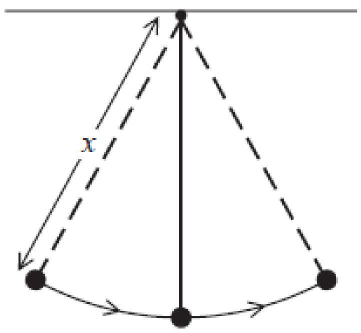
(Total for question = 6 marks)

Q22.

A pendulum consists of a bob of mass *m* and a string of length *x*.

The diagram shows the pendulum swinging through the arc of a circle. At the bottom of its swing the tension in the string is *T* and the velocity of the bob is *v*.



Which of the following is correct for the bob at the bottom of the swing?

☐ **A** $T = \frac{mv^2}{x} - mg$

☐ **B** $T = \frac{mv^2}{x} + mg$

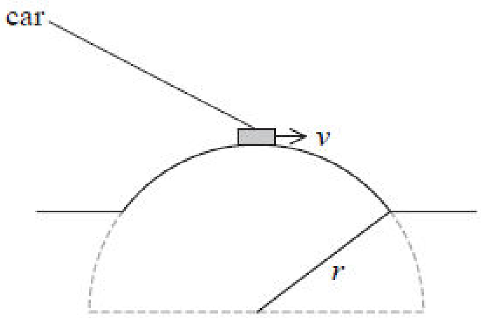
☒ **C** $T = mg - \frac{mv^2}{x}$

☒ **D** $T = \frac{mv^2}{x}$

(Total for question = 1 mark)

Q23.

Hump back bridges are sometimes found in country areas. The road surface is curved, describing an arc of a circle. If cars cross the bridge at too high a speed there is a danger they will lose contact with the road surface.



The responsibility for setting speed limits on many roads on which hump back bridges are found rests with the local traffic authority. One local traffic authority has suggested that a speed limit of 25 mph is appropriate for a hump back bridge with radius of curvature 10 m.

Assess the suitability of a speed limit of 25 mph for this bridge.

10 mph = 4.5 m s^{-1}

(5)

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(Total for question = 5 marks)

Q24.

At the beginning of the 20th century, Rutherford carried out large-angle alpha particle scattering experiments using gold ($^{197}_{79}Au$) foil.

The vast majority of the alpha particles went straight through the foil whilst a few were deflected straight back.

Rutherford also carried out the experiment with aluminium ($^{27}_{13}Al$) foil.
The aluminium foil had the same thickness as the gold foil and the alpha particles had the same initial kinetic energy.

The following observations were made.

Observation 1:
The fraction of alpha particles scattered at any particular angle for aluminium foil was always much less than for gold foil.

Observation 2:
The alpha particles scattered from aluminium foil had less kinetic energy than the alpha particles scattered from gold foil.

Explain how these observations can be used to deduce how an aluminium nucleus compares to a gold nucleus.

(4)

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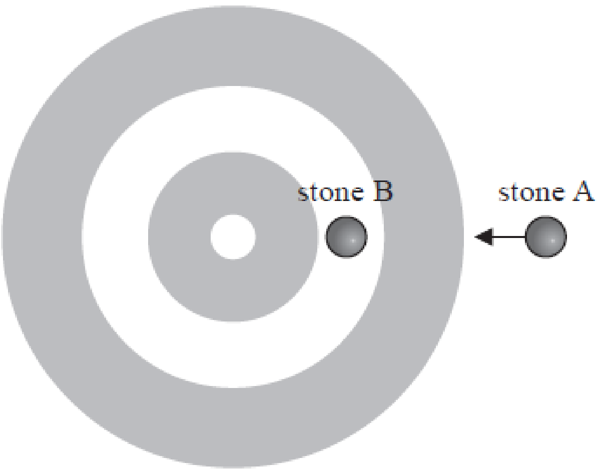
(Total for question = 4 marks)

Q25.

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

* 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*.



The collision is elastic. Just before the collision stone A has a velocity *v*. After the collision stone B moves off with velocity *v*.

Discuss how the relevant conservation laws apply to this collision.

(6)

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(Total for question = 6 marks)

Q26.

Which of the following statements is always true for an inelastic collision?

☒ **A** Both momentum and kinetic energy are conserved.

