Name: ____

Topic 2: Mechanics Part 3

Date:

Time:

Total marks available:

Total marks achieved: ______

Questions

Q1.

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.

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

(3)

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(Total for question = 3 marks)

Q2.

Which of the following is a possible unit for rate of change of momentum?

☒ **A** kg m s^{-2}

☒ **B** kg m s^{-1}

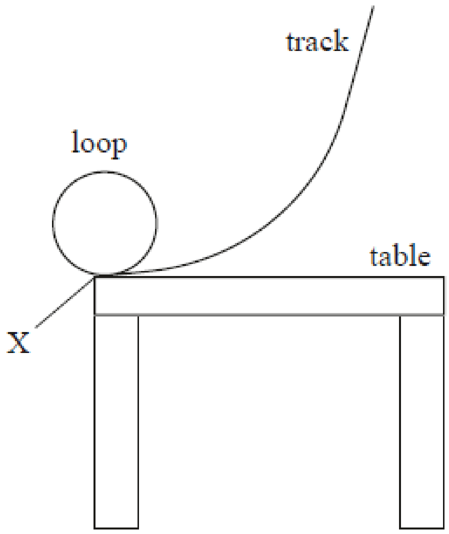
☒ **C** N s^{-1}

☒ **D** N s

(Total for question = 1 mark)

Q3.

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



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

The 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

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

Explain why.

(2)

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(Total for question = 2 marks)

Q4.

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

The following table gives some data for the comet.

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

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

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

(3)

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

(2)

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Gravitational field strength = ...

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

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

(2)

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Height = ...

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

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

(3)

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(Total for question = 10 marks)

Q5.

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.

The star S0-2 is in a highly elliptical orbit around the position of the black hole.

At its point of closest approach, S0-2 is at a distance of 1.8×10^{13} m from the centre of the black hole.

At the most distant point of its orbit, S0-2 is 2.7×10^{14} m from the black hole.

(i) Show that the change in gravitational potential between the closest and most distant points in this orbit is about 3×10^{13} J kg^{-1}.

(2)

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(ii) At its point of closest approach, the star is travelling at a speed of 8.1×10^{6} m s^{-1}.

Calculate the speed of S0-2 at the furthest point in its orbit using the change in gravitational potential.

mass of S0-2 = 2.4×10^{31} kg

(3)

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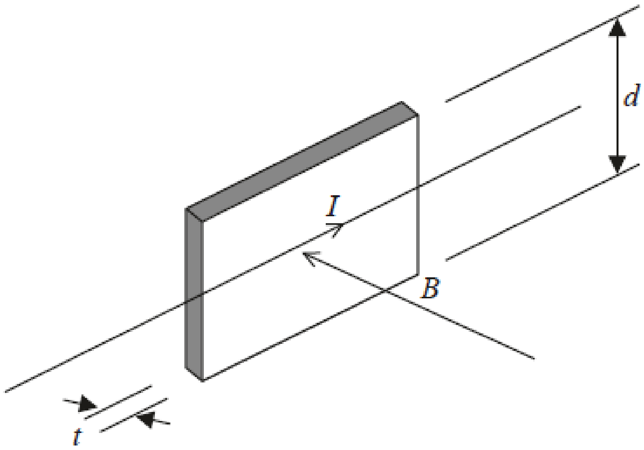
Speed = ...

(Total for question = 5 marks)

Q6.

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

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



Electrons collect at the top edge of the slice and the bottom edge becomes positively charged. As a result a potential difference known as a Hall voltage V_{HALL} develops.

Show that the units are the same on each side of the equation

$$V_{HALL} = \frac{BI}{nte}$$

(3)

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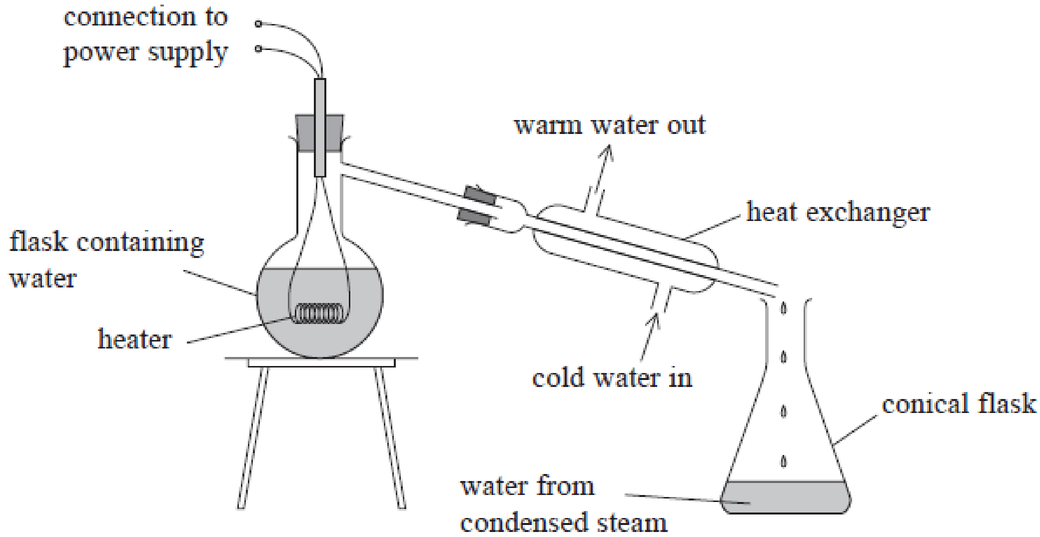
(Total for question = 3 marks)

Q7.

The apparatus shown can be used to determine a value for the specific latent heat of vaporisation of water.



(a) In one experiment the current in the heater was 8.20 A, and the potential difference across the heater was 230 V.

(i) Show that the power of the heater was about 2 kW.

(2)

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(ii) There was 0.655 kg of water in the flask at an initial temperature of 22.5 °C.
The heater was switched on, and the water in the flask was heated to boiling point.

Calculate the minimum time taken for the water to be heated to 100.0 °C.

specific heat capacity of water = 4190 J kg^{-1} K^{-1}

(3)

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Minimum time taken for water to be heated = ...

