Name: ____

Topic 7: Electric and Magnetic Fields Part 4

Date:

Time:

Total marks available:

Total marks achieved: ______

Questions

Q1.

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.

The platform continues to move with simple harmonic motion at the same frequency, but its amplitude is doubled.

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

(2)

....

....

....

....

(Total for question = 2 marks)

Q2.

A capacitor is charged and then discharged through a resistor of resistance *R*.
As the capacitor discharges, the maximum current is 5 mA and the time for the current to fall to 2.5 mA is 6 s.

The experiment is repeated using the same charging potential difference but a lower value of *R*.

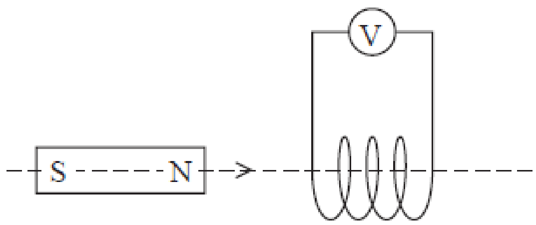
Select the row of the table that shows possible values of current and time.

	Maximum current / mA	Time for current to halve / s
☒ **A**	3	4
☒ **B**	3	8
☒ **C**	7	4
☒ **D**	7	8

(Total for question = 1 mark)

Q3.

A magnet is passed along the axis of a short coil of wire.



An e.m.f. is induced across the ends of the coil.

Which of the following would increase the maximum e.m.f. induced?

☒ **A** decreasing the area of the coil

☒ **B** decreasing the number of turns per metre in the coil

☒ **C** increasing the speed of the magnet

☒ **D** reversing the polarity of the magnet

(Total for question = 1 mark)

Q4.

An electron and an alpha particle enter a uniform magnetic field which is acting perpendicular to their motion. The electron is travelling at four times the velocity of the alpha particle. The force on the electron is *F*.

The force on the alpha particle is

☐ **A** $F/2$

☐ **B** F

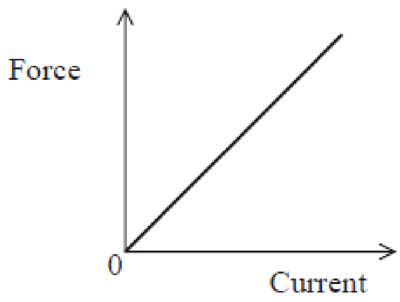
☐ **C** $4F$

☐ **D** $16F$

(Total for question = 1 mark)

Q5.

A current-carrying conductor with length *l* is placed at right angles to a magnetic field with magnetic flux density *B*. The graph shows how the force on the wire varies with the current passing through it.



The gradient of the graph is equal to

☐ **A** B

☐ **B** Bl

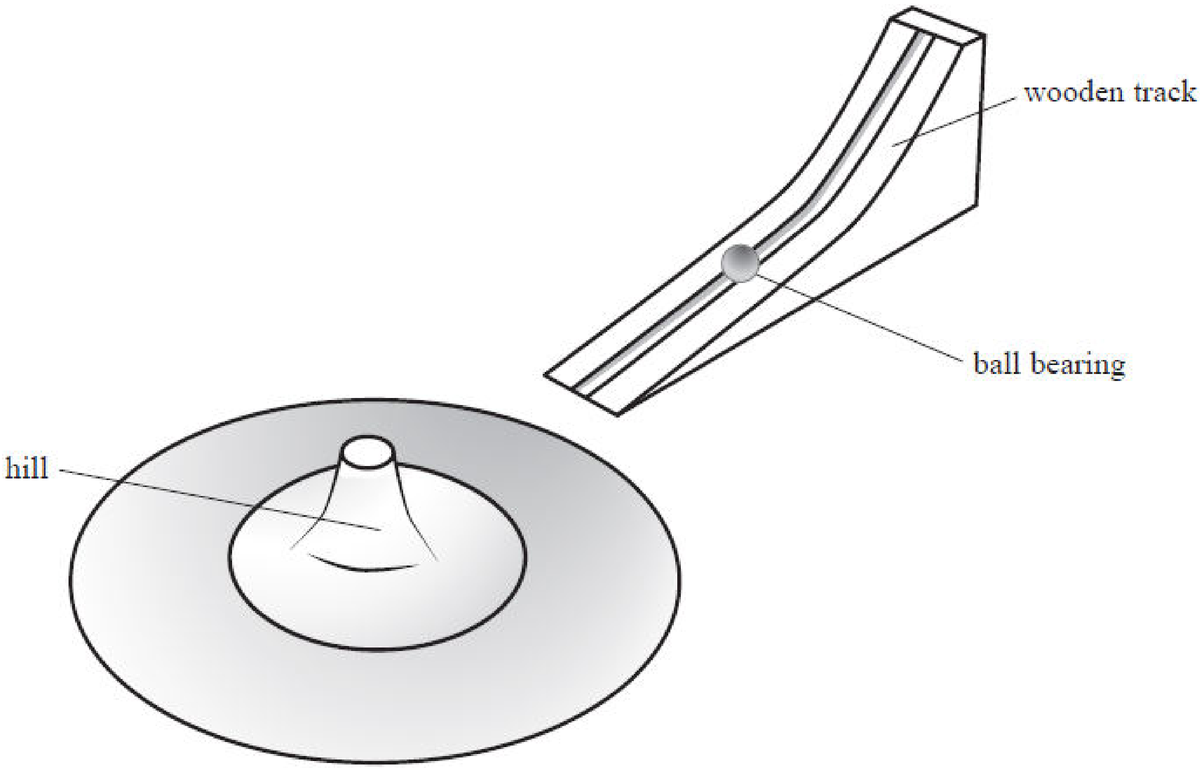
☐ **C** $\frac{1}{B}$

☐ **D** $\frac{B}{l}$

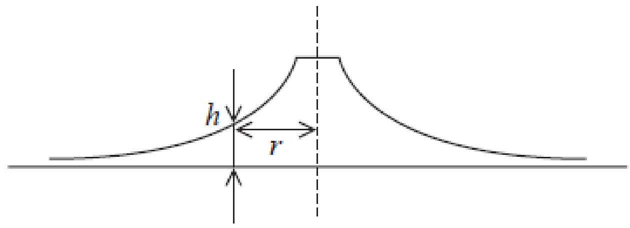
(Total for question = 1 mark)

Q6.