☒ **B** Neither momentum nor kinetic energy is conserved.

☒ **C** Kinetic energy is not conserved.

☒ **D** Momentum is not conserved.

(Total for question = 1 mark)

Q27.

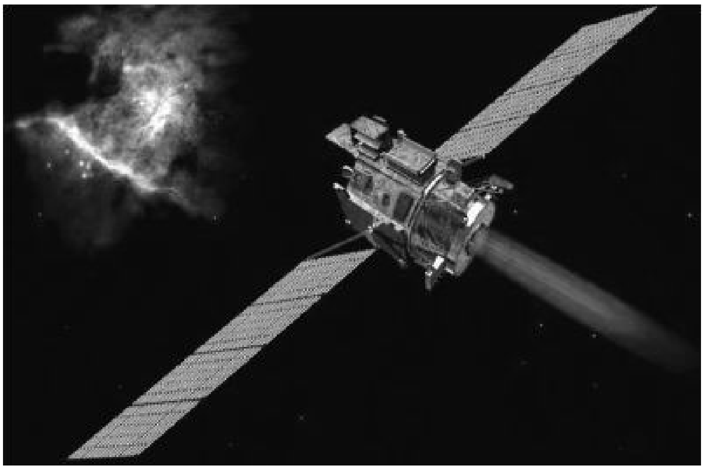
A bullet is fired into a block of wood. Select the line of the table that applies to this situation.

	Collision	Kinetic energy	Momentum
☒ A	elastic	conserved	conserved
☒ B	inelastic	not conserved	conserved
☒ C	elastic	conserved	not conserved
☒ D	inelastic	not conserved	not conserved

(Total for question = 1 mark)

Q28.

* The photograph shows a probe moving in space.



Whilst moving, empty fuel tanks can be ejected by means of an explosion. This has the effect of increasing the speed of the probe.

Discuss whether conservation of momentum and conservation of energy apply in this situation and why the speed of the probe increases.

(6)

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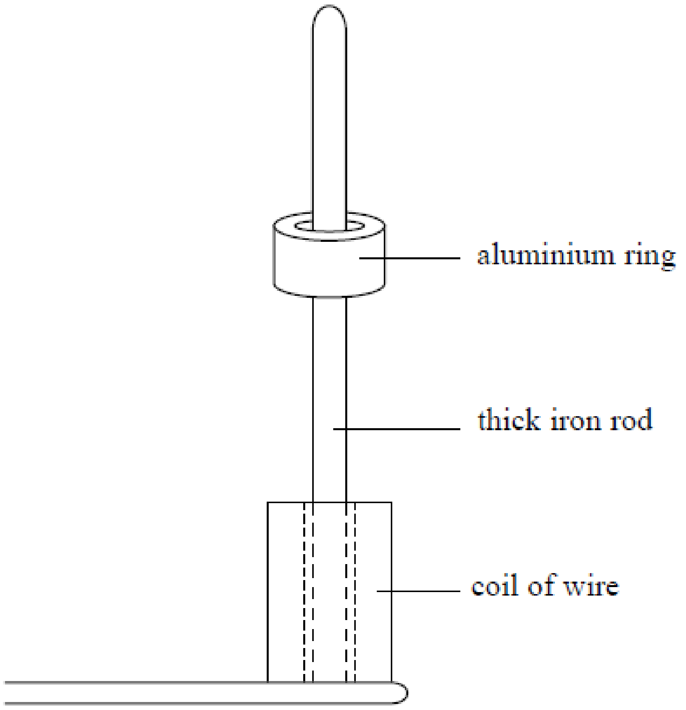
(Total for question = 6 marks)

Q29.

A coil of wire is placed around the lower end of an iron rod. The coil is supplied with an alternating current.

A thick aluminium ring is placed around the iron rod above the coil. The coil remains in the position shown.



The current is switched off and the aluminium ring comes to rest on top of the coil.
The supply to the coil is changed and a direct current (dc) is switched on. An upwards force *F* acts on the ring for 0.05 s accelerating it to a final speed, *v*. The ring then moves freely through a height of 30 cm.

Mean diameter of ring = 4.8 cm
Mass of ring = 0.019 kg
Magnetic field strength = 0.032 T

(i) Use conservation of energy to calculate the speed *v* of the ring after 0.05 s.

(2)

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v = ...