(b) The heater was left on and water continued to boil in the flask. The water was allowed to boil for a few minutes. The conical flask was then placed under the heat exchanger and water was collected in it.

(i) Give a reason why the water was left boiling for a few minutes before the conical flask was put in place.

(1)

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(ii) Water with a mass of 95.0 g was collected in a time of 125 s.

Calculate the rate of energy transfer in the heat exchanger.

specific latent heat of vaporisation of water = 2.26×10^6 J kg^{-1}

(3)

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Rate of energy transfer in the heat exchanger = ...

(iii) Discuss your answers to (a)(i) and (b)(ii).

(3)

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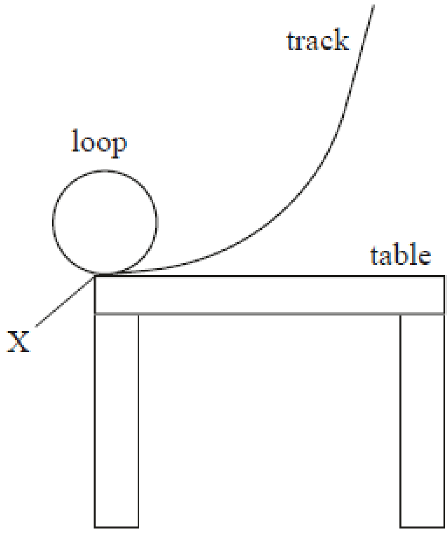
(Total for question = 12 marks)

Q8.

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



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

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

X is 0.65 m above the floor.

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

(4)

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Horizontal displacement = ...

(Total for question = 4 marks)

Q9.

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

While a stone is moving towards the target, the curlers vigorously sweep the ice directly in front of the stone.

Explain why this may make the stone travel further.

(2)

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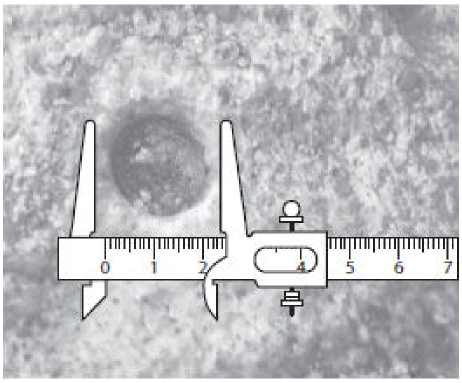
(Total for question = 2 marks)

Q10.

Impact craters are formed when meteorites strike the surface of a planet. A student investigated some factors that might influence the formation of impact craters. He did this by dropping spheres of modelling clay into a tray of sand.

The diameter of the crater produced by each sphere was measured using vernier calipers as shown.



This process was repeated for spheres of different diameters.

In one test, the spheres were dropped from the same height.

Determine the factor by which the kinetic energy of the sphere just before impact increases when the sphere diameter is increased from 2.0 cm to 4.0 cm.

(3)

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Factor = ...

(Total for question = 3 marks)

Q11.

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.

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

mass of dummy = 75 kg

(3)

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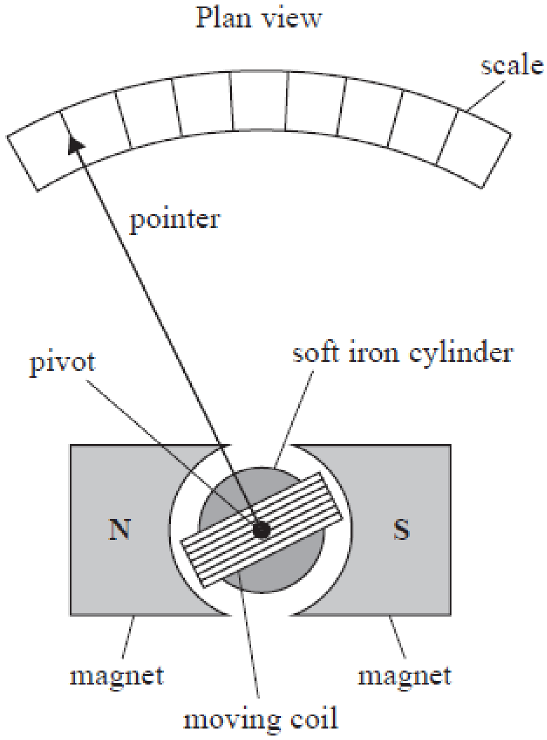
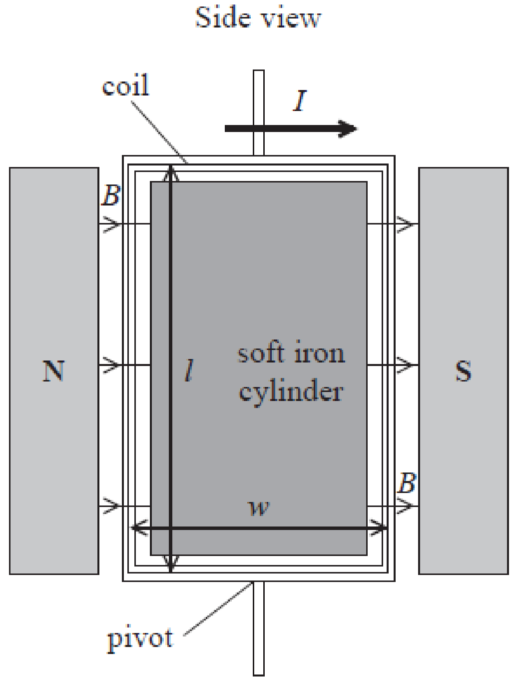
(Total for question = 3 marks)

Q12.

The diagrams show the plan view and side view of a moving coil ammeter.





The fixed soft iron cylinder and magnets produce a uniform magnetic field of magnetic flux density *B*. The coil is able to rotate within this magnetic field. The coil has width *w* and length *l*. There is a current *I* in the coil in the direction shown in the side view diagram.

(i) Explain which way the coil will rotate.