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)

....

....

....

....

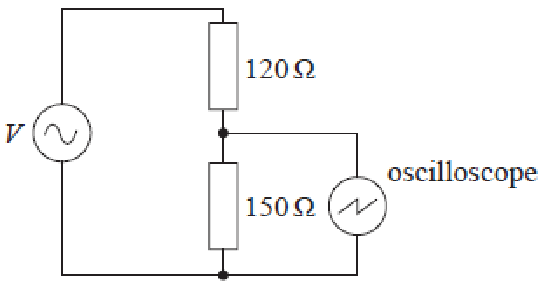
....

(Total for question = 3 marks)

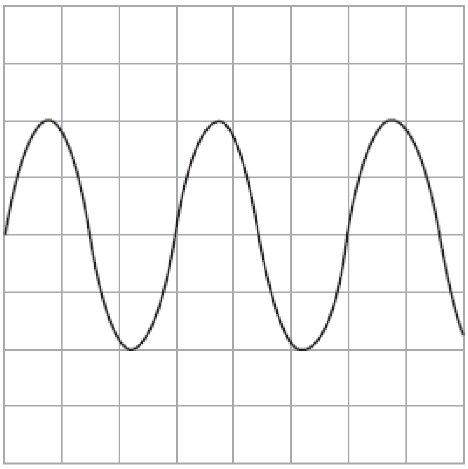
Q7.

A student connected the output from a source of alternating potential difference (p.d.) to a series resistor combination.

She connected an oscilloscope across the 150 Ω resistor as shown.



The trace obtained on the oscilloscope is shown below.



(i) Determine the peak p.d. across the 150 Ω resistor.

y-sensitivity of oscilloscope = 2.0 V per division

(2)

....

....

....

Peak p.d. across 150 Ω resistor = ...

(ii) Calculate the root mean square (r.m.s.) value of the current in the circuit.

(3)

....

....

....

....

....

r.m.s. value of current = ...

(iii) Calculate the power dissipated in the circuit.

(3)

....

....

....

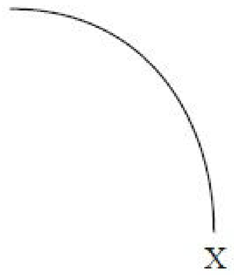
....

Power dissipated in circuit = ...

(Total for question = 8 marks)

Q8. Scientists studying anti-matter recently observed the creation of a nucleus of anti-helium 4, which consists of two anti-protons and two anti-neutrons.

The diagram represents the path of a proton through a magnetic field starting at point X.



Add to the diagram the path of an anti-helium 4 nucleus also starting at point X and initially travelling at the same velocity as the proton.

Explain any differences between the paths.

(5)

....

....

....

....

....

....

....

....

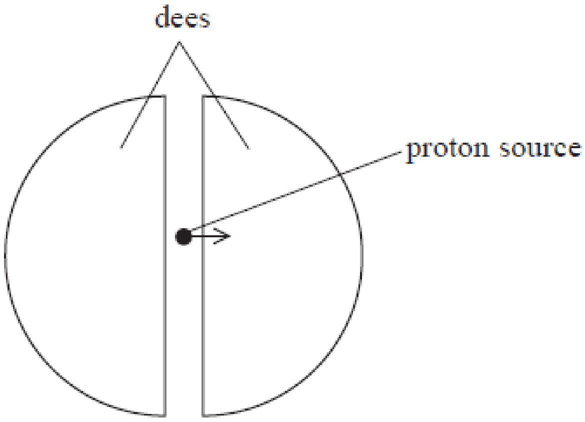
....

....

(Total for Question = 5 marks)

Q9.

A cyclotron is a particle accelerator which can be used to accelerate protons. The cyclotron consists of two semicircular electrodes called 'dees'. An alternating potential difference is applied across the gap between the dees. A uniform magnetic field is applied at right angles to the plane of the dees.



(i) Complete the diagram to show the path of the protons.

(1)

(ii) State the direction of the magnetic field needed in order to produce the path you have sketched.

(1)

....

(iii) Explain how the kinetic energy of the protons is increased as they follow the path you have shown.

(3)

....

....

....

....

....

....

....

(iv) Show that the magnetic flux density *B* of the applied magnetic field is given by

$$B = \frac{2\pi f m}{e}$$

where *f* is the frequency of the alternating potential difference, *m* is the mass of the proton and *e* is the charge on the proton.

(3)

....

....

....

....

....

....

....

....

(v) In a particular cyclotron *B* is 1.2 mT.
Calculate the frequency *f* of the alternating potential difference.

(2)

....

....

....

....

f = ...

Q10.

Protons interact with particles in the upper atmosphere and create new particles. Pions can be produced from high energy proton collisions.

(i) State why the following reaction is not possible.

$$p + p \rightarrow \mathrm{p} + p + \pi^-$$

(1)

....

....

(ii) State one similarity and one difference between the electric field of a proton and the electric field of a π^-.

(2)

....

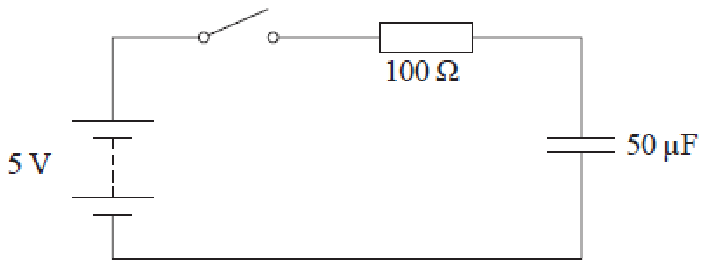
....