(ii) Use the idea of impulse to calculate the magnitude of the mean force *F* acting on the ring and hence the mean current *I* in the ring.

(6)

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F = ...

I = ...

(Total for question = 8 marks)

Q30.

The diagram shows a battery-powered clock on a wall. It has a minute hand and an hour hand.

(a) Calculate the average angular velocity of the minute hand.

(2)

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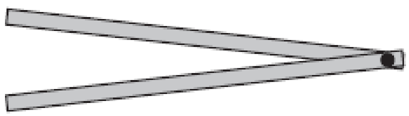
Angular velocity = ...

(b) The diagram shows the position of the minute hand when the time is 1 : 44 and when the time is 1 : 46.



The diagram is not to scale.

Show that the work done against the force of gravity to move the minute hand from 1 : 44 to 1 : 46 is about 1 mJ.

mass of minute hand = 14 g

length of minute hand = 8.0 cm

(5)

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(c) The clock uses a 1.5 V cell and draws a maximum current of 8.0 μA.

After a time, the maximum power of the cell has reduced to 65% of its initial value making the clock run slowly.

Calculate the time taken for the minute hand to move from the 1 : 44 position to the 1 : 46 position.

(3)

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Time taken = ...

(Total for question = 10 marks)

Mark Scheme

Q1.

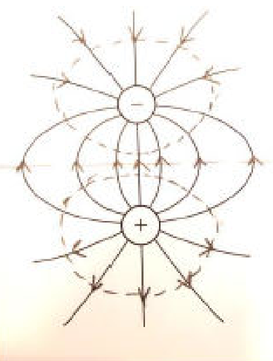
Question number	Acceptable answers	Additional guidance	Mark
(i)	• Recognise that for passenger to remain in their seat normal reaction $R \geq 0$ **(1)** **or** centripetal force >= weight **(1)** • Equate centripetal force and weight (for R=0) **(1)** • $v = 9.1\ \text{m s}^{-1}$ **(1)**	Example of calculation: $\frac{mv^2}{r} = mg$ $v = \sqrt{rg} = \sqrt{8.5\,\text{m} \times 9.81\,\text{m s}^{-2}} = 9.13\,\text{m s}^{-1}$	3
(ii)	• Equate decrease in gravitational potential energy to increase in kinetic energy at top of loop **(1)** • Adds this to 17.0 **(1)** • $\Delta h = 21.3$ m **(1)**	Example of calculation: $mgh = \frac{1}{2}mv^2$ $h = \frac{v^2}{2g} = \frac{(9.13\,\text{m s}^{-1})^2}{2 \times 9.81\,\text{m s}^{-2}} = 4.25\,\text{m}$ $\Delta h = 17 + 4.3 = 21.3$ m	3

Q2.

Question number	Acceptable answers	Additional guidance	Mark
(i)	• Use of $a = \frac{v^2}{r}$ **(1)** • $a = 6.1\text{g}$ **(1)**	Example of calculation: $a = \frac{v^2}{r} = \frac{(22.5\,\text{m s}^{-1})^2}{8.5\,\text{m}} = 59.6\,\text{m s}^{-2}$ $a = 59.6/9.8 = 6.1$ g	2
(ii)	An explanation that makes reference to: • Radius of curvature smallest at the top of the loop **(1)** **OR** radius larger at the bottom of the loop **(1)** • So acceleration at bottom is less for the same speed **(1)**		2

Q3.

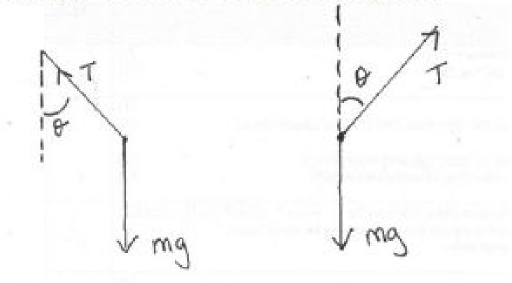
Question Number	Acceptable answers	Additional guidance	Mark
(a)	• Replace Work W by force × distance **(1)** • Replace distance ÷ time by velocity v **(1)** • Use $v = r \times$ Angular velocity **(1)** • Recognise $F \times r$ is the moment of F **(1)**	Alternative method: Consider one revolution of axle , Load rises $2\pi r$ Work done = $2\pi rF$ Time taken = $2\pi \div \omega$ Power = Work ÷ time= $2\pi rF \div 2\pi/\omega$ to give reqd eq	4