(2)

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(ii) Show that the moment M on the coil about the pivot, due to the magnetic field, is given by

$$M = BAIN$$

where
A is the cross-sectional area of the coil
N is the number of turns of wire on the coil.

(4)

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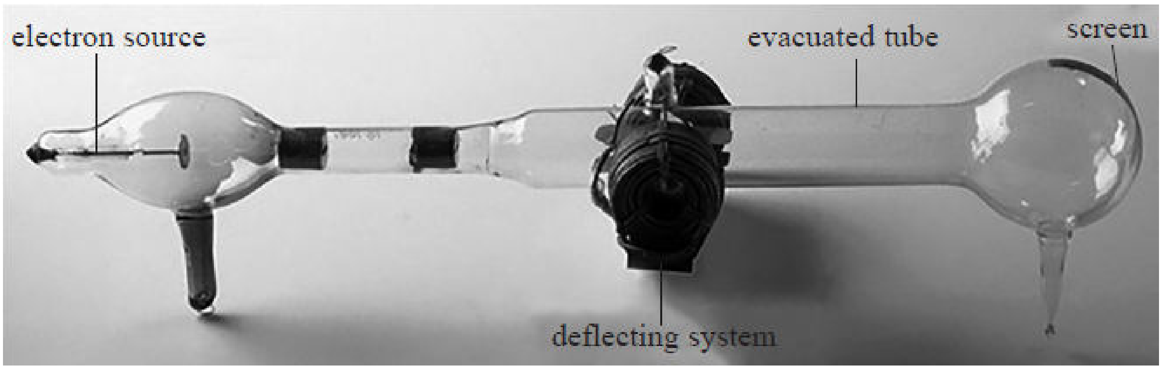
(Total for question = 6 marks)

Q13.

At the end of the 19^{th} century, J.J. Thompson used electric and magnetic fields to deflect beams of charged particles. A photograph of his apparatus is shown.



© Science Museum London

Electrons were accelerated through a potential difference to produce a beam of high-energy electrons. The beam was then deflected in perpendicular directions by the magnetic and electric fields. The final position of the beam on the screen was determined by the charge and mass of the electrons.

In a modern version of Thompson's experiment, a uniform electric field of electric field strength *E* is applied so that the electric and magnetic forces on the electrons are equal and in opposite directions.

(i) Show that for electrons to be undeflected their velocity must be given by

$$v = \frac{E}{B}$$

where *B* is the magnetic flux density of the magnetic field.

(2)

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(ii) The beam is produced by accelerating electrons through a potential difference of 250 V.

The electric field strength is 1.4×10^4 V m^{-1}. The magnetic flux density is 1.5×10^{-3} T.

Calculate the value of the specific charge *e*/*m* for the electron using this data.

(3)

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e/*m* = ...

(Total for question = 5 marks)

Q14.

A current of 1.50 A flows in a straight wire of length 0.450 m. The wire is placed in a uniform magnetic field of flux density 2.00 × 10^{-3} T which acts perpendicular to the wire.
Under these conditions the magnetic force balances the weight of the wire.

Calculate the mass of the wire.

☒ **A** 1.32 × 10^{-2} kg

☒ **B** 1.35 × 10^{-3} kg

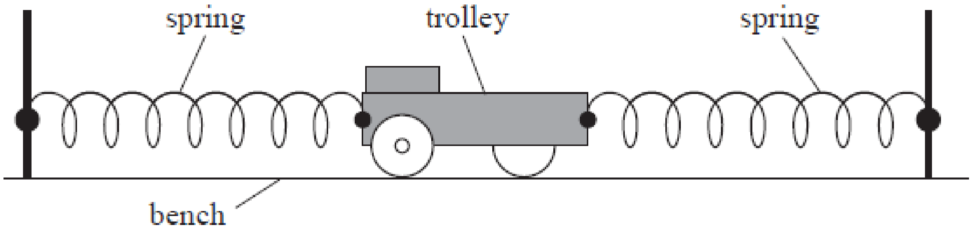
☒ **C** 1.38 × 10^{-4} kg

☒ **D** 1.35 × 10^{-4} kg

(Total for question = 1 mark)

Q15.

A trolley is attached to the ends of two springs as shown. When displaced from its equilibrium position, the trolley moves with simple harmonic motion.



The student displaces the trolley a greater distance from the equilibrium position, so the amplitude of oscillation is doubled. The trolley still moves with simple harmonic motion.

Explain how the maximum kinetic energy of the trolley will change.

(3)

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(Total for question = 3 marks)

Q16.

A cyclist travels up a slope through a vertical height *h* in a time *t*. The mass of the cyclist and his bike is *m*.

The average power of the cyclist is

☐ **A** $\frac{mg}{t}$

☐ **B** $\frac{t}{mg}$

☐ **C** $\frac{mgh}{t}$

☐ **D** $\frac{t}{mgh}$

(Total for question = 1 mark)

Q17.

Two objects of mass *m* travel towards each other on a smooth horizontal surface, each with velocity of magnitude *v*. The collision is elastic.

After the collision the

☐ **A** total kinetic energy is $2mv^2$

☐ **B** total kinetic energy is mv^2

☒ **C** total momentum is $2mv$

☒ **D** total momentum is mv

(Total for question = 1 mark)

Q18.

Astronauts on the 1971 Apollo 14 mission to the Moon brought back many rock samples. It is now believed that one of these contains a piece of rock that originated on Earth about 4 billion years (4×10^9 years) ago.

The piece of rock is believed to have been launched into space when an asteroid struck the Earth.

The gravitational potential between the Earth and the Moon due to the combined effect of their gravitational fields increases to a maximum value of $-1.28\ \text{MJ kg}^{-1}$ at a point between them.

Calculate the minimum speed at which a rock would have to leave the Earth in order to reach the Moon.

