Name: ______________________________________

Topic 2: Mechanics Part 2

Date:

Time:

Total marks available:

Total marks achieved: ______

Questions

Q1.

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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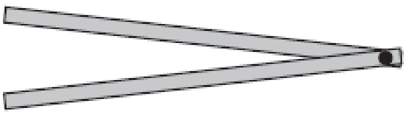
Angular velocity = ...

(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 = ...

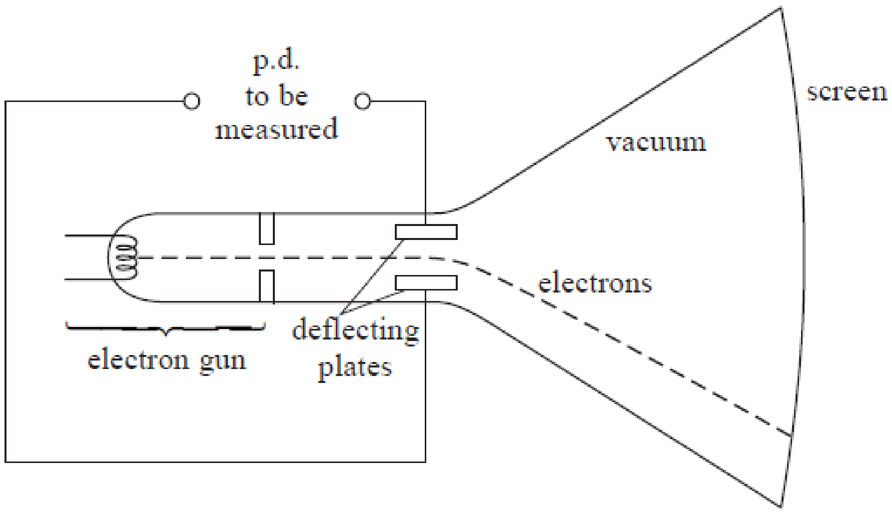
(Total for question = 10 marks)

Q2.

Cathode ray tubes are used in oscilloscopes.

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

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



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

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

(1)

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

(2)

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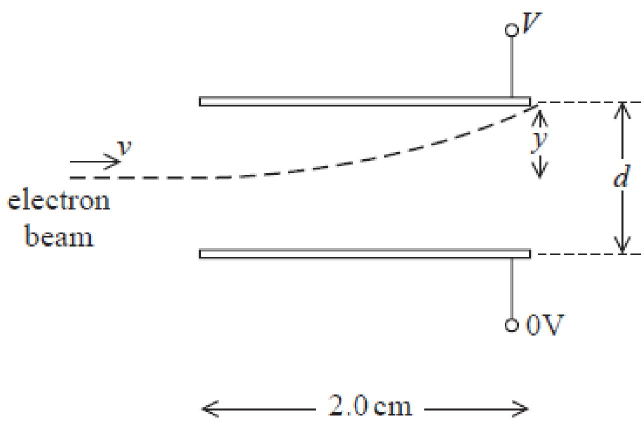
(b) The electron beam then enters a uniform electric field between the two parallel horizontal deflecting plates. The magnitude and direction of the deflection is determined by the p.d. *V* that is applied across the plates.

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



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

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

(2)

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

V = 50 V
d = 0.01 m

(5)

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y = ...

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

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

(4)

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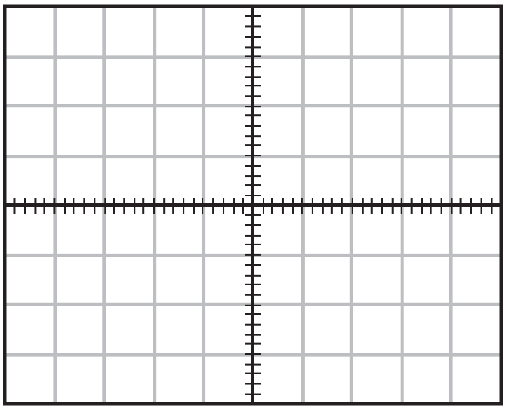


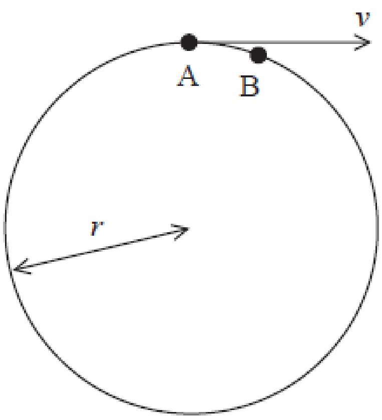
1 square = 25 V

(Total for question = 14 marks)

Q3.

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

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



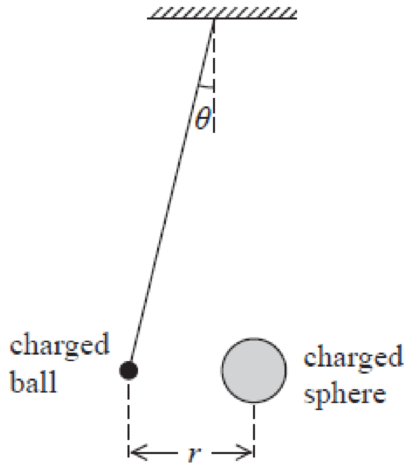
Draw a labelled vector diagram, in the space below, of the velocities at the two positions that shows the acceleration is directed towards the centre of the orbit.

(2)

(Total for question = 2 marks)

Q4.

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



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

(2)

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

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

$$F = W \tan \theta$$

(2)

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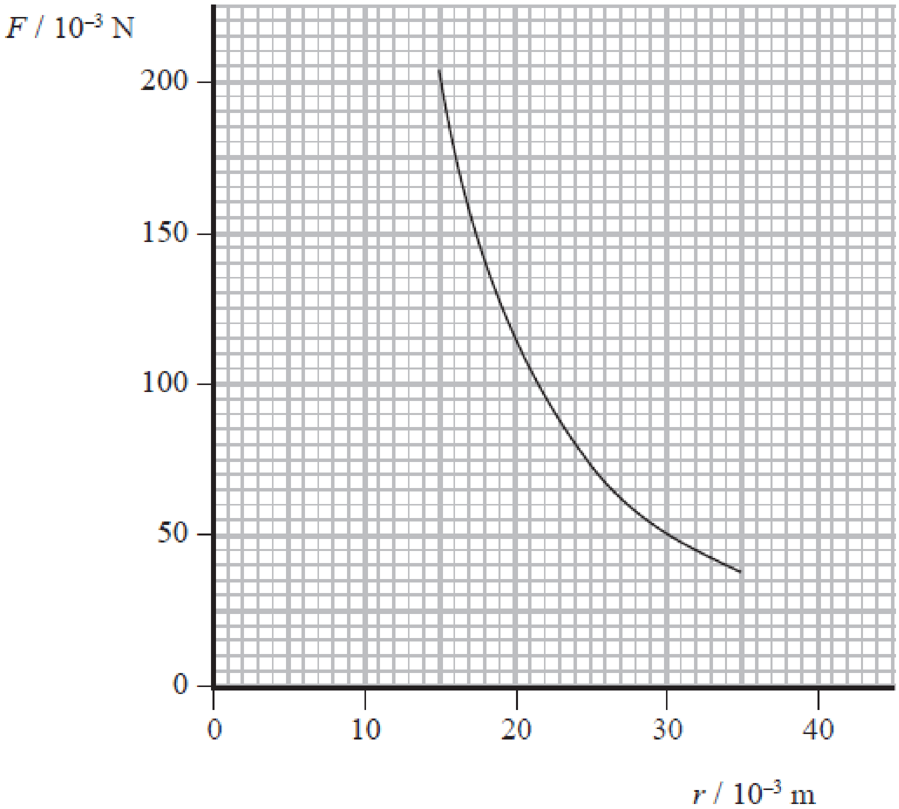
(b) (i) The student can increase the magnitude of the force by moving the sphere towards the suspended ball.
She takes pairs of measurements of *r* and *θ* and calculates the magnitude of the force *F*. She then plots a graph of *F* against *r*.