Question Number	Acceptable answers		Additional guidance	Mark
(b)(i)	• Arrow away from + charge **Or** arrow towards − charge • At least 3 Equipotential lines, perpendicular to field lines • Symmetrical about vertical/horizontal axis and not touching/crossing	(1) (1) (1)	MP3 dependent on lines being perpendicular in MP2 	3

Question Number	Acceptable answers		Additional guidance	Mark
(b)(ii)	• Use of $F = \frac{Q_1 Q_2}{4\pi\varepsilon_0 r^2}$ • $F = 0.036$ (N)	(1) (1)	Example of calculation: $F = 8.99 \times 10^9 \text{ Nm}^2\text{C}^{-2} \frac{(0.1 \times 10^{-6}\text{ C})^2}{(0.05\text{m})^2}$ $F = 0.036\text{N}$	2

Question Number	Acceptable answers		Additional guidance	Mark
(c)	• Use of moment = $F x$ • Expression for correct moment • Use of power = moment of force x angular velocity • Only realistic possibility is pond pump and $P = 0.6$W (calculated answer could also be force and then comparison with b(i))	(1) (1) (1) (1)	Show that value gives 3.2×10^{-3} Nm and 0.64 W Example of calculation: 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

Q4.

Question Number	Answer		Mark
	Free body force diagram showing 2 forces only Weight/*W*/*mg* Tension / *T* (Each additional forces e.g. horizontal component or resultant force, 1 mark penalty) **If θ is angle to the vertical then**: (Resolving vertically): $T\cos\theta = mg$ (Resolving horizontally): $T\sin\theta = mv^2/r$ **Or** $T\sin\theta = mr\omega^2$ Derives $\tan\theta = v^2/ rg$ **and** links to observations **Or** Derives $\tan\theta = r\omega^2/ g$ **and** links to observations If angle to horizontal is used candidates can score MP3 and 4.[then sin and cos swop over and tan of angle will be reciprocal of above] <u>Examples of free body force diagrams</u>  (full credit for the last 3 marks can be given to candidates who draw a vector triangle and derive tan $\theta = T_{horzt}$/mg and then $\tan\theta = r\omega^2/ g$ **and** observation)	 (1) (1) (1) (1) (1)	5
	Total for question		**5**

Q5.

Question Number	Acceptable answers	Additional guidance	Mark
	The only correct answer is D **314**	A, B and C all contain numerical errors	**1**

Q6.

Question Number	Answer	Mark
	B	1

Q7.

Question Number	Answer	Mark
	C	**1**

Q8.

Question Number	Answer	Mark
	D	**1**

Q9.

<table>
<tr><th>Question Number</th><th>Acceptable Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr>
<td>*</td>
<td>
This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully sustained reasoning.
Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.
The 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
</td>
<td>
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"
</td>
<td>6</td>
</tr>
</table>

Q10.

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

Q11.

Question Number	Acceptable answers	Additional guidance	Mark
	Use of $F = mv^2 / r$ with $F = Gm_1 m_2 / r^2$ **(1)** Use of $v = 2\pi r / T$ **(1)** $T = 6.64 \times 10^8$ s (= 21 years) **(1)** **Or** Use of $F = m\omega^2 r$ with $F = Gm_1 m_2 / r^2$ Use of $\omega = 2\pi / T$ $T = 6.64 \times 10^8$ s (= 21 years)	<u>Example of calculation</u> $F = Gm_1 m_2 / r^2 = m_2 v^2 / r = (2\pi r)^2 m_2 / rT^2$ $T^2 = 4\pi^2 r^3 / G m_1$ $= 4\pi^2 \times (1.9 \times 10^{14}\ \text{m})^3 / (6.67 \times 10^{-11}\ \text{N m}^2\ \text{kg}^{-2} \times 9.2 \times 10^{36}\ \text{kg})$ $T = 6.64 \times 10^8$ s (= 21 years)	3