In your calculation, you may assume the rock has zero kinetic energy when it has maximum potential energy.

mass of Earth = 5.97×10^{24} kg
radius of Earth = 6370 km

(4)

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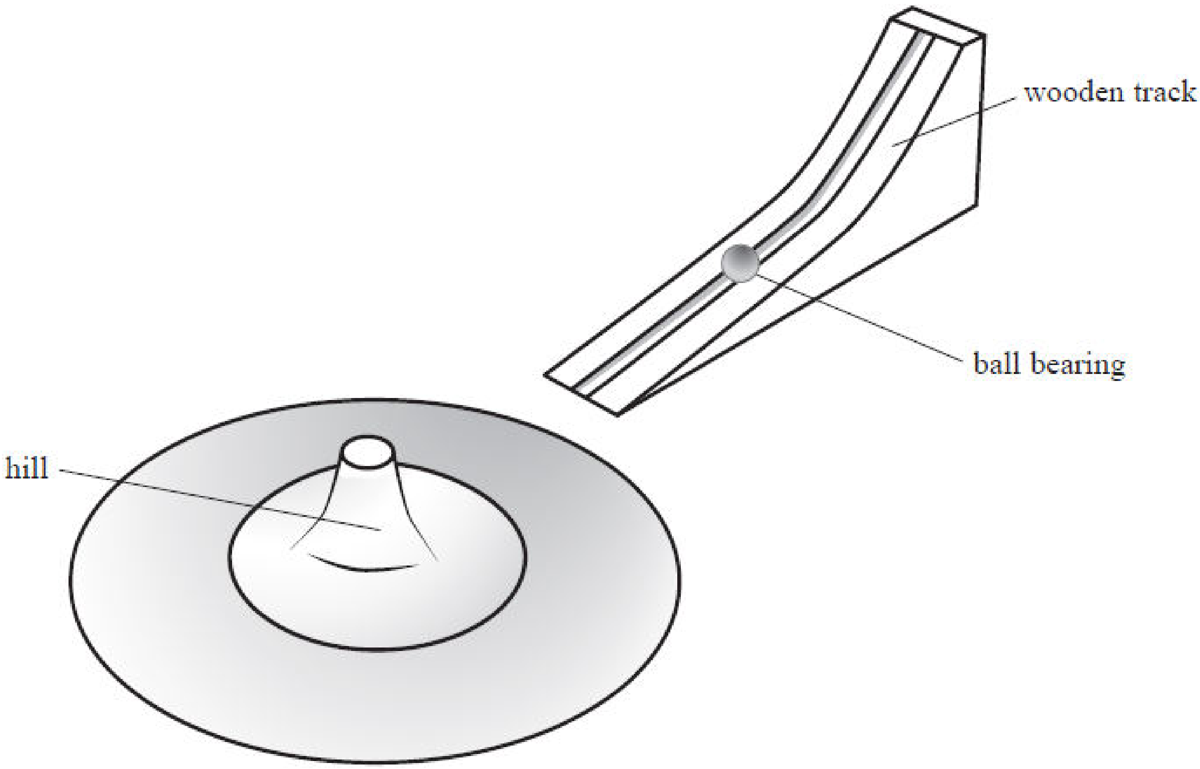
Minimum speed = ...

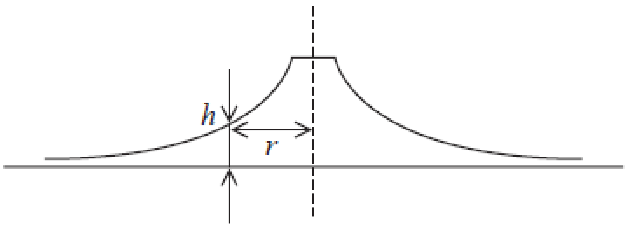
(Total for question = 4 marks)

Q19.

The diagram shows a model used to demonstrate alpha particle scattering. A ball bearing is set rolling on a wooden track. The track is positioned so that the ball bearing rolls onto a metal sheet with a curved surface known as a 'hill'.



The diagram shows a vertical cross-section through the hill. The surface is curved so that the height of a point *h* on the curved surface is inversely proportional to the distance *r* from the centre of the hill.



Explain why the hill is suitable as a model for the electric field surrounding the nucleus of an atom.

(3)

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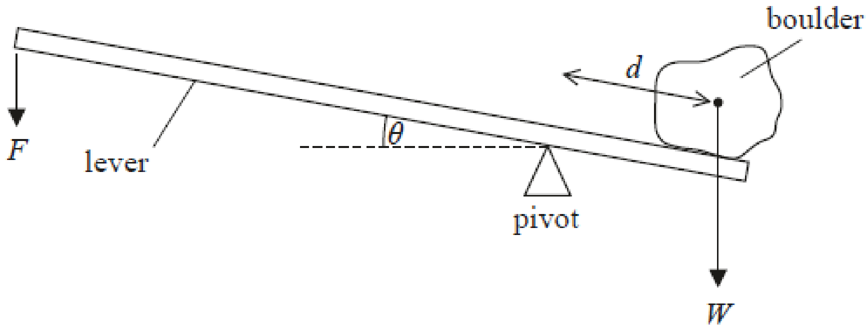
(Total for question = 3 marks)

Q20.

A person uses a pivoted lever to lift a boulder of weight *W* as shown.



The centre of gravity of the boulder is a distance *d* from the pivot. The angle of the lever to the horizontal is *θ*.

Which expression is equal to the moment of *W* about the pivot?

☒ **A** Wd

☒ **B** $Wd \cos \theta$

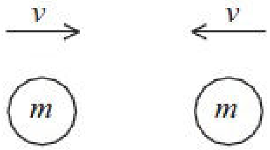
☒ **C** $Wd \sin \theta$

☒ **D** $Wd \tan \theta$

(Total for question = 1 mark)

Q21.

Two identical spheres of mass *m* are both travelling with a speed *v* towards each other.



The spheres collide head-on.

Which of the following statements **must** be true after the collision?