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

(4)

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

Calculate the charge on the ball.

(3)

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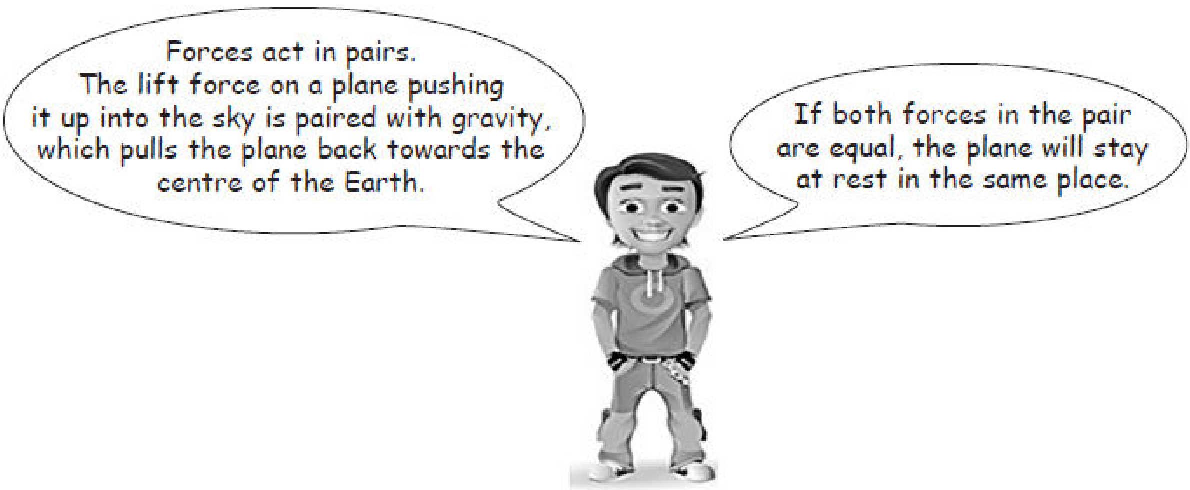
Charge = ...

(Total for question = 11 marks)

Q5.

* The following extract comes from a section on forces, on a website written for children.



Criticise this extract.

(6)

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(Total for question = 6 marks)

Q6.

(a) State what is meant by the de Broglie wavelength.

(2)

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(b) An electron is accelerated from rest, in a vacuum, through a potential difference of 500 V.

(i) Show that the final momentum of the electron is about 1×10^{-23} N s.

(3)

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(ii) Calculate the de Broglie wavelength for this electron.

(2)

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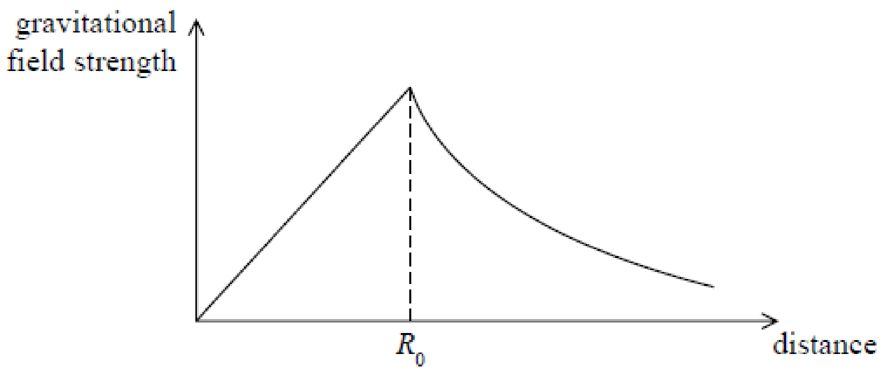
de Broglie wavelength = ...

(Total for question = 7 marks)

Q7.

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



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

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

(3)

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(Total for question = 3 marks)

Q8.

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

Photograph 1

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

Photograph 2

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

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

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

(3)

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

(3)

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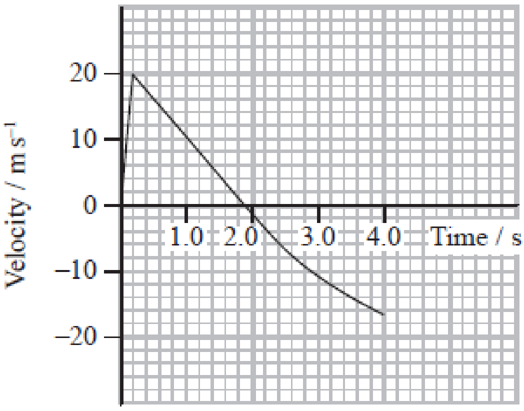
(Total for question = 6 marks)

Q9.

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

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



Determine the height to which the rocket travelled.

(2)

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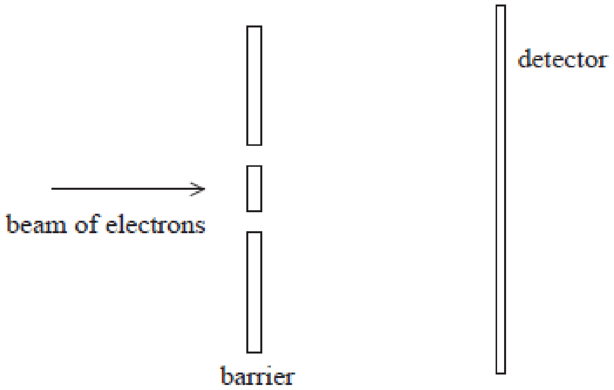
Height = ...

(Total for question = 2 marks)

Q10.

In 1965, Richard Feynman proposed a double slit experiment to investigate the wave properties of electrons.

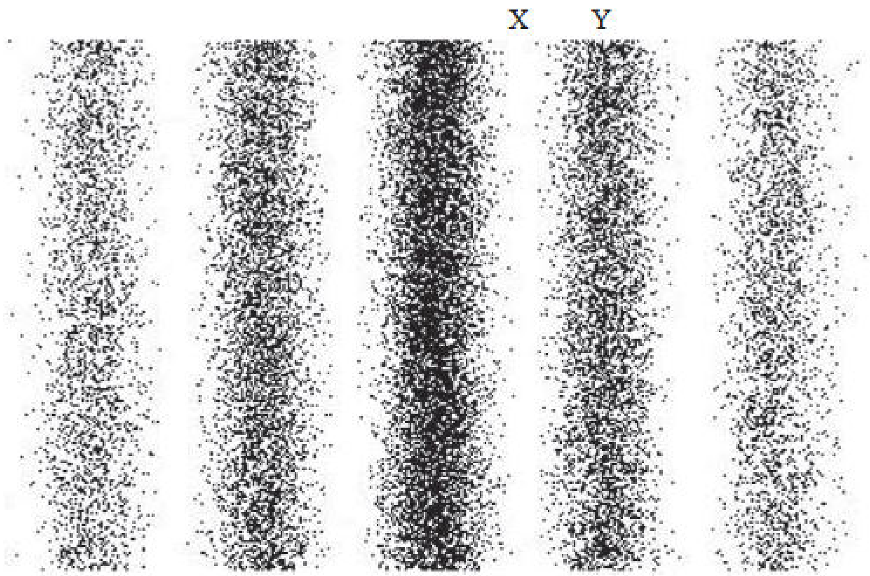
The experiment was later carried out using the arrangement shown.