....

....

Q11.

A circuit consists of a battery of e.m.f. 5 V and negligible internal resistance, a switch, a 100 Ω resistor and an uncharged 50 μF capacitor.



Describe what happens to the potential difference across the resistor and the potential difference across the capacitor after the switch is closed.

(4)

....

....

....

....

....

....

....

....

(Total for question = 4 marks)

Q12.

A capacitor of capacitance *C* is charged to a potential difference *V* by a power supply.

The energy stored on the charged capacitor is *W*.

What would be the energy stored if the potential difference were 2*V*?

(1)

☒ **A** $\frac{W}{4}$

☒ **B** $\frac{W}{2}$

☒ **C** $2W$

☒ **D** $4W$

(Total for question = 1 mark)

Q13.

Which of the following is a property of a uniform electric field?

☒ **A** A field that doesn't change over time.

☒ **B** A field that acts equally in all directions.

☒ **C** A field that only produces a force on moving charged particles.

☒ **D** A field that has the same strength at all points.

(Total for question = 1 mark)

Q14.

A capacitor of capacitance *C* is discharged through a resistor of resistance *R*. The initial discharge current is I_0.

Which of the following expressions gives the current after a time equal to *RC*?

☐ **A** $\frac{I_0}{e}$

☐ **B** $\frac{I_0}{2}$

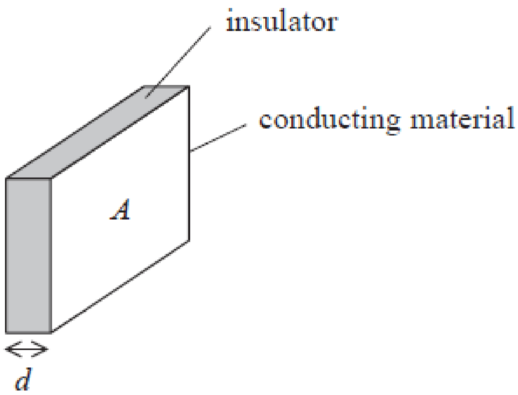
☐ **C** $I_0 e^{-RC}$

☐ **D** $I_0 \ln \frac{1}{e}$

(Total for question = 1 mark)

Q15.

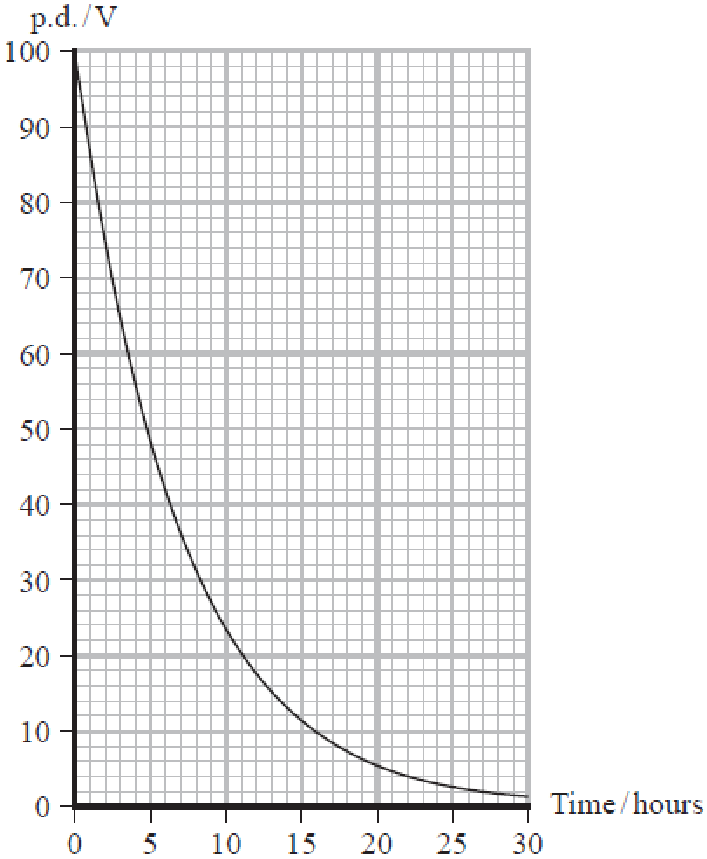
A parallel plate capacitor consists of a thin layer of insulator of thickness *d* between two plates of conducting material of area *A*.



The capacitor has a capacitance 0.1 µF and is charged to a p.d. of 100 V by connecting it to an electrical supply.

The capacitor is then disconnected from the supply and the p.d. between the two plates slowly decreases. This is because the insulator is not perfect and a small charge can flow through it.

The graph shows how the p.d. varies with time.



The insulator is a type of plastic and should have a resistivity greater than 10^{14} Ω m.

Deduce whether the plastic used in this capacitor has a resistivity greater than this value.

$A = 5.6 \times 10^{-3}$ m^2

$d = 0.6 \times 10^{-6}$ m

(5)

....

....

....

....

....

....

....

....

....

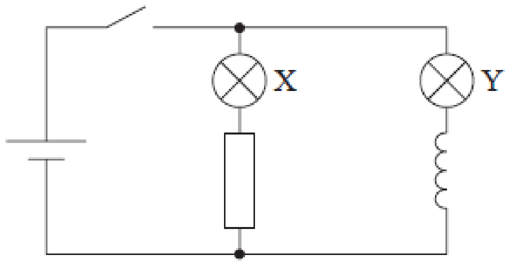
....

....

(Total for question = 5 marks)

Q16.

A circuit is set up as shown in the diagram. Lamps X and Y are identical.
The coil has a soft iron core. The resistor and the coil have the same resistance.



The switch is closed and lamp X lights instantly.

Which statement best describes lamp Y after the switch is closed?