☒ **A** total momentum = $2mv$

☒ **B** total momentum = 0

☒ **C** total kinetic energy = mv^2

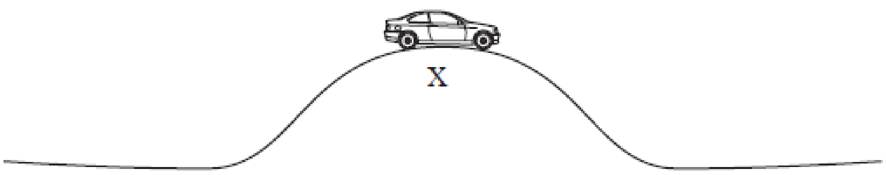
☒ **D** total kinetic energy = 0

(Total for question = 1 mark)

Q22.

The photograph shows a bridge.

The diagram shows a car of mass 950 kg at the highest point X of the bridge.



The bridge forms part of a vertical circle of radius 20.0 m.

(a) Calculate the total upward force R of the road on the car:

(i) when the car is stationary at X,

(1)

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R = ...

(ii) when the car is passing point X at a speed of 12.0 m s^{-1}

(3)

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R = ...

(b) The car is repeatedly driven over the bridge at gradually increasing speeds. Above a certain speed the car loses contact with the road at X.
State why this happens.

(1)

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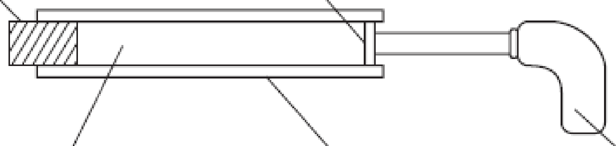
(Total for question = 5 marks)

Q23.

The photographs show a wooden pop gun before and after the cork is popped.

The diagram shows a cross-section through the pop gun.



Initially the piston is at the right-hand end of the cylinder, as shown. Then the cork is pushed into the other end of the cylinder.

When the handle is pushed in, the pressure of the air in the cylinder increases. This exerts an additional force on the cork.

Once the additional force is sufficient to overcome the frictional force between the cork and the cylinder, the cork is pushed out.

Show that the pressure of the air in the cylinder must be about 2×10^5 Pa in order to push the cork out.

maximum frictional force = 8.8 N
cross-sectional area of cork = 9.2×10^{-5} m^2
atmospheric pressure = 1.0×10^5 Pa

(3)

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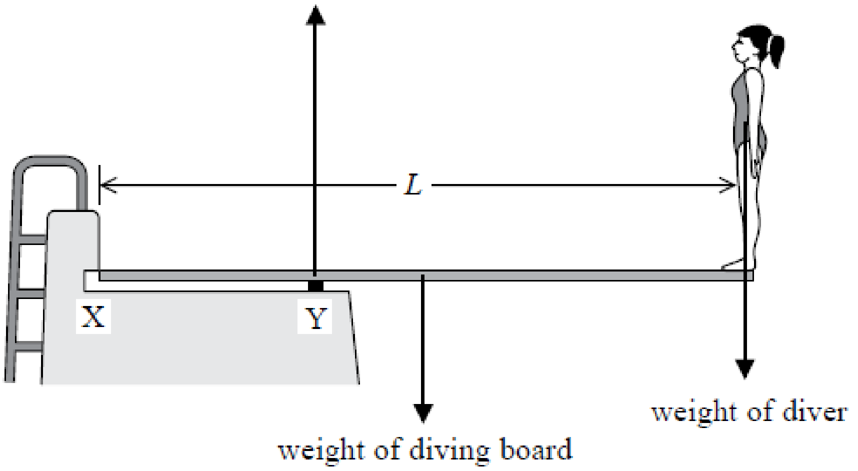
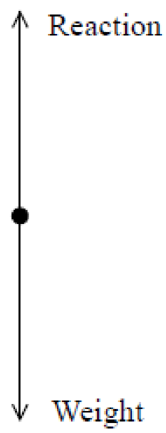
(Total for question = 3 marks)

Q24.

The diagram shows a diver of weight 680 N on a diving board.



The free-body force diagram for the diver standing on the board is shown.



The two forces shown do **not** form a Newton third law pair.

Give **two** reasons why.

(2)

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(Total for question = 2 marks)

Q25.

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

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

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

(3)

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(Total for question = 3 marks)

Q26.

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

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

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

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

(3)

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g = ...

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

(3)

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Percentage uncertainty = ...

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

(2)

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(Total for question = 8 marks)

Q27.

The photograph shows cars driving around a roundabout at a constant speed.

The resultant force *F* on a car causes it to follow a circular path.

Which of the following statements about *F* is **incorrect**?

☐ **A** *F* is equal to the product of the mass and angular velocity of the car.

☐ **B** *F* is equal to the product of the momentum and angular velocity of the car.

☐ **C** *F* is in the same direction as the acceleration of the car.

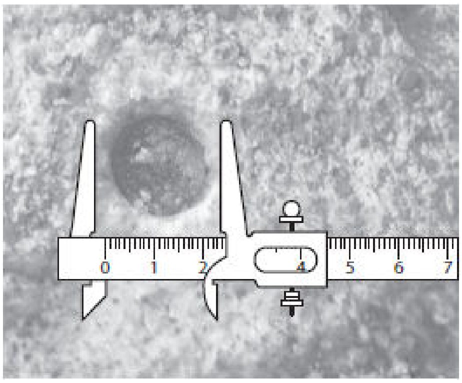
☐ **D** *F* is perpendicular to the momentum of the car.

(Total for question = 1 mark)

Q28.

Impact craters are formed when meteorites strike the surface of a planet. A student investigated some factors that might influence the formation of impact craters. He did this by dropping spheres of modelling clay into a tray of sand.

The diameter of the crater produced by each sphere was measured using vernier calipers as shown.



This process was repeated for spheres of different diameters.

* The student also dropped the spheres from different heights. His results are shown in the table.

Drop height / m	Sphere diameter / cm	Crater diameter / cm
0.30	2.0	3.6
	4.0	7.0
	6.0	6.8
0.60	2.0	4.8
	4.0	7.5
	6.0	7.3
0.90	2.0	5.6
	4.0	8.0
	6.0	8.3

The student wrote the following conclusion:

"The greater the drop height, the greater the diameter of the crater formed when a sphere hits the sand. This is because the impact velocity increases as the drop height is increased. As the speed of the sphere increases the diameter of the crater formed also increases. Also, the bigger the sphere the bigger the crater."