A beam of electrons was directed at a barrier with two slits.

The detector recorded the positions where electrons arrived after passing through the slits.

The following pattern was obtained. Black dots represent points where electrons were detected. A band where electrons were not detected has been labelled X and a band where electrons were detected has been labelled Y.



The path difference for electrons arriving at band X from the separate slits was 2.5×10^{-1} m. For electrons arriving at band Y the path difference was 5.0×10^{-1} m.

Explain why this pattern is observed when the electron energy is 9.6×10^{-1} J.

The electrons are travelling at non-relativistic speeds.

(6)

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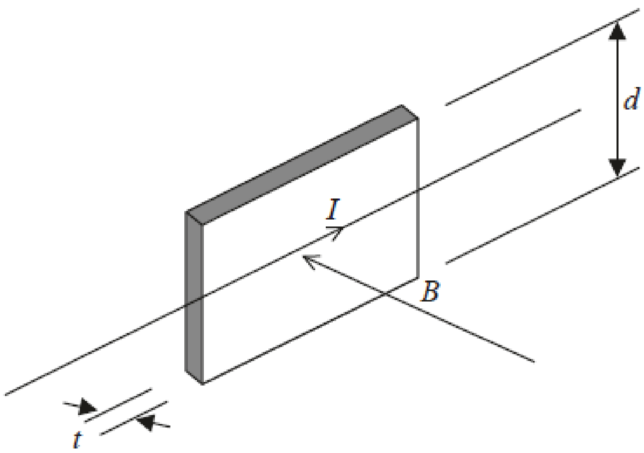
(Total for question = 6 marks)

Q11.

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

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



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

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

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

B_H = 19.0 μT

B_V = 49.0 μT

(2)

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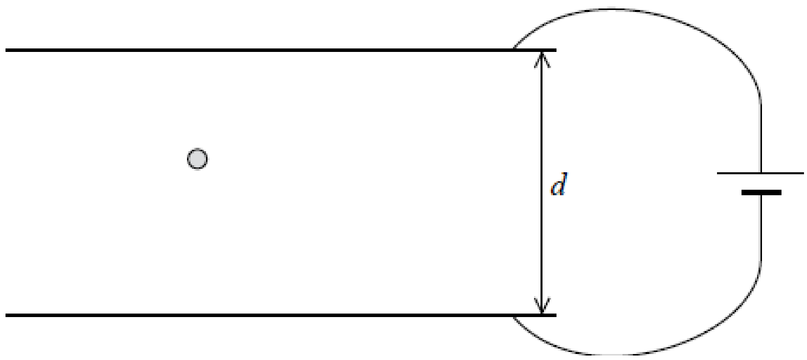
Angle = ...

(Total for question = 2 marks)

Q12.

In an experiment to determine the charge on an electron, negatively charged oil drops are allowed to fall between two parallel metal plates separated by a distance *d*.

A potential difference (p.d.) is applied across the plates. The diagram shows one oil drop between the plates.



When the p.d. is 0 V the oil drop accelerates to terminal velocity. The p.d. is increased. It is observed that at a particular p.d. *V* the oil drop stops falling and remains stationary between the plates.

* Explain the motion of the oil drop in terms of the forces acting on it as the p.d. is increased from 0 to *V*.

(6)

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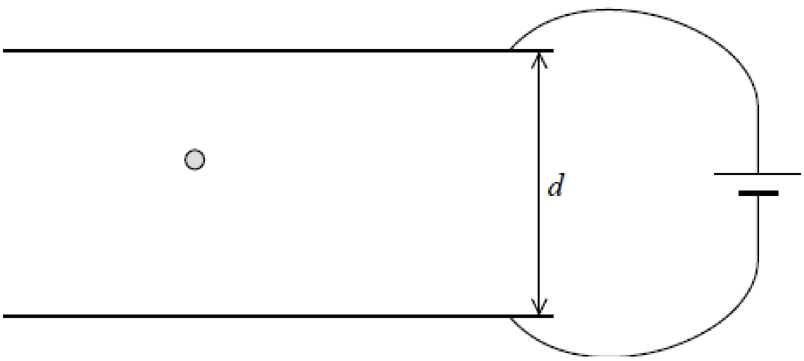
(Total for question = 6 marks)

Q13.

In an experiment to determine the charge on an electron, negatively charged oil drops are allowed to fall between two parallel metal plates separated by a distance *d*.

A potential difference (p.d.) is applied across the plates. The diagram shows one oil drop between the plates.



When the p.d. is 0 V the oil drop accelerates to terminal velocity. The p.d. is increased. It is observed that at a particular p.d. *V* the oil drop stops falling and remains stationary between the plates.

(a) The oil drop has a mass *m*. Show that the charge *q* on the oil drop is given by

$$q = \frac{mgd}{V}$$

(2)

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(b) Explain what would happen to the oil drop if the p.d. is increased further.

(2)

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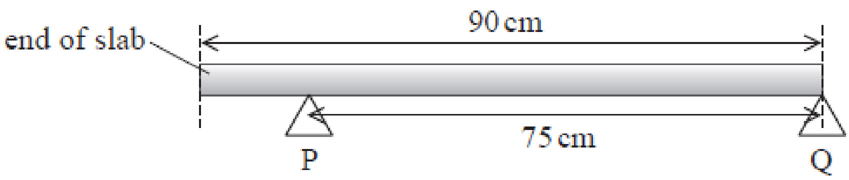
(Total for question = 4 marks)

Q14.

A uniform paving slab is to be used as a garden step.

The paving slab has a weight of 310 N and a length of 90 cm and will be supported at two points, P and Q, as shown. The distance between P and Q will be 75 cm.



This might be unsafe because a person who places all their weight at the end of the slab might tip the slab.

A person of mass 70 kg stands at the end of the slab.

Deduce whether the slab will tip.

(4)

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(Total for question = 4 marks)

Q15.

An electric kettle is used to heat water from room temperature to boiling point.

(a) (i) Calculate the electrical power used by the kettle.

potential difference = 230 V

current = 12.5 A

(2)

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Electrical power = ...

(ii) The kettle is switched on for 140 s.

Calculate the total energy supplied to the kettle.

(2)

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Total energy supplied = ...

(iii) The amount of thermal energy transferred to the water is calculated to be 351 000 J.

Calculate the efficiency of the kettle at heating the water.

(2)

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Efficiency = ...

(b) A student suggests that the useful energy required is thermal and the kettle only produces thermal energy, so it should be 100 % efficient.

Discuss this suggestion.