(1)

☒ **A** Lights after a delay with a final brightness less than X

☒ **B** Lights after a delay with a final brightness the same as X

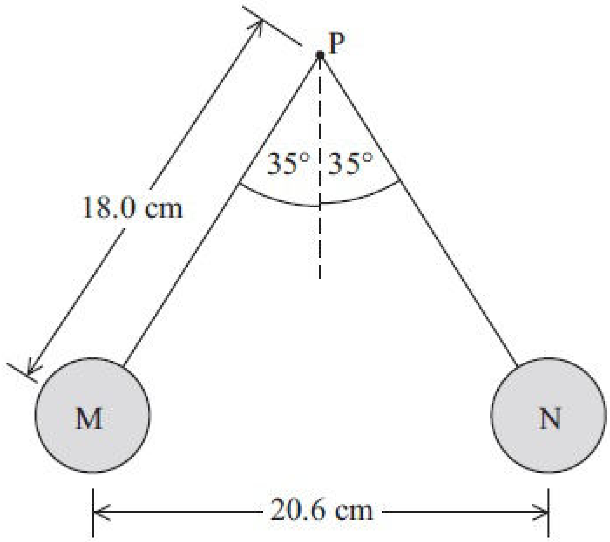
☒ **C** Lights instantly with less brightness than X

☒ **D** Lights instantly with the same brightness as X

(Total for question = 1 mark)

Q17.

Two identical table tennis balls, M and N, are attached to non-conducting threads and suspended from a point P. The balls are each given the same positive charge and they hang as shown in the diagram. The mass of each ball is 2.7 g.



(a) Draw a free-body force diagram for ball M, label your diagram with the names of the forces.

(2)

(b) (i) Show that the tension in one of the threads is about 3×10^{-2} N.

(3)

....

....

....

....

....

(ii) Show that the electrostatic force between the balls is about 2×10^{-2} N.

(2)

....

....

....

....

....

(iii) Calculate the charge on each ball.

(3)

....

....

....

....

....

Charge = ...

(c) State and explain what would have happened if the charge given to ball M was greater than the charge given to ball N.

Calculate the charge on each ball.

(2)

....

....

....

....

....

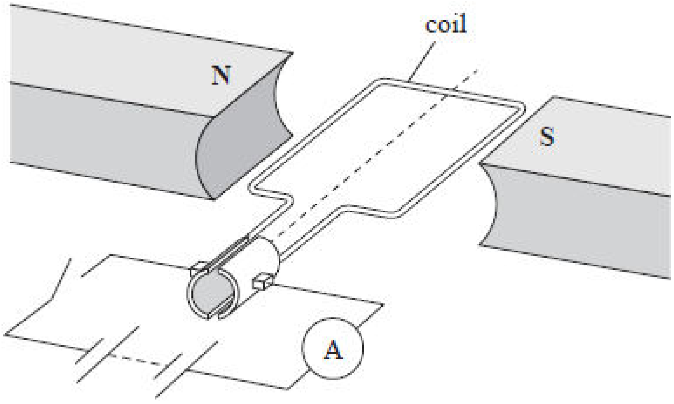
....

(Total for question = 12 marks)

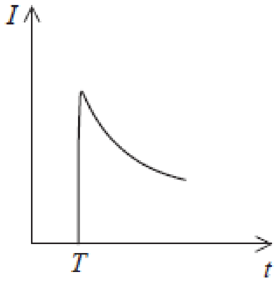
Q18.

* A simple electric motor consists of a coil that is free to rotate in a magnetic field.

A student connects the motor to an ammeter and a battery.



The graph shows how the current *I* in the coil varies with time *t*. The switch is closed at time *T*.



Explain why the current rises to a maximum then decreases.
Your answer should include a reference to Faraday and Lenz's laws.

(6)

....

....

....

....

....

....

....

....

....

....

....

....

....

....

(Total for question = 6 marks)

Q19.

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 wire carries an alternating current of peak value 3 A.

Which of the following is the root-mean-square value of this current?

☐ **A** 1.5 A

☐ **B** 2.1 A

☐ **C** 4.2 A

☐ **D** 9.0 A

(Total for question = 1 mark)

Q20. In an experiment to investigate the structure of the atom, α-particles are fired at a thin metal foil, which causes the α-particles to scatter.

(a) (i) State the direction in which the number of α-particles detected will be a maximum.

(1)

....

(ii) State what this suggests about the structure of the atoms in the metal foil.

(1)

....

(b) Some α-particles are scattered through 180°.

State what this suggests about the structure of the atoms in the metal foil.

(2)

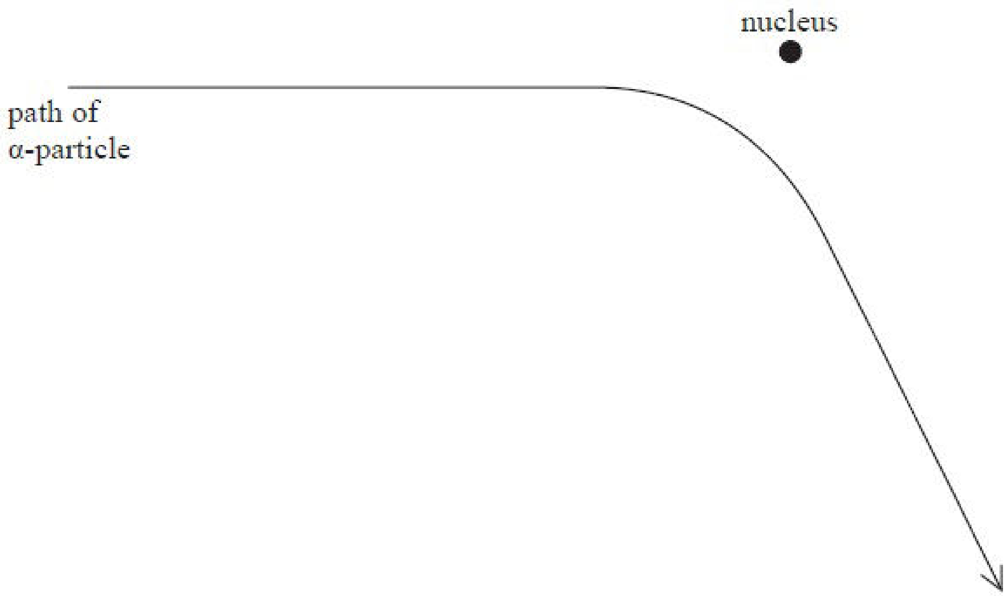
....