Q12.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	• Use of $F = \frac{GMm}{r^2}$ with $F = \frac{mv^2}{r}$ (1) • Correct substitutions to calculate r (1) • $h = 5.4 \times 10^5$m (1) **OR** • Use of $g = \frac{GM}{r^2}$ to find value of g at orbit height (1) • Use of $a = \frac{v^2}{r}$ with value of g at orbit height (1) • $h = 5.4 \times 10^5$m (1)	Example of calculation: $\frac{GMm}{r^2} = \frac{mv^2}{r}$ $r = \frac{GM}{v^2}$ $r = \frac{6.67\times10^{-11}\text{N m}^2\text{kg}^{-2}\times5.97\times10^{24}\text{ kg}}{(7.59\times10^3\text{ m s}^{-1})^2}$ $r = 6.91\times10^6$m $\therefore h = (6.91\times10^6 - 6.37\times10^6)\text{ m} = 5.42\times10^5$m	3
(ii)	• Use of $GPE = \frac{GMm}{r}$ (1) • GPE = 5.7×10^{10} J (1) (ecf from (a)(i))	Example of calculation: $GPE = GMm\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$ $\therefore GPE = 6.67\times10^{-11}\text{Nm}^2\text{kg}^{-2} \times 5.97\times10^{24}\text{ kg} \times 11600\text{ kg}\left(\frac{1}{6.37\times10^6\text{m}} - \frac{1}{6.91\times10^6\text{m}}\right)$ $\therefore GPE = 5.67\times10^{10}$J	2

Question Number	Acceptable Answer	Additional Guidance	Mark
(iii)	• This would bring the gravitational potential energy closer to zero (1) • This would mean that the satellite would orbit at a greater height as $GPE \propto \frac{1}{r}$ (1) • To remain in orbit the centripetal acceleration must equal the gravitational field strength at the orbit height **Or** Since gravitational force smaller, $\frac{mv^2}{r}$ would be reduced (1) • (Hence) r is greater so v must be smaller **Or** $v^2 = \frac{GM}{r}$ and satellite would orbit at lower speed (1) **OR** • HST will have more kinetic energy at the original orbit height (1) • The centripetal force will be too small to keep it in this orbit (1) • The satellite would be travelling too fast, so it would move to a higher orbit (1) • (Hence) r is greater so v must be smaller **Or** $v^2 = \frac{GM}{r}$ and satellite would orbit at lower speed (1)		4

Q13.

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

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

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

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

Q14.

Question Number	Acceptable Answer	Additional Guidance	Mark
	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

Q15.

Question mark	Acceptable Answers		Additional Guidance	Mark
(i)	• Correct conversion to angle in radians • $\omega = 5.2$ (rads^{-1})	(1) (1)	<u>Example of calculation</u> $\omega = 50 \times 2\pi / 60$ s $= 5.24$ rads^{-1}	**2**
(ii)	• Reference to $F = mr\omega^2$ • appreciation that r is large **Or** (the equipment) has a **high** (linear) velocity	(1) (1)	Alt: mass (of equipment) could be large	**2**
(iii)	• use of $r\omega^2$ • $a = 25g$ **and** appropriate comment	(1) (1)	Show that value gives 22.5g Allow reverse argument starting with 25g to ω=5.28 rads^{-1} <u>Example of calculation</u> $a = 8.8$ (m) x 5.24^2 (rads^{-1})^2 $a = 238$ (ms^{-2}) ÷9.81 (ms^{-2}) $= 24.6\times g$	**2**

Q16.

Question Number	Acceptable answers	Additional guidance	Mark
(i)	• Use of $v = \frac{2\pi r}{T}$ or $\omega = \frac{2\pi}{T}$ (1) • Use of $a = \frac{v^2}{r}$ or $r\omega^2$ (1) • $a = 8.8\ \text{m s}^{-2}$ (1)	Example of calculation $v = \frac{2\pi 6800000\text{m}}{92\times60\text{s}} = 7740\ \text{m s}^{-1}$ $a = \frac{7740^2(\text{m s}^{-1})^2}{6800000\ \text{m}} = 8.81\ \text{m s}^{-2}$ or $\omega = \frac{2\pi}{92\times60\ \text{s}} = 1.14\times10^{-3}\ \text{rad s}^{-1}$ $a = 6800000\ \text{m} \times (1.14\times10^{-3}\ \text{rad s}^{-1})^2$ $a = 8.81\ \text{m s}^{-2}$	3
(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 • 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

Q17.