(2)

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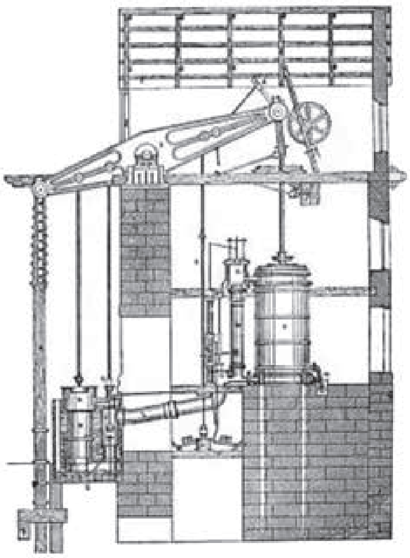
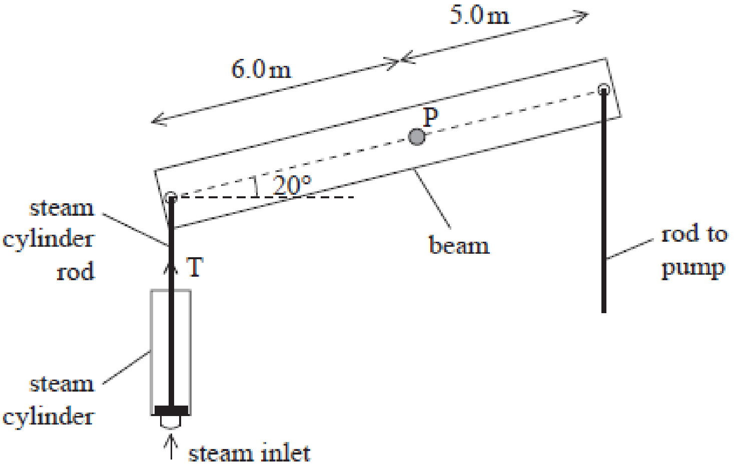
(Total for question = 8 marks)

Q16.

Beam engines contributed to powering the Industrial Revolution in Britain in the 18th century. A beam engine consisted of a beam which could rock to and fro around a well-oiled pivot. Attached to the beam there are two rods, one connected to a piston in a steam cylinder and the other connected to a pump.



The diagram below shows a simplified arrangement of a beam engine.



The engine, which ran continuously, could lift a mass of 2500 kg of water through 12 m each minute.
The engine used 1250 kg of coal a day. 1 kg of coal can release 22.3 MJ of energy.
The beam engine was said to have an efficiency of 10 %.

Deduce whether this claim for efficiency was correct.

(5)

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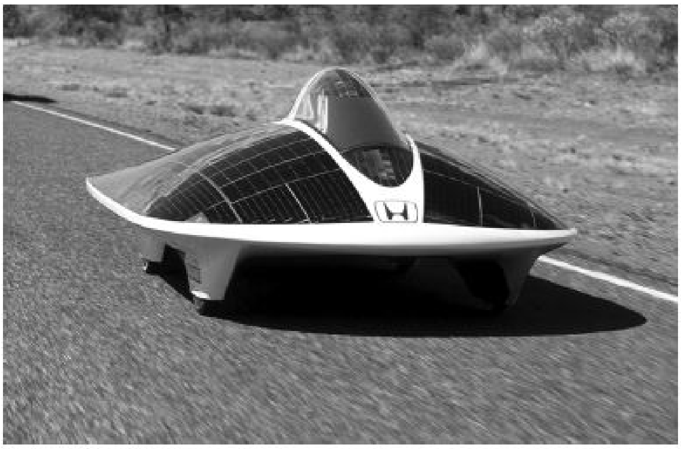
(Total for question = 5 marks)

Q17.

The world solar challenge is set every two years, in Australia. The challenge is to complete a three thousand kilometre route with a vehicle powered only by the Sun.

Vehicles have their surfaces fitted with solar panels, as shown in the photograph.



(Source: © LAURENT DOUEK/LOOK AT SCIENCES/SCIENCE PHOTO LIBRARY)

Solar power alone would not be suitable for a family car because it is not sunny all the time.

Give two further reasons why solar power alone would not be suitable.

(2)

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(Total for question = 2 marks)

Q18.

The following extract is taken from a quote by Rutherford, speaking about the scattering of alpha particles by a thin gold foil.

> We knew the alpha particle was a very fast, massive particle with a great deal of energy, and the chance of an alpha particle being scattered backward was very small. Then I remember two or three days later Geiger coming to me in great excitement and saying "We have been able to get some of the alpha particles coming backward …" It was almost as incredible as if you fired a 15-inch shell at a piece of tissue paper and it came back and hit you.

(a) Rutherford compared the scattering of alpha particle through large angles to firing "a 15-inch shell at a piece of tissue paper and it came back and hit you."

Explain, with reference to the properties of the alpha particle, why a relatively large force is needed to deflect alpha particles through a large angle.

(2)

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(b) Before the alpha particle scattering experiment, scientists believed that the mass and charge of an atom were uniformly distributed throughout the atom in a radius of about 1.4×10^{-10} m. Following the scattering experiments, a model of the atom was developed in which there was a concentrated centre of charge called the nucleus.

Assess the validity of this model of the atom given that the magnitude of the force required to scatter these alpha particles by a large angle is about 2.0 N. You should include a calculation in your answer.

proton number of gold = 79

(5)

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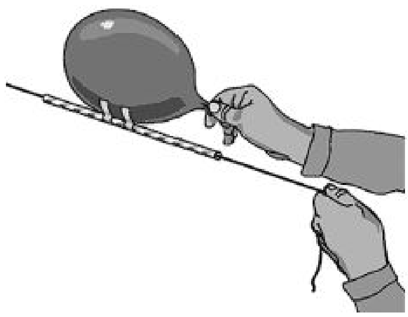
Q19.

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



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

(3)

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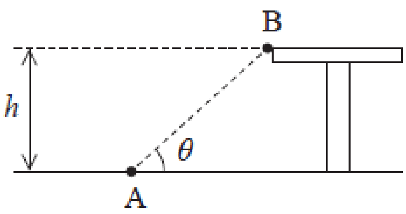
Q20.

An object of mass *m* is moved from point A on the ground, to point B on a bench of height *h* as shown in the diagram.



Which of the following is a correct expression for the work done on the object?

(1)

☒ **A** $\frac{mgh}{\sin\theta}$

☒ **B** $\frac{mgh}{\cos\theta}$

☒ **C** mgh

☒ **D** $mgh\sin\theta$

(Total for question = 1 mark)

Q21.

A student investigated the terminal velocity of steel spheres falling through oil.

The student obtained the following results.

radius of steel sphere = 1.50 mm
volume of steel sphere = 1.41×10^{-8} m^3
mass of steel sphere = 1.10×10^{-4} kg
maximum speed of sphere = 0.849 m s^{-1}

The student had the following table.

Type of oil	Density at 26 °C / kg m^{-3}	Viscosity at 26 °C / Pa s
Corn	918	0.0447
Hazelnut	918	0.0504
Sunflower	918	0.0414

Identify which type of oil the student used.

(4)

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(Total for question = 4 marks)

Q22.

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

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

distance travelled = 1.2 m

time taken = 0.77 s

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

Assume the acceleration is constant.

(2)

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....

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

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

mass of car = 0.050 kg

radius of curved part of track = 0.042 m

(2)

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Maximum horizontal force = ...

(Total for question = 4 marks)

Q23.

The force between two identical point charges, X and Y, is *F*.

Charge X is doubled; charge Y remains the same.

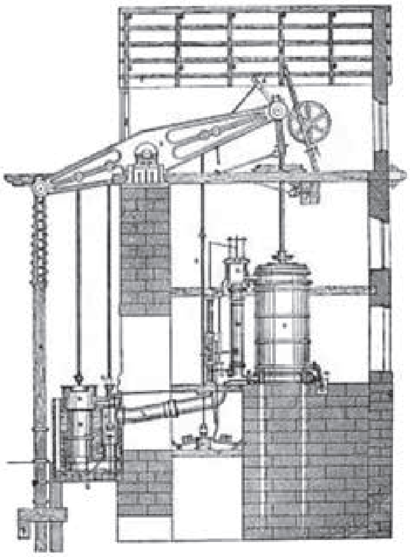
Which row of the table gives the force on each charge?