Assess the validity of the student's conclusion.

(6)

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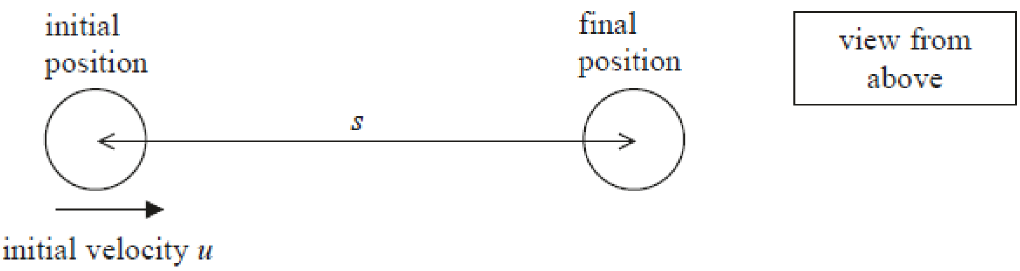
(Total for question = 6 marks)

Q29.

A student carried out an experiment with coins.

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



The student recorded the distance s moved by the coin.

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

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

Discuss the validity of this suggestion.

(6)

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(Total for question = 6 marks)

Q30.

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 is an example of a scalar quantity?

☐ **A** displacement

☐ **B** energy

☐ **C** momentum

☐

D velocity

(Total for question = 1 mark)

Mark Scheme

Q1.

Question Marks	Acceptable Answers	Additional guidance	Mark
	• 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

Q2.

Question Number	Answer	Mark
	A	1

Q3.

Question Number	Acceptable answers		Additional guidance	Mark
	• Use of $F = \frac{mv^2}{r}$ • States that $F = mg$ only as reaction force is zero	(1) (1)	Example of derivation: $mg = \frac{mv^2}{r}$ $v = \sqrt{gr}$	(2)

Q4.

Question Number	Acceptable answers		Additional guidance	Mark
(a)	• use of density = mass / volume • use of $V = 4/3\ \pi r^3$ • r = 1720 m	(1) (1) (1)	Example of calculation: $V = 1.0 \times 10^{13}$ kg ÷ 470 kg m^{-3} $= 2.13 \times 10^{10}$ m^3 $= 4/3\ \pi r^3$ $r = \sqrt[3]{(2.13 \times 10^{10} \text{ m}^3 \times 3) \div 4\pi}$ = 1720 m	**(3)**

Question Number	Acceptable answers		Additional guidance	Mark
(b)	• use of $g = GM/r^2$ • $g = 2.3 \times 10^{-4}$ N kg^{-1}	(1) (1)	Example of calculation: $g = 6.67 \times 10^{-11}$ N m^2 kg^{-2} × 1.0×10^{13} kg / (1720 m)^2 $g = 2.25 \times 10^{-4}$ N kg^{-1}	**(2)**

Question Number	Acceptable answers		Additional guidance	Mark
(c)	• use of $s = ½\ gt^2$ • $s = 1.2 \times 10^3$ m	(1) (1)	Example of calculation: $s = 0.5 \times 2.25 \times 10^{-4}$ m s^{-2} × (3300 s)^2 $= 1.2 \times 10^3$ m	**(2)**

Question Number	Acceptable answers		Additional guidance	Mark
(d)	An explanation that makes reference to the following: • the calculated height is comparable with the radius (of asteroid) • the field should be considered as radial rather than parallel, so the gravitational field strength is decreasing significantly for the probe OR $g = GM/r^2$ the change in *r* is comparable with the radius, so there will be a significant change in *g* • acceleration is less, so the actual height would be less	(1) (1) (1) (1)		**(3)**

Q5.

Question Number	Acceptable answers		Additional guidance	Mark
(i)	• Use of $V = -Gm / r$ • Change in $V = 3.18 \times 10^{13}$ (J kg^{-1})	(1) (1)	Example of calculation $\Delta V = -Gm\,(1/r_2 - 1/r_1)$ $= -6.67 \times 10^{-11}$ N m^2 kg^{-2} $\times 9.2 \times 10^{36}$ kg $\times$ $((1/2.7 \times 10^{14}$ m $- 1/1.8 \times 10^{13}$ m) $= 3.18 \times 10^{13}$ J kg^{-1}	2
(ii)	• Equate change in gravitational potential energy to change in kinetic energy **Or** use of $E_p = mV$ • Use of $E_k = \frac{1}{2} mv^2$ • $v = 1.4 \times 10^6$ m s^{-1}	(1) (1) (1)	Example of calculation $m \times 3.18 \times 10^{13}$ J kg^{-1} $= (0.5 \times m \times (8.10 \times 10^6$ m s$^{-1})^2) - (0.5 \times m\, v_2^2)$ $v_2 = 1.4 \times 10^6$ m s^{-1}	3

Q6.

Question Number	Acceptable answers	Additional guidance	Mark
	• Uses V = J/C **Or** V = Nm/C **Or** V = Wb s^{-1} **(1)** • Use of T = N/Cms^{-1} **Or** T = N/Am **Or** T = Wb m^{-2} **Or** Sub of B=F/IL and cancels I's **(1)** • Uses units of n = m^{-3} and completes agreement **(1)** Alternative with base units: • Uses base unit of force = kg m s^{-2} **Or** base unit of energy = kg m^2 s^{-2} **(1)** • Uses base unit of charge = A s **Or** uses A = Cs^{-1} **Or** Sub of B=F/IL and cancel I's or A's **(1)** • Uses base units of n = m^{-3} and completes agreement **(1)**	Example of unit simplification: J/C should equal $\frac{N}{Am} \times A \div m^{-3}Cm$ $= \frac{Nm}{C} = \frac{J}{C}$	(3)

Q7.