Question Number	Answer	Mark
	B	1

Q18.

Question Number	Acceptable Answer	Additional Guidance	Mark
	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**

Q19.

Question Number	Answer		Mark
(a)	Use of $v = 2\pi r/t$ **Or** $v = r\omega$ **and** $T = 2\pi/\omega$ $t = 1.5 \times 10^3$ s [24.6 minutes] <u>Example of calculation</u> $t = 2\pi r/v$ $t = (2\pi \times 61\ \text{m}) / 0.26\ \text{m s}^{-1}$ $t = 1473$ s	**(1)** **(1)**	**2**
(b)	Use of $F = mv^2/r$ $F = 11$ N <u>Example of calculation</u> $F = 9.7 \times 10^3\ \text{kg} \times (0.26\ \text{m s}^{-1})^2 / 61\ \text{m}$ $F = 10.7$ N	**(1)** **(1)**	**2**
(c)(i)	Three arrows all pointing to the centre of the circle (accept free hand and lines of varying length)	**(1)**	**1**
* **(c)(ii)**	(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate) Maximum at C / bottom **and** Minimum at A / top At C contact/reaction force (R) greater than weight (accept $R - W = mv^2/r$ or $R = W + mv^2/r$) At A contact/reaction force is less than the weight. (accept $W - R = mv^2/r$ or $R = W - mv^2/r$) Any statement that centripetal force / acceleration is provided by weight/reaction **Or** centripetal force is the resultant force This is a qwc question so a bald statement of the equations can score the marks but to get full marks there must be clear explanation in words.	**(1)** **(1)** **(1)** **(1)**	**4**

Q20.

Question Number	Answer		Mark
(a)	Velocity/direction changing **Or** (object is) accelerating Force towards centre of circle	(1) (1)	2
(b)	High(er) speed means large(r) force **Or** small(er) radius means large(r) force (For sharp bends) centripetal/resultant/required force would need to be greater than maximum frictional force **Or** (for sharp bends) friction cannot provide the (required) centripetal/resultant force	(1) (1)	2
(c)(i)	Resolving forces vertically $\underline{N} \sin \theta = mg$ Resolving forces horizontally $\underline{N} \cos \theta = mv^2/r$ Division of vertical equation by horizontal equation to get correct answer	(1) (1) (1)	3
(c)(ii)	Use of $\tan \theta = gr/v^2$ $\theta = 57°$ Example of calculation $\tan \theta = (9.81 \text{ m s}^{-2} \times 18.7 \text{ m})/ (11.0 \text{ m s}^{-1})^2$ $\theta = 56.6°$	(1) (1)	2
	Total for question		**10**

Q21.

Question Number	Answer		Mark
(a)	Evidence of frictional force = $(0.35 \times mg)$ Use of $F = mr\omega^2$ **Or** $F = mv^2/r$ Use of $\omega = 2\pi/T$ **Or** $v = 2\pi r/T$ $t = 3.0$ s Example of calculation frictional force = $0.35 \times 20 \text{ kg} \times 9.81 \text{ m s}^{-2} = 68.7 \text{ N}$ $F = mr\omega^2$ $\omega = \sqrt{(68.7 \text{ N} / (20 \text{ kg} \times 0.80 \text{ m})}$ $\omega = 2.1 \text{ rad s}^{-1}$ $t = 2\pi/2.1 \text{ rad s}^{-1}$ $t = 3.0$ s	(1) (1) (1) (1)	4
(b)	There would be no difference Both expressions for force depend on mass **Or** algebraic equation for ω or T derived (could be in the working for (a)) showing ω or T independent of m **Or** statement that masses cancel if supported by evidence in (a)	(1) (1)	2
	Total for question		**6**

Q22.

Question Number	Answer	Mark
	B	**1**

Q23.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• top of bridge identified as point at which car has greatest chance of losing contact. (1) • at the point which car loses contact with bridge push from bridge onto car becomes zero (1) **Or** resultant force on car = weight of car • Newton's 2nd law applied with $a = \frac{v^2}{r}$ (1) • v_{max} = 9.9 m s1 (1) • 25 mph = 11.3 m s^{-1}, so speed limit is not suitable (1)	Example of calculation: $mg = \frac{mv^2}{r}$ $v = \sqrt{rg} = \sqrt{10\,\text{m} \times 9.8\,\text{ms}^{-2}} = 9.9\,\text{ms}^{-1}$ 25 mph = $\left(\frac{25}{10}\right) \times 0.45\,\text{ms}^{-1} = 11.25\,\text{ms}^{-1}$	**(5)**

Q24.