	X	Y
☐ **A**	*F*	*F*
☐ **B**	*F*	*2F*
☐ **C**	*2F*	*F*
☐ **D**	*2F*	*2F*

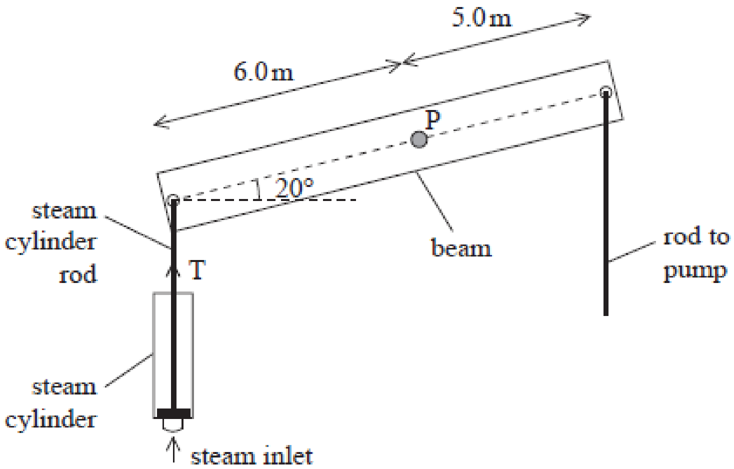
(Total for question = 1 mark)

Q24.

Beam engines contributed to powering the Industrial Revolution in Britain in the 18th century. A beam engine consisted of a beam which could rock to and fro around a well-oiled pivot. Attached to the beam there are two rods, one connected to a piston in a steam cylinder and the other connected to a pump.



The diagram below shows a simplified arrangement of a beam engine.



The beam has a constant thickness and a mass of 3.05×10^4 kg. The length of the beam is 11.0 m. The pivot P is positioned 6.0 m from the steam cylinder end of the beam.

In its resting position the steam cylinder rod is supported by the base of the steam cylinder with the beam at an angle of 20° to the horizontal.

The steam cylinder rod exerts a force *T* on the beam. The force exerted on the beam by the pump rod can be neglected.

Calculate the force *T*.

(4)

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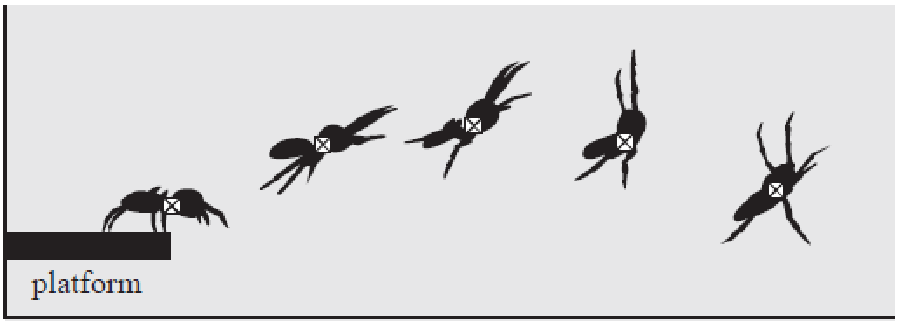
T = ...

(Total for question = 4 marks)

Q25.

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

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



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

(4)

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

(5)

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

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

mass of spider = 150 mg

(3)

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Average force = ...

(Total for question = 12 marks)

Q26.

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

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

By means of calculations justify this statement.

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

(4)

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

(3)

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Velocity = ...

(Total for question = 7 marks)

Q27.

A space rocket lifts off vertically.

The rocket lifts off because

☒ **A** the exhaust gases exert a force on the ground.

☒ **B** the exhaust gases exert a force on the rocket.

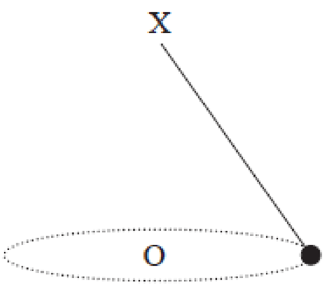
☒ **C** the ground exerts a force on the rocket.

☒ **D** the rocket exerts a force on the ground.

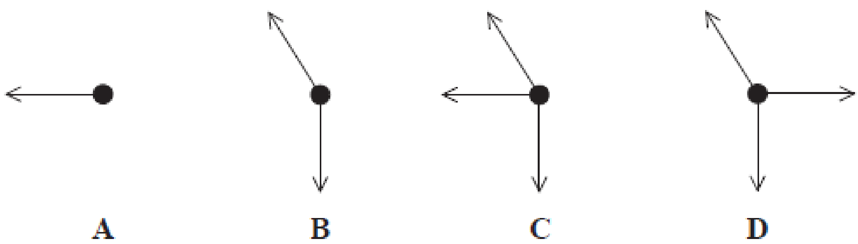
(Total for question = 1 mark)

Q28.

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?



(1)

☒ **A**

☒ **B**

☒ **C**

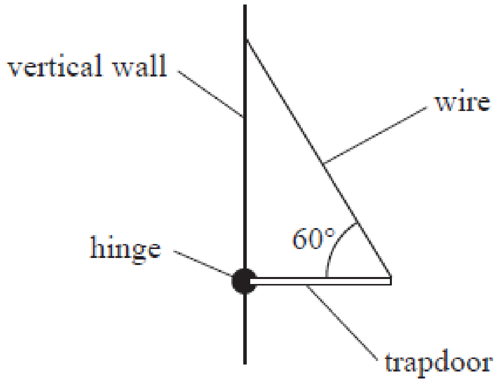
☒ **D**

(Total for question = 1 mark)

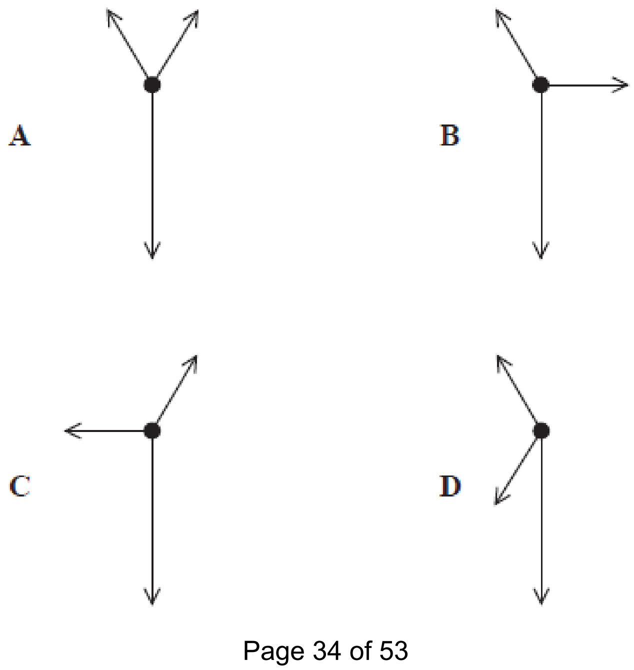
Q29.

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

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



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



☒ **A**

☒ **B**

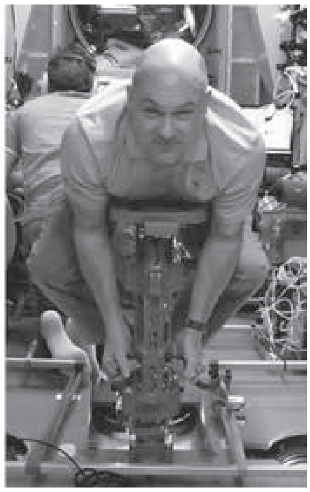
☒ **C**

☒ **D**

(Total for question = 1 mark)

Q30.

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



Describe how, using a stopwatch and a ruler, the following quantities could be determined for the oscillating platform:

(i) the frequency of oscillation

(2)

....