....

....

....

(c) The diagram shows the path of an α-particle passing near to a single nucleus in the metal foil.



(i) Name the force that causes the deflection of the α-particle.

(1)

....

(ii) On the diagram, draw an arrow to show the direction of the force acting on the α-particle at the point where the force is a maximum. Label the force F.

(2)

(iii) The foil is replaced by a metal of greater proton number.

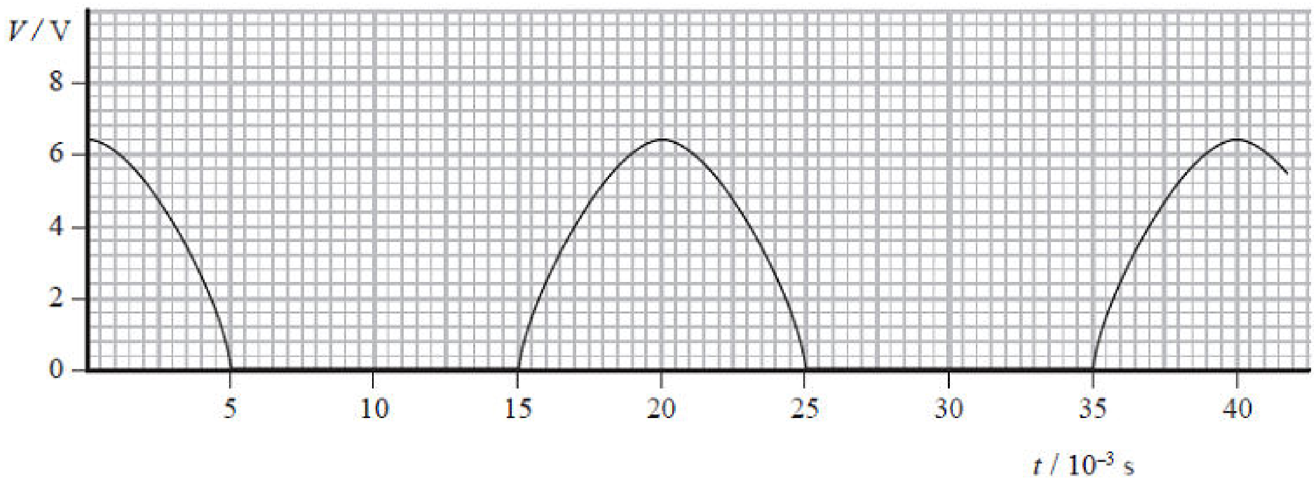
Draw the path of an α-particle that has the same initial starting point and velocity as the one drawn in the diagram.

(2)

(Total for Question = 9 marks)

Q21.

The graph shows how the output *V* from the terminals of a power supply labelled d.c. (direct current) varies with time *t*. This type of supply will not allow current to flow backwards through it.



(a) A student connects a capacitor across the terminals of this power supply in order to try to produce a constant voltage.

Suggest how this produces a constant voltage.

(2)

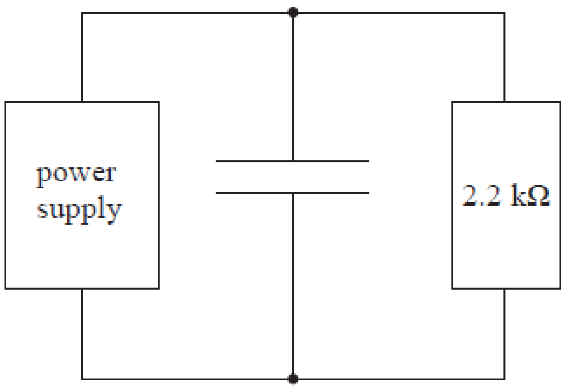
....

....

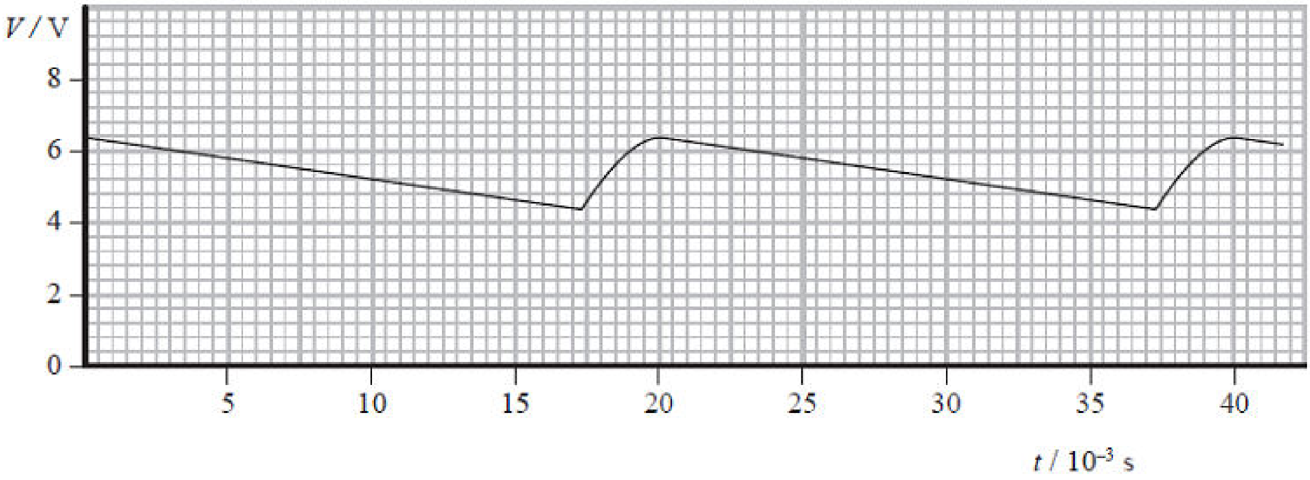
....