Question Number	Acceptable Answer	Additional Guidance	Mark
(a)(i)	• Use of $P = VI$ **(1)** • P = 1900 W (1.9 kW) **(1)**	Example of calculation P=230 V × 8.20 A = 1890 W	2
(a)(ii)	• Use of $\Delta E = mc\Delta\vartheta$ **(1)** • Use of $P = \frac{\Delta E}{\Delta t}$ **(1)** • Δt = 112 s or 113 s [106 s or 107 s if show that value used] **(1)** ECF from (a)(i)	Example of calculation $\Delta E = 0.655 \text{ kg} \times 4190 \text{ J kg}^{-1}\text{K}^{-1} \times (100 - 22.5)\text{K}$ $\Delta E = 2.13 \times 10^5 \text{ J}$ $\Delta t = \frac{2.13 \times 10^5 \text{J}}{1890 \text{ W}} = 112.5 \text{ s}$	3

Question Number	Acceptable Answer	Additional Guidance	Mark
(b)(i)	• After a short time of boiling in the flask, all the apparatus would be at 100 °C. **Or** so energy is not being used to heat up the flask **Or** so steam won't condense in the flask (1)		1
(b)(ii)	• Use of $\Delta E = mL$ (1) • Use of $P = \frac{\Delta E}{\Delta t}$ (1) • 1720 W (1.72 kW) (1)	Example of calculation $\frac{\Delta m}{\Delta t} = \frac{95 \times 10^{-3}\ \text{kg}}{125\ \text{s}}$ $= 7.6 \times 10^{-4}\ \text{kg s}^{-1}$ $\frac{\Delta E}{\Delta t} = 7.6 \times 10^{-4}\ \text{kg s}^{-1} \times 2.26 \times 10^{6}\ \text{J kg}^{-1}$ $P = 1720\ \text{J s}^{-1}$	3
(b)(iii)	• Comparison of answer to (a)(i) with answer to (b)(ii) (1) • Not all of the energy from the heater is used to turn water from liquid state into vapour **Or** energy is being used to heat the heat exchanger **Or** not all the steam condenses in the heat exchanger (1) • Some energy is transferred to the surroundings (1)	e.g. rate at which thermal energy is supplied to the water in the flask is greater than rate at which thermal energy is removed from the water in the heat exchanger. If answer for (b)(ii) is bigger than 2 kW,1 mark for correct comparison can be scored.	3

Q8.

Question Number	Acceptable answers	Additional guidance	Mark
	• 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: $0.65\,\text{m} = \frac{1}{2} 9.81\,\text{m s}^{-2} t^2$ $t = 0.364\,\text{s}$ $s = 3.0\,\text{m s}^{-1} \times 0.364\,\text{s}$ $s = 1.09\,\text{m}$	(4)

Q9.

Question Number	Acceptable Answer	Additional Guidance	Mark
	An explanation that makes reference to the following points: • Sweeping the ice smooths out the surface **Or** Sweeping the ice melts the suraface 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

Q10.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• Speed of impact is the same for both spheres (1) • mass of sphere ∝ (diameter)^3 (1) • $E_k = \frac{1}{2}mv^2$ so factor = 8 (1) **OR** • Final $E_k = \Delta E_{grav}$ (1) • mass of sphere ∝ (diameter)^3 (1) • $\Delta E_{grav} = mg\Delta h$, so factor = 8 (1)	For MP2 accept radius instead of diameter A bald correct answer scores MP3 only Example of calculation: $\frac{m_2}{m_1} = \left(\frac{4\text{ cm}}{2\text{ cm}}\right)^3 = 8$ $\frac{E_{k2}}{E_{k1}} = \frac{m_2}{m_1} = 8$	3

Q11.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• Cross sectional area × length used to calculate volume (1) • Use of $E_k = \frac{1}{2}mv^2$ (1) • Energy per unit volume = 1.7×10^8 (J m^{-3}) (1)	Example of calculation: 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

Q12.

Question Number	Acceptable answers	Additional guidance	Mark
(i)	An explanation that makes reference to the following points: • Fleming left hand rule force will cause force on left hand side of coil into page **Or** right hand side of coil out of page (1) • The coil will turn clockwise as shown in the plan view (MP2 dependent on MP1) (1)	allow 1 mark for statement "rotates clockwise because of FLHR"	2
(ii)	• Moment of F around pivot = $F \times w/2$ (1) • Use of $F = BIl$ (1) • Moment due to F on both sides = $2 \times BIl \times w/2$ (1) • As N turns and $l \times w = A$; Total moment = $BAIN$ (1)	alt: Use of Torque of a couple = $F \times w$ then MP1 and 3 This equation should be substituted into a product with a "distance" to be awarded 'use of'	4

Q13.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	• Use of $F = BQv$ and $F = EQ$ (1) • Algebra to show $v = \frac{E}{B}$ (1)		2
(ii)	• Use of $W = QV$ and $E_k = \frac{1}{2}mv^2$ (1) • Use of $v = \frac{E}{B}$ (1) • $\frac{e}{m} = 1.7 \times 10^{11}$ C kg^{-1} (1)	<u>Example of calculation:</u> $v = \frac{E}{B} = \frac{1.4 \times 10^4 \text{ V m}^{-1}}{1.5 \times 10^{-3} \text{ T}}$ $\quad \frac{e}{m} = \frac{v^2}{2V}$ $\frac{e}{m} = \frac{(9.33 \times 10^6 \text{ m s}^{-1})^2}{2 \times 250 \text{ V}} = 1.74 \times 10^{11}$ C kg^{-1}	3

Q14.

Question Number	Answer	Mark
	C	1

Q15.

Question Number	Acceptable Answer	Additional Guidance	Mark
	An explanation that makes reference to the following points: • $v_{max} = \omega A$ and ω constant (1) • If A doubles, then v_{max} doubles (1) • Hence max E_k will quadruple, since $E_k = \frac{1}{2}mv^2$[dependent upon MP2] (1) OR • $\Delta E_{el} = \frac{1}{2}F\Delta x$ and $\Delta F = k\Delta x$ (1) • $\Delta E_{el} \propto (\Delta x)^2$ since k is constant (1) • Hence max E_k will quadruple, since max E_k = max ΔE_{el} (dependent upon MP2) (1)		3

Q16.

Question Number	Acceptable Answer	Additional guidance	Mark
	C	$\frac{mgh}{t}$	**(1)**

Q17.