....

....

....

(ii) the maximum speed of the platform.

(2)

....

....

....

....

(Total for question = 4 marks)

Mark Scheme

Q1.

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: $W = 0.014\ \text{kg} \times 9.81\ \text{N kg}^{-1} \times (2 \times 0.04 \sin 6^\circ\ \text{m})$ $W = 1.1 \times 10^{-3}$ J	**(5)**

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

Q2.

Question Number	Answer	Additional guidance	Mark
(a)(i)	thermionic emission		**(1)**

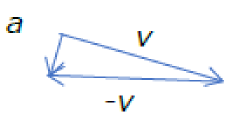
Question Number	Acceptable Answer	Additional guidance	Mark
(a)(ii)	• equate $\frac{1}{2}mv^2$ and VQ (1) • $v = 2.3 \times 10^7$ m s^{-1} (1)	<u>Example of calculation:</u> $E = 1500\text{ V} \times 1.6 \times 10^{-19}\text{ C} = 2.4 \times 10^{-16}\text{ J}$ $v = \sqrt{\frac{2 \times 2.4 \times 10^{-16}\text{ J}}{9.11 \times 10^{-31}\text{ kg}}} = 2.3 \times 10^7$ m s^{-1}	**(2)**

Question Number	Acceptable Answer	Additional guidance	Mark
(b)(i)	• use of $F = EQ$ and $E = \frac{V}{d}$ <u>OR</u> see $F = \frac{VQ}{d}$ (1) • equate $F = ma$ and $F = EQ$ (1)		**(2)**

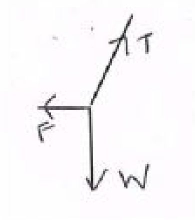
Question Number	Acceptable Answer	Additional guidance	Mark
(b)(ii)	• use of speed = distance/time (1) • $t = 8.7 \times 10^{-10}$ (s) (1) • use of $a = \frac{VQ}{dm}$ (1) • use of $s = ut + \frac{1}{2}at^2$ with $u = 0$ and vertical acceleration to find s (1) • $s = 3.3 \times 10^{-4}$ m (1)	Example of calculation: $t = \frac{0.02\text{ m}}{2.3\times10^{7}\text{m s}^{-1}} = 8.7 \times 10^{-10}$ s $s = \frac{1}{2} \times \left(\frac{50\text{ V} \times 1.6 \times 10^{-19}\text{ C}}{0.01\text{ m} \times 9.11 \times 10^{-31}\text{ kg}}\right) \times (8.7 \times 10^{-10}\text{ s})^2$ $s = 3.3 \times 10^{-4}$ m	**(6)**

Question Number	Acceptable Answer	Additional guidance	Mark
(c)	• use of $V = V_0/\sqrt{2}$ (1) • vertical line (1) • positive and negative deflection shown (1) • maximum deflection 75 V (1)	Example of calculation: $V_0 = 53\text{ V} \times \sqrt{2} = 75\text{ V}$	**(4)**

Q3.

Question Number	Acceptable answers	Additional guidance	Mark
	• vector velocities of same length with arrows as shown to indicate a difference. The "minus" v line should be approximately horizontal. (1) • third side identified as Δv/acceleration in direction approximately towards centre of circle (1)	Example of diagram  Accept "-v" line as arrow to right and labelled "v"	**2**

Q4.

Question Number	Answer	Mark
(a)(i)	W/mg and T correct (1) $F/E/$ electric force correct (1) <u>Example of diagram</u>  	**2**
(a)(ii)	See $T\cos\theta = W$ (1) See $T\sin\theta = F$ (1) **Or** Draws a correct triangle of forces (1) Correctly labels θ (1) (if a triangle is drawn it must be a closed polygon with correctly orientated direction of arrows)	**2**
(b)(i)	Records 1pair of values from graph (1) Records 2nd pair of values from graph (1) Use of $F\,r^2$ (1) Shows that $F_1r_1^2 = F_2r_2^2$ (1) (accept answers with or without the powers of ten included) <u>Example of answer</u> Ignoring powers of 10 $115\text{ N} \times 20^2\text{ m}^2 = 46000$ $51\text{ N} \times 30^2\text{ m}^2 = 45900$	**4**
(b)(ii)	Uses constant from (b) ignoring powers of ten errors **Or** uses a pair of values from graph (1) Use of $F = kQ_1Q_2/r^2$ with 1.6×10^{-19} C (1) $Q = 7.2 \times 10^{-9}$ C (1) <u>Example of answer</u> $100\,Q^2 = 46000 \times 10^{-9}\text{ N m}^2 / 8.99 \times 10^9\text{ N m}^2\text{ C}^{-2}$ $Q^2 = 5.12 \times 10^{-17}\text{ C}^2$ $Q = 7.2 \times 10^{-9}$ C	**3**
	Total for question	**11**

Q5.

<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 logical structured answer with linkage and fully-sustained reasoning.
Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.
The following table shows how the marks should be awarded for indicative content.

<table>
<tr><th>Number of indicative 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>

Indicative content:

Newton's 3rd law pair of forces must be of the same type
Or Newton's 3rd law pair of forces must act on different bodies
The two forces mentioned are not a 3rd Law pair
Or gravity is not a good description of force
The lift on the plane should be paired with the push of the plane on the air
Or the gravitational force of Earth on plane should be paired with the gravitational force of plane on Earth.
If the vertical resultant force is zero the plane will not accelerate vertically
So the plane could be 'at rest' or moving with uniform velocity in the vertical direction
There must be some horizontal motion so plane can't be in same place
</td><td>The following table shows how the marks should be awarded for structure and lines of reasoning

<table>
<tr><th></th><th>Number of marks awarded for structure 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>
<tr><td></td><td></td></tr>
<tr><td></td><td></td></tr>
</table>

Linkage Marks

IC points 1 – 3
Two of these points could score one linkage mark

IC points 4 – 6
Two of these points could score one linkage mark</td><td>6</td></tr>
</table>

Q6.

Question Number	Answer		Mark
(a)	The wavelength (associated) with a particle/electron with a given momentum **Or** $\lambda = h/p$ all terms defined	(1) (1) (1) (1)	**2**
(b)(i)	Use of $E_k = eV$ Use of $E_k = p^2/2m$ **Or** use of $E_k = mv^2/2$ **and** $p = mv$ Momentum = 1.21×10^{-23} kg m s^{-1} <u>Example of calculation</u> $E_k = 1.6 \times 10^{-19}$ C$\times$ 500 V $p^2 = 2\ m\ E_k = 2 \times 9.11 \times 10^{-31}$ kg $\times$ ($1.6 \times 10^{-19} \times 500$) J $p = 1.21 \times 10^{-23}$ kg m s^{-1}	(1) (1) (1)	**3**
(b)(ii)	Use of $\lambda = h/p$ $\lambda = 5.49 \times 10^{-11}$ m (ecf value of p from (i)) (show that value gives 6.63×10^{-11} m) <u>Example of calculation</u> $p = 6.63 \times 10^{-34}$ J s / 1.21×10^{-23} kg m s^{-1} $\lambda = 5.49 \times 10^{-11}$ m	(1) (1)	**2**
	Total for question		7

Q7.

Question number	Acceptable answers	Additional guidance	Mark
	A description that makes reference to the following points: • g is directly proportional to r up to R_0 **(1)** • and then g decreases with increasing r **(1)** • where g is proportional to the inverse of the square of r **(1)**		**3**

Q8.