....

(b) The student then connects a resistor across the capacitor as shown.



The graph shows the variation of the potential difference *V* across the resistor with time *t*.



(i) Estimate the average potential difference across the resistor.

(1)

....

....

Average potential difference = ...

(ii) Calculate the average current in the resistor.

(2)

....

....

Average current = ...

(iii) Determine the time in each cycle for which the capacitor discharges through the resistor.

(1)

....

....

Discharge time = ...

(iv) Calculate the charge passing through the resistor during one discharge of the capacitor and hence determine the capacitance of the capacitor.

(4)

....

....

....

....

....

....

....

....

Charge = ...

Capacitance = ...

(c) The student wants to produce a potential difference across the same resistor that has less variation in magnitude.
State, with a reason, what the student could do to achieve this.

(2)

....

....

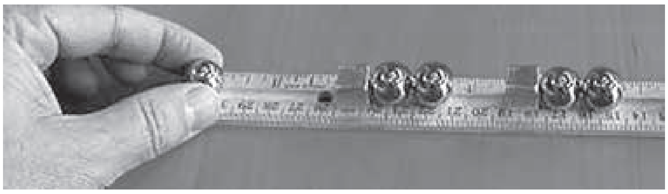
....

....

(Total for question = 12 marks)

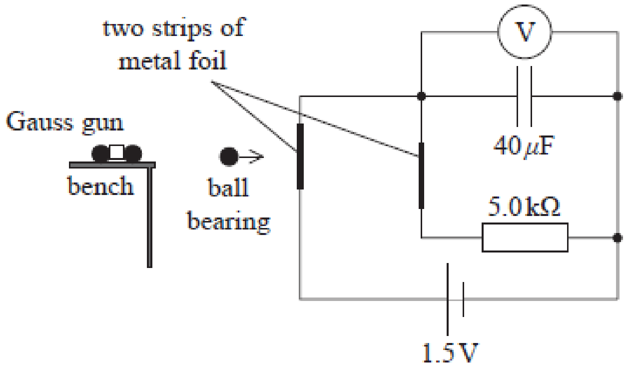
Q22.

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



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

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



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

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

(2)

....

....

....

....

Energy stored = ...

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

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

(2)

....

....

....

....

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

Calculate the horizontal velocity of the ball bearing.

(2)

....

....

....

....

Horizontal velocity = ...

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

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

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

(2)

....

....

....

....

....

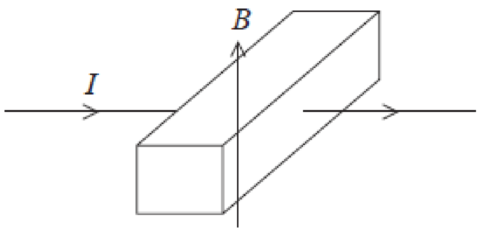
....

(Total for question = 8 marks)

Q23.

Some liquids conduct electricity. This property can be used to pump these liquids through pipes.

A short section of a rectangular pipe containing a liquid is shown in the diagram. The pipe is placed in a magnetic field of flux density *B* and a current *I* is passed through the liquid as shown.



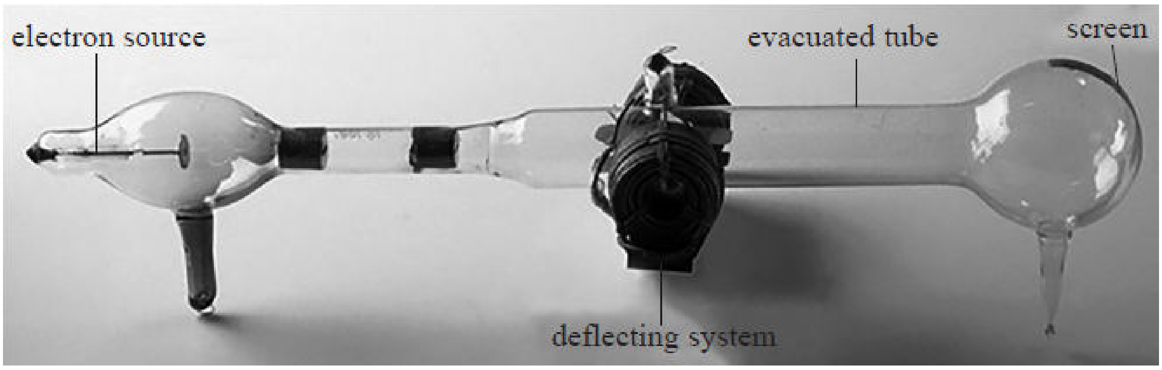
Add an arrow to the diagram above to show the direction in which the liquid will move.

(1)

(Total for question = 1 mark)

Q24.

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



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.

Explain how electrons from the source become a beam of high-energy electrons.

(2)

....

....

....

....

(Total for question = 2 marks)

Q25.

A conductor of length 50 mm carries a current of 3.0 A at 30º to a magnetic field of magnetic flux density 0.40 T.

The magnitude of the magnetic force acting on the conductor is

☐ **A** 0.030 N

☒ **B** 0.050 N

☒ **C** 30 N

☒ **D** 52 N

(Total for question = 1 mark)

Q26.

A length of current-carrying wire is placed at right angles to a uniform magnetic field of flux density *B*. When the current in the wire is *I* the force acting on the wire is *F*.

What is the force when the flux density is increased to 2*B* and the current reduced to 0.25*I*?

☒ **A** 8*F*

☒ **B** 2*F*

☒ **C** *F*/2

☒ **D** *F*/4

(Total for question = 1 mark)

Q27.

A unit for magnetic flux is the

☒ **A** Wb

☒ **B** Wb m^2

☒ **C** T

☒ **D** T m^{-2}

(Total for question = 1 mark)

Q28.