Question Number	Acceptable answers	Additional guidance	Mark
	An explanation that makes reference to the following points: Observation 1 • (the fraction of alpha scattering is less for aluminium) so the force of repulsion is less (at a given distance) **(1)** • therefore the charge on an aluminium nucleus is less than on gold nucleus **(1)** Observation 2 • (the E_k is less for scattered alpha for aluminium) so recoiling nucleus must have some/more kinetic energy **(1)** • The mass of an aluminium nucleus is less than mass of a gold nucleus **(1)**		**4**

Q25.

Question Number	Acceptable Answer	Additional Guidance	
	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.	(see table below)	

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

	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

	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**

Q26.

Question Number	Answer	Mark
	C	**1**

Q27.

Question number	Acceptable answers	Additional guidance	Mark
	B		**1**

Q28.

Question Number	Answer		Mark
*	(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate)		
	statement that indicates that the conservation of momentum does apply	(1)	
	the idea that the probe and tank move in opposite directions [accept move apart] **Or** the idea that the probe and tank experience equal and opposite forces	(1)	
	Probe and tank experience equal **changes** in momentum (in opposite directions)	(1)	
	Statement that indicates that (total) energy is conserved	(1)	
	Kinetic energy of the system increases (so speed increases)	(1)	
	(Some) chemical energy converted to KE	(1)	6
	Total for question		**6**

Q29.

Question number	Acceptable answers	Additional guidance	Mark
(i)	• Use of $\frac{1}{2} mv^2 = mgh$ **(1)** • $v = 2.43 \text{ m s}^{-1}$ **(1)**	Example of calculation: $v = \sqrt{2gh} = \sqrt{2 \times 9.81 \times 0.30} = 2.43 \text{ m s}^{-1}$	**2**
(ii)	• Use of impulse = change in momentum **(1)** • Recognises initial velocity is zero **(1)** • Hence $F = 0.923$ N **(1)** • Use of $l = \pi d$ **(1)** • Equates calculated value of F with BIl **(1)** • Hence I = 191 A **(1)**	Example of calculation: $Ft = mv - mu$ where $u = 0$ So $F = (0.019 \text{ kg} \times 2.43 \text{ m s}^{-1})/0.05 \text{ s} = 0.923$ N $l = \pi \times 0.048 \text{ m} = 0.151$ m $I = 0.923 \text{ N}/(0.032 \text{ T} \times 0.151 \text{ m}) = 191$ A	**6**

Q30.

Question Number	Acceptable Answer		Additional guidance	Mark
(a)	• use of $T = \frac{2\pi}{w}$ • 1.7×10^{-3} rad s^{-1} or $\frac{\pi}{1800}$ rad s^{-1}	(1) (1)	Example of calculation: $w = \frac{2\pi}{(60 \times 60)\ \text{s}}$	**(2)**

Question Number	Acceptable Answer		Additional guidance	Mark
(b)	• recognises weight acts halfway along hand • uses correct angle between the two positions • determines change in vertical height (= 0.008 m) • use of $\Delta E = mg\Delta h$ • work done = 1.1 (mJ)	(1) (1) (1) (1) (1)	Example of calculation: $W = 0.014\ \text{kg} \times 9.81\ \text{N kg}^{-1} \times (2 \times 0.04 \sin 6^\circ\ \text{m})$ $W = 1.1 \times 10^{-3}\ \text{J}$	**(5)**

Question Number	Acceptable Answer		Additional guidance	Mark
(c)	• use of $P = VI$ • use of $P = \frac{W}{t}$ AND 65% • t = 141 s	(1) (1) (1)	Example of calculation: $P = 1.5\ \text{V} \times 8.0 \times 10^{-6}\ \text{A} = 1.2 \times 10^{-5}\ \text{W}$ $t = \frac{1.1 \times 10^{-3}\ \text{J}}{0.65 \times 1.2 \times 10^{-5}\ \text{W}} = 141\ \text{s}$	**(3)**