Question number	Acceptable answers	Additional guidance	Mark
	A description that makes reference to the following points: • Refer to $v^2 = u^2 + 2as$ **(1)** • Where s is height reached, v is zero, $a = -g$ **(1)** • So $u = \sqrt{2gs}$ **(1)**	Allow argument ½ $mv^2 = mgh$ to get the same results.	**3**
(ii)	• Air resistance will act on the popper… **(1)** • …As a decelerating force **(1)** **OR**… dissipating energy **(1)** • So the initial speed will be lower than in the absence of air resistance, so the suggestion is not correct **(1)**		**3**

Q9.

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

Q10.

Question Number	Acceptable answers	Additional guidance	Mark
	• Use of $E_K = p^2 / 2m$ (1) • Use of $\lambda = h/p$ (1) • λ =5.0 × 10^{-11} (m) calculated from E_K (1) **Or** E_K = 9.7 × 10^{-17} (J) calculated fro λ =5.0 × 10^{-11} m **Or** p = 1.3 × 10^{-23} (kg m s^{-1}) calculated from E_K **and** p = 1.3 × 10^{-23} (kg m s^{-1}) calculated from λ =5.0 × 10^{-11} m • path difference at X is $\lambda/2$ **Or** path difference at Y is λ (1) • (electron) waves at X are in antiphase **Or** (electron) waves at Y are in phase (1) • at X destructive interference/superposition takes place **Or** at Y constructive interference/superposition takes place (1)	MP1 accept use of $p = mv$ **and** Use of $E_k = ½ mv^2$ MP4 accept (n + ½) λ or n λ respectively Example of calculation $p = \sqrt{(2 \times 9.11 \times 10^{-31}\text{ kg} \times 9.6 \times 10^{-17}\text{ J})}$ $p = 1.32 \times 10^{-23}$ kg m s^{-1} $\lambda = 6.63 \times 10^{-34}$ Js / 1.32×10^{-23} kg m s^{-1} $\lambda = 5.0 \times 10^{-11}$ m	6

Q11.

Question Number	Acceptable answers		Additional guidance	Mark
	• Uses $\tan\theta = B_V \div B_H$ Or uses $\tan\theta = B_H \div B_V$ • Angle = 69°	(1) (1)	Example of calculation: $\tan\theta = 49/19$ $\theta = 68.8°$ Accept use of vector triangle as alternative to calculation	(2)

Q12.

Question number	Acceptable answers	Additional guidance	Mark
*	This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning. Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning. The following table shows how the marks should be awarded for indicative content.	Guidance on how the mark scheme should be applied: The mark for indicative content should be added to the mark for lines of reasoning. For example, an answer with five indicative marking points which is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning). If there are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).	

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

Question number	Acceptable answers	Additional guidance	Mark
* (continued)	The following table shows how the marks should be awarded for structure and lines of reasoning.		

	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

Question number	Acceptable answers	Additional guidance	Mark
* (continued)	**Indicative content** • At terminal velocity the forces on the drop are balanced **OR** weight = drag • The p.d. creates an electrostatic force acting upwards on the drop • The electrostatic force increases as p.d. increases • The net upward force causes the drop to have a negative acceleration • As speed decreases the drag decreases • The drop remains stationary when the forces are balanced **OR** until the drop remains stationary when weight = electrostatic force		**6**

Q13.

Question number	Acceptable answers	Additional guidance	Mark
(b)	• Equate the electric force and the gravitational force **(1)** • Use of E=V/d to obtain $q = mgd/V$ **(1)**	$qE = mg$ $q(V/d) = mg$ $q = mgd/V$	**2**
(c)	An explanation that makes reference to: • Electrostatic/upward force (on drop) would be greater than the weight/downward force **(1)** • So drop would accelerate upwards **(1)**	Indication of which force is greater, unbalanced is insufficient.	**2**

Q14.

Question Number	Acceptable answers		Additional guidance	Mark
	• take one moment around P	(1)	either person or paving slab	
	• Use of $W = mg$	(1)		
	• Use of weight/mass of paving slab at centre point	(1)	e.g. distance to P = 30 cm	
	• It would tip because the moment of the weight of person is 103 N m / 10300 N cm and is larger than the moment of the weight of slab 93 N m / 9300 N cm	(1)	Example of calculation: Moment of weight of person $= 70\ \text{kg} \times 9.81\ \text{N kg}^{-1} \times 0.15\ \text{m} = 103\ \text{N m}$ Moment of weight of paving slab $= 310\ \text{N} \times 0.30\ \text{m} = 93\ \text{N m}$	**4**

Q15.

Question Number	Answer		Mark
(a)(i)	Use of $P = IV$ Power = 2900 W <u>Example of calculation</u> Power = 12.5 A × 230 V = 2875 W	(1) (1)	2
(a)(ii)	$P = E/t$ Energy = 400 000 J (ecf from (i)) <u>Example of calculation</u> Energy = 2875 W × 140 s = 402 500 J	(1) (1)	2
(a)(iii)	Use of efficiency = useful energy output / total energy input = 0.87 or 87% (ecf from (ii)) (do not award if > 100%) <u>Example of calculation</u> Efficiency = 351 000 J / 402 500 J = 0.87 or 87%	(1) (1)	2
(b)	Some energy transferred by heating the kettle / element / wires / surroundings **Or** Some energy transferred as sound So not all of the (input) energy is transferred to (heating) the water **Or** so useful energy output is less than energy input **Or** only the energy heating the water is useful	(1) (1)	2
	Total for question		**8**

Q16.

Question Number	Acceptable answers		Additional guidance	Mark
	• Use of $\Delta E_{grav} = mg\Delta h$ • convert for a unit time, e.g. day or second ie W • Calculation of energy input provided by coal in unit time • Use of Efficiency = energy output/energy input **Or** in terms of power • Efficiency = 1.5 % so not correct	(1) (1) (1) (1) (1)	(allow reverse argument starting with 10% efficiency for full credit) Example of calculation: $\Delta E_{grav} = 2500 \times 9.81 \times 12$ $\Delta E_{grav} = 294\text{kJ per minute}$ $\Delta E_{grav} = 294\text{kJ} \times 60 \times 24$ $\Delta E_{grav} = 424\text{MJ per day}$ energy input = 1250 × 22.3 MJ Efficiency = 424 MJ/ 27900 MJ = 1.5%	5

Q17.

Question Number	Acceptable answers	Additional guidance	Mark
	Max 2 • normal car would have much more mass (1) • too much area of solar cell needed so impractical (1) • going uphill would need far more power (1)		**2**

Q18.

Question Number	Acceptable Answer	Additional guidance	Mark
(a)	An explanation that makes reference to the following: • due to the large mass and speed <u>OR</u> large momentum <u>OR</u> large energy (1) • the alpha particle would have a large <u>change</u> in momentum when deflected through large angles which requires a large force (1)		**(2)**

Question Number	Acceptable Answer		Additional guidance	Mark
(b)	• use of $F = \frac{Q_1 Q_2}{4\pi\varepsilon_0 r^2}$	(1)	Accept calculating a force for $r = 1.4 \times 10^{-10}$ and comparing forces	
	• charge of alpha $= 2 \times 1.6 \times 10^{-19}$ (C)	(1)	<u>Example of calculation:</u>	
	• r = 1.3×10^{-13} (m)	(1)	$r = \sqrt{8.99 \times 10^9\ \text{N m}^2\text{C}^{-2} \times \frac{(79 \times 2)(1.6 \times 10^{-19}\ \text{C})^2}{2}}$	
	• comparison of the two distances	(1)	$r = 1.3 \times 10^{-13}$ m	
	• conclusion that the alpha particle must reach a closer distance to give a larger force and relates this to the model	(1)		**(5)**

Q19.