Electric field strength can have the unit of

☒ **A** V m

☒ **B** V C^{-1}

☒ **C** N m^{-1}

☒ **D** N C^{-1}

(Total for question = 1 mark)

Q29.

Show that the unit of magnetic flux density (Tesla) in SI base units is kg A^{-1} s^{-2}.

(2)

....

....

....

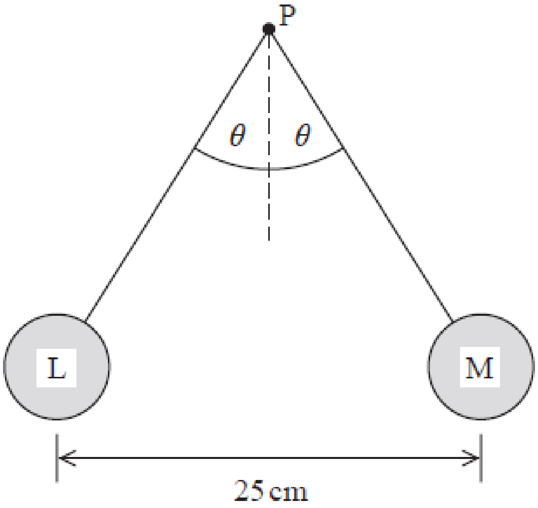
....

(Total for question = 2 marks)

Q30.

Two small spheres L and M are attached to non-conducting threads and suspended from a point P. Each sphere is given an equal positive charge of 4.0×10^{-7} C. The spheres hang in equilibrium as shown in the diagram.

The mass of each sphere is 2.7 g.



By considering the forces acting on one of the spheres, calculate the tension in the thread and the angle θ.

(6)

....

....

....

....

....

....

....

....

....

....

Tension = ...

θ = ...

Mark Scheme

Q1.

Question Number	Acceptable Answer		Additional Guidance	Mark
	An explanation that makes reference to the following: • $E_k = \frac{1}{2}mv^2$ **and** $v_{max} = 2\pi f x_{max}$ • Max kinetic energy is quadrupled	(1) (1)		2

Q2.

Question Number	Acceptable Answer	Additional guidance	Mark
	C	7, 4	**(1)**

Q3.

Question Number	Acceptable Answer	Additional guidance	Mark
	C	increasing the speed of the magnet	**(1)**

Q4.

Question Number	Acceptable Answer	Additional guidance	Mark
	A	F/2	**(1)**

Q5.

Question Number	Acceptable Answer	Additional guidance	Mark
	B	*BI*	**(1)**

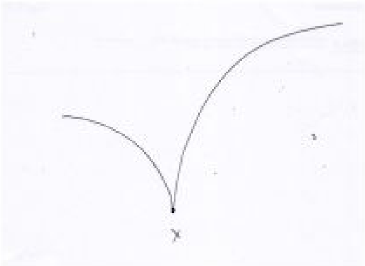
Q6.

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

Q7.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	• Use of y-sensitivity value (1) • $V_0 = 4.0$ V (1)	Example of calculation: $V_0 = 2 \times 2.0\ V = 4.0$ V	2
(ii)	• Use of $I = \frac{V}{R}$ (1) • Use of $I_{\text{rms}} = \frac{I_0}{\sqrt{2}}$ **Or** use of $V_{\text{rms}} = \frac{V_0}{\sqrt{2}}$ (1) • $I_{\text{rms}} = 0.019$ A ECF from(i) (1)	Example of calculation $I_0 = \frac{4.0\ \text{V}}{150\ \Omega} = 0.0267$ A $I_{\text{rms}} = \frac{0.0267\ \text{A}}{\sqrt{2}} = 0.0189$ A	3
(iii)	• Use of $R = R_1 + R_2$ (1) • Use of $P = I^2R$ (or other valid power equation) (1) • $P = 0.096$ W ECF from(i) and (ii) (1)	Example of calculation: $R = 150\ \Omega + 120\ \Omega = 270\ \Omega$ $P = I^2R$ $= (0.019\ \text{A})^2$ $\times 270\ \Omega = 0.0964$ A	3

Q8.

Question Number	Answer		Mark
	Diagram: Path curves in opposite sense With a greater radius of curvature [For Mp2 drawn line must start at X , upwards at less than 45° to vertical and go above printed line. Look at curvature close to X, do not penalise if later it curves more/less.]  **Explanation: (these marks are independent of the diagram)** (Antihelium) has opposite charge (to proton) **Or** reference to proton +ve **and** antihelium -ve See $r = p/BQ$ r is doubled **Or** p/Q is doubled [equation may appear near diagram.]	**(1)** **(1)** **(1)** **(1)** **(1)**	 **5**
	Total for question		**5**

Q9.

Question Number	Answer		Mark
(i)	Outward spiral from centre in either direction, minimum of two complete loops	(1)	1
(ii)	Direction consistent with diagram: Clockwise path, field out of page Anticlockwise path, field into page	(1)	1
(iii)	Electric field/p.d. between dees causes (resultant) force/acceleration Proton makes half a revolution in half a cycle of the a.c. **Or** facing dee (always) negative when proton reaches gap. **Or** whenever the proton gets to a gap, the p.d. has reversed k.e./speed (only)increases each time the proton crosses the gap **Or** work done by the field in the gap increases the k.e.	(1) (1) (1)	3
(iv)	$Bev=mv^2/r$ **Or** $r=p/Be$ $v=2\pi r/T$ $T=1/f$ (seeing $f=v/(2\pi r)$ scores MP2 & 3) **Or** $Bev=mr\omega^2$ $v=r\omega$ $\omega=2\pi f$ (seeing $v/r=2\pi f$ scores MP2 & 3)	(1) (1) (1) (1) (1) (1)	3
(v)	Use of $B=2\pi fm/e$ with mass of proton $f=1.8\times10^4$ Hz <u>Example of calculation</u> $f=eB/2\pi m$ $f=(1.6\times10^{-19}\text{ C}\times1.2\times10^{-3}\text{ T})/(2\pi\times1.67\times10^{-27}\text{kg})$ $f=1.8\times10^4$ Hz	(1) (1)	2

Q10.