Question Number	Acceptable Answer	Additional guidance	Mark
	B	total kinetic energy is mv^2	**(1)**

Q18.

Question Number	Acceptable answers	Additional guidance	Mark
	• Use of $V_{grav} = -GM/R$ (1) • Calculate $\Delta V_{grav} = V_{grav\ Moon} - V_{grav\ Earth}$ (1) • Use of $m\,\Delta V_{grav} = E_k = \frac{1}{2}mv^2$ (1) • $v = 11\ 000\ m\ s^{-1}$ (1)	<u>Example of calculation</u> $V_{grav} = -6.67 \times 10^{-11}\ N\ m^2\ kg^{-1} \times 5.97 \times 10^{24}\ kg$ / $6\ 370\ 000\ m = -62.5\ MJ\ kg^{-1}$ $\Delta V_{grav} = -62.5\ MJ\ kg^{-1} - -1.28\ MJ\ kg^{-1}$ $= -61.2\ MJ\ kg^{-1}$ $\frac{1}{2} v^2 = 61.2\ MJ\ kg^{-1}$ $v = 11\ 100\ m\ s^{-1}$	4

Q19.

Question Number	Acceptable answers	Additional guidance	Mark
	• The curved surface is (analogous to) a radial field (1) • (as $h \propto {}^{1}/_{r}$ then) potential (energy) $\propto {}^{1}/_{r}$ (1) • compares with $V \propto {}^{1}/_{r}$ around a point charge (1)		3

Q20.

Question Number	Acceptable answers	Additional guidance	Mark
	B		1

Q21.

Question Number	Answer	Mark
	B	1

Q22.

Question Number	Answer		Mark
(a)(i)	$R = 9.32$ kN <u>Example of answer</u> $R = 950\text{ kg} \times 9.81\text{ m s}^{-2}$ $R = 9320$ N	(1)	1
(a)(ii)	Use of $F = mv^2/r$ $R = mg - mv^2/r$ $R = 2480$ N ecf their value of R <u>Example of calculation</u> $R = 9320\text{ N} - (950\text{ kg} \times 12.0^2\text{ m}^2\text{ s}^{-2} / 20.0\text{ m})$ $R = 2480$ N	(1) (1) (1)	3
(b)	An answer that either states implicitly or implies that 'The required centripetal force > mg and so cannot be provided'.	(1)	1
	Total for question		**5**

Q23.

Question Number	Acceptable answers	Additional guidance	Mark
	• Use of $p = F/A$ (1) • Cylinder pressure = calculated pressure + atmospheric pressure (1) • $p = 2.0 \times 10^5$ Pa (1)	<u>Example of calculation</u> $p = 8.8\text{ N} / 9.2 \times 10^{-5}\text{ m}^2$ $= 9.57 \times 10^4$ Pa Total $p = 9.57 \times 10^4\text{ Pa} + 1.0 \times 10^5\text{ Pa}$ $= 1.957 \times 10^5$ Pa	3

Q24.

Question number	Acceptable answers	Additional guidance	Mark
	• The forces are different types **(1)** • The forces act on the same object **(1)**		2

Q25.

Question Number	Acceptable answers	Additional guidance	Mark
	• 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

Q26.

Question Number	Acceptable Answer	Additional Guidance	Mark
(a)	• calculates mean value of time (1) • use of $s = ut + \frac{1}{2}at^2$ (1) • a = 9.5 m s^{-2} to 2/3 sf (1)	Example of calculation: Average time, t_{av} = (0.45 s +0.51 s + 0.43 s)/3 = 0.46 s $s = ut + \frac{1}{2}at^2 \quad \therefore a = \frac{2 \times 1.00\,\text{m}}{(0.46\,\text{s})^2} = 9.45\,\text{m s}^{-2}$	**(3)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(b)	• calculates % uncertainty in t using range / half-range **Or** calculates uncertainty in s using precision of instrument (1) • doubles uncertainty in t (1) • uncertainty in a = 18 % (1)	Example of calculation: Uncertainty in t = (0.04/0.46) × 100% = 8.7 % Uncertainty in t^2 = 2 × 8.7 % = 17.4 % Uncertainty in s = (0.01/1.00)× 100 % = 1 % Uncertainty in g = 18.4 %	**(3)**

Question Number	Acceptable Answer		Additional Guidance	Mark
(c)	• % uncertainty in t would decrease • longer times identified as key factor in reducing uncertainty in value obtained for *g*	(1) (1)		**(2)**

Q27.

Question Number	Answer	Mark
	A	1

Q28.

<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 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>

Indicative content:
• The table shows that increasing the drop height does increase the crater diameter
• Increasing the drop height increases the impact velocity/E_k
• Because there is a greater acceleration time
Or because there is a greater transfer of GPE to KE
• The table does not show that increasing the sphere diameter (always) increases the crater diameter
• For smaller spheres (from 2 to 4 cm), increasing sphere diameter does increase crater diameter **Or** for bigger spheres (from 4 to 6 cm), increasing the sphere diameter has little effect on crater diameter
• More data is needed for firmer conclusions</td><td>
<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 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>

For IC3 accept reference to an appropriate equation

For IC5 accept "no effect" or "inconsistent effect" for "little effect"</td><td>6</td></tr>
</table>

Q29.

Question Number	Acceptable answers		Additional guidance	Mark
	• Use of $v^2=u^2+2as$	(1)		
	• $v = 0$ so $u = \sqrt{-2as}$	(1)	ignore whether minus sign included or not	
	• a is a deceleration caused by friction (with surface)	(1)	Alternative: • Work done by friction (with surface)	
	• States $F = ma$ where F is friction	(1)	• States $W= Fs$	
	• As $F = km = ma$ so a must be constant **Or** $F=ma$ if F proportional to m then a must be constant	(1)	• States $E_k = ½\ mu^2$ • So $Fs = ½\ mu^2$	(6)
	• so acceleration a the same (as 1 p coin) so statement correct	(1)	• As $F = km$ • m's cancel so statement correct	

Q30.

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