Question Number	Acceptable Answer		Additional guidance	Mark
	An explanation that makes reference to:			
	• correct reference to Newton's 3rd law	(1)		
	• balloon moves in opposite direction to the air	(1)		
	• applies Newton's 2nd law so that resultant force on balloon causes it to accelerate <u>OR</u> applies Newton's 2nd law so that resultant force on balloon causes its momentum to change	(1)		**(3)**

Q20.

Question Number	Acceptable answers	Additional guidance	Mark
	C	*mgh*	**1**
	A uses the distance AB rather than height B uses a component of height D uses a component of height		

Q21.

Question Number	Acceptable answers		Additional guidance	Mark
	• Use of $\rho = m/V$ • Use of relationship upthrust = weight of liquid • Use of $F = 6\pi\eta rv$ • $\eta = 3.97 \times 10^{-2}$ (Pa s) so it is sunflower oil	**(1)** **(1)** **(1)** **(1)**	<u>Example of calculation</u> mass of oil displaced $= 9.20 \times 10^{2}$ kg m^{-3} $\times 1.41 \times 10^{-8}$ m^{3} $= 1.30 \times 10^{-5}$ kg upthrust $= 1.30 \times 10^{-5}$ kg $\times 9.81$ m s^{-2} $= 1.27 \times 10^{-4}$ N weight of sphere $= 1.10 \times 10^{-4}$ kg $\times$ 9.81 m s^{-2} $= 1.08 \times 10^{-3}$ N weight = upthrust + drag 1.08×10^{-3} N $= (6\pi \times \eta \times 1.5 \times 10^{-3}$ m $\times 0.849$ m s$^{-1}) + 1.27 \times 10^{-4}$ N $\eta = 3.97 \times 10^{-2}$ Pa s	**4**

Q22.

Question Number	Acceptable answers		Additional guidance	Mark
i	• use of $s = \frac{(u+v)}{2} \times t$ • $v = 3.1$ (m s^{-1})	(1) (1)	Example of calculation: 1.1 m $= \frac{(0+v)}{2} \times 0.77$ s $v = 3.1$ m s^{-1}	2
ii	• use of $F = mv^2/r$ • $F = 11$ N (allow ecf from (i))	(1) (1)	Example of calculation: $F = \frac{0.050 \text{ kg} \times 3.1^2 (\text{m s}^{-1})^2}{0.042 \text{ m}}$ $F = 11.4$ N "show that value" gives $F = 10.7$ N	2

Q23.

Question Number	Acceptable answers	Additional guidance	Mark
	D		1

Q24.

Question Number	Acceptable answers		Additional guidance	Mark
	• Take a correct moment about pivot P • Converts the mass to weight of beam ie ×9.81 seen • Appreciates centre of mass 0.5 m from P • $T = 25$ kN	(1) (1) (1) (1)	eg T.6.cos20 or sin70 If cos20's are absent from both sides of equation then can still credit 4 marks Example of Calculation: $T \times 6(\text{m}) \times \cos 20 = 3.05 \times 10^4 (\text{kg}) \times 9.81 (\text{ms}^{-2}) \times 0.5(\text{m}) \times \cos 20$ $T = 24.9$kN	4

Q25.

Question Number	Acceptable answers		Additional guidance	Mark
(i)	• distance between at least two pairs of images • distances between images are the same in x direction • distance between images varies in y direction showing a changing velocity • velocity in the x direction is constant so x direction is independent of y direction	(1) (1) (1) (1)	MP1 and 2 could come from marks on the diagram	4
(ii)	• use of $v^2 = u^2 + 2as$ or $s = ut + \frac{1}{2}at^2$ • initial vertical component velocity = 0.47 m s^{-1} • use of $v_H = d/t$ in the horizontal • Use of Pythagorus with v_H and u_V • Resultant velocity = 1.1 m s^{-1}	(1) (1) (1) (1) (1)	alt to MP2 : 0.5 m s^{-1} (allow 0.4 to 0.6) if using distance taken from first two images and $v_H = d/t$ Example of calculation: $0 = u^2 - 2 \times 9.81$ m s^{-2} $\times$ 0.011 m u_V = 0.465 m s^{-1} $v_H = \frac{0.08 \text{ m}}{0.08 \text{ s}}$ v_H = 1.0 m s^{-1} $v = \sqrt{(0.47^2 + 1.0^2)}$ Resultant velocity = 1.1 m s^{-1}	5
(iii)	• Use of $\Delta W = F \Delta s$ • Use of $E_k = ½ mv^2$ • F = 0.015 N Alternative • Use of $v^2 = u^2 + 2as$ • Use of $F = ma$ (dependent on MP1) • F = 0.015 N	(1) (1) (1) (1) (1) (1)	Allow ECF from (a)(ii) Example of calculation: $2 \times F \times 0.003\text{m} = \frac{1}{2} \times 150 \times 10^{-6}\text{kg} \times 1.1^2\ (\text{m s}^{-1})^2$ F = 0.015 N "show that" value gives F = 0.013 N Alternative $1.1^2\ (\text{ms}^{-1})^2 = 2 \times a \times 0.003$ m a = 202 m s^{-2} $2 \times F = 150 \times 10^{-6}\ \text{kg} \times 202\ \text{ms}^{-2}$ F = 0.015 N	3

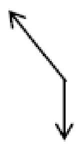
Q26.

Question number	Acceptable answers	Additional guidance	Mark
(i)	• use of $F = Q_1Q_2/4\pi\varepsilon_0 r^2$ **(1)** • use of $F = Gm_1m_2/r^2$ **(1)** • Expresses forces as a ratio **(1)** **OR** calculates the individual forces F_e=8.1 x 10^{-8} N F_g = • 3.6 x 10^{-47} N **(1)** • Ratio = 2 x 10^{39} or 5 x 10^{-40} and identifies gravitational force as insignificant **(1)**		**4**
(ii)	• use of $F = mv^2/r$ and $F = Q_1Q_2/4\pi\varepsilon_0 r^2$ **(1)** • to derive $v = \sqrt{\frac{Q_1Q_2}{4\pi\epsilon_0 rm}}$ **(1)** • velocity = 2.2× 10^6 m s^{-1} **(1)**	Example of calculation: $v = \sqrt{\frac{Q_1Q_2}{4\pi\epsilon_0 rm}}$ $v = \sqrt{\frac{1.6\times10^{-19}\text{ C}\times1.6\times10^{-19}\text{ C}}{4\pi\times8.85^{-12}\text{ Fm}^{-1}\times5.3\times10^{-11}\text{m}\times9.1\times10^{-31}\text{ kg}}}$ $v = 2.185 \times 10^6$ m s^{-1}	**3**

Q27.

Question Number	Acceptable answers	Additional guidance	Mark
	B		1

Q28.

Question Number	Acceptable answers	Additional guidance	Mark
	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		

Q29.

Question Number	Acceptable answers	Additional guidance	Mark
	The only correct answer is A B is not correct as these forces are not in equilibrium C is not correct as these forces are not in equilibrium D is not correct as these forces are not in equilibrium		**1**

Q30.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	• (Use the stopwatch to) time a large number of oscillations to determine the time period **(1)** • Calculate the frequency using $f = \frac{1}{T}$ **(1)**	MP1: At least 5 oscillations required	**2**
(ii)	• (Use the metre rule to) measure the max displacement of the platform (from the equilibrium position) **(1)** • Calculate the maximum speed using $v_{max} = 2\pi f x_{max}$ **(1)**	MP2: allow use of $v_{max} = \frac{2\pi}{T} x_{max}$	**2**