Question Number	Acceptable Answer	Additional guidance	Mark
(i)	charge not conserved		**(1)**

Question Number	Acceptable Answer	Additional guidance	Mark
(ii)	• both radial fields <u>OR</u> (1) the magnitude of the fields is the same (at a given distance) • different directions (1)		**(2)**

Q11.

Question Number	Acceptable answers		Additional guidance	Mark
	• p.d. across capacitor increases **Or** p.d. across resistor decreases	(1)		
	• p.d. across capacitor increases to 5V	(1)		
	• p.d. across resistor starts at 5V and reduces to 0V	(1)		**4**
	• Exponentially	(1)		

Q12.

Question Number	Acceptable answers	Additional guidance	Mark
	D uses $W = \frac{1}{2}CV^2$ so if V is doubled W is 4×	$4W$	**1**
	A divides the energy by 4 (rather than multiply) B forgets to square the potential difference and divides C forgets to square the potential difference		

Q13.

Question Number	Answer	Mark
	D	**1**

Q14.

Question Number	Acceptable answers	Additional guidance	Mark
	A		1

Q15.

Question Number	Acceptable answers	Additional guidance	Mark
	• Use of $\ln V = \ln V_0 - \frac{t}{RC}$ **(1)** **Or** Draws initial tangent to curve and uses $T = RC$ **Or** Determines t when V has decreased to approx. 37% • Conversion hours to seconds **(1)** • Calculates resistance in range 2.4×10^{11} to 2.8×10^{11} (Ω) **(1)** • Use of $R = \rho l / A$ **(1)** • Resistivity in range 2.2×10^{15} Ω to 2.6×10^{15} Ω m so yes above 10^{14} Ω m **(1)**	Example of calculation: $ln6 = ln100 - \frac{20 \times 3600\ \text{s}}{R\ \times 0.1 \times 10^{-6}(\text{s})}$ $R = 2.6 \times 10^{11}\ \Omega$ $2.6 \times 10^{11}\Omega = \frac{\rho \times 0.6 \times 10^{-6}\ \text{m}}{5.6 \times 10^{-3}\ \text{m}^2}$ Resistivity = $2.4 \times 10^{15}\ \Omega$ m Using $T = RC$ $7 \times 3600\ \text{s} = 0.1 \times 10^{-6}\ \text{F} \times R$ $R = 2.5 \times 10^{11}\ \Omega$ (allow T in range 7 – 8 hour)	5

Q16.

Question Number	Acceptable answers	Additional guidance		Mark
	B The induced emf in the coil will oppose the cell emf and cause a delay in the current to lamp Y	Lights after a delay with a final brightness the same as X		1
	A assumes the resistance of the coil is more than the resistor C ignores the magnetic effect of the coil and assumes the resistance of the coil is more than the resistor D ignores the magnetic effect of the coil			

Q17.

Question Number	Answer		Mark
(a)	Weight/W/mg vertically down Tension/T parallel to thread and pointing away Electrical (force) horizontal to left Accept electrostatic (force), repulsive (force), coulomb (force) repelling (force). Do **not** accept just F or drag All three correct 2 marks Any two correct 1 mark The lines must start on the ball and have arrow heads to indicate direction. Minus 1 mark for each extra force line. (Candidates who draw forces on M correctly but also include forces on N score 1)		**2**
(b)(i)	Use of $T \cos 35° = mg$ **Or** $T \sin 55° = mg$ g to kg and × 9.81 Tension = 3.2×10^{-2} (N) Example of calculation $T \cos 35° = mg$ $T = (2.7 \times 10^{-3}\ \text{kg} \times 9.81\ \text{N kg}^{-1}) / \cos 35°$ $T = 0.0323$ N	**(1)** **(1)** **(1)**	**3**
(b)(ii)	Equates electric force to $T \sin 35°$ **Or** $T \cos 55°$ **Or** $W \tan 35°$ **Or** use of pythagoras $F_E = 0.018$ **Or** 0.019 (N) ($F_E = 0.017$ N if show that value used. ecf T from (i) Example of calculation $F_E = 0.032 \times \sin 35°$ $F_E = 0.018$ N	**(1)** **(1)**	**2**
(b)(iii)	Use of $F = Q^2/4\pi\varepsilon_0 r^2$ **Or** $F = kQ^2/r^2$ (ecf value of F from (ii) conversion cm to m $Q = (2.9 - 3.1) \times 10^{-7}$ C (candidates who half the value of r can score the first 2 marks) Example of calculation $Q^2 = Fr^2/k$ $Q^2 = (0.020\ \text{N}) \times (20.6 \times 10^{-2}\ \text{m})^2/(8.99 \times 10^9\ \text{N m}^2\ \text{C}^{-2})$ $Q = 3.07 \times 10^{-7}$ C	**(1)** **(1)** **(1)**	**3**
(c)	Both balls would move through the same angle/distance **Or** the balls are suspended at equal angles (to the vertical) (Because) the force on both balls is the same	**(1)** **(1)**	**2**

Q18.

<table>
<tr><th>Question Number</th><th>Acceptable Answers</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 following table shows how the marks should be awarded for indicative content.

Indicative content:
• (Maximum/Initial) current is equal to battery emf divided by R
Or current as switch closed
Or current as complete circuit
Or current due to battery
• Coil rotates
• (movement of) coil "cuts/changes" (magnetic) flux (linkage) / field
• Which induces an emf (according to Faraday's law)
• Opposes original emf/current according to Lenz's law
Or current reduced as effect opposes change
• The faster the coil rotates the larger this (back) emf/effect the smaller the current</td>
<td>
<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>

ic3 needs a link to coil moving
ic4 depends on ic3
</td>
<td>6</td>
</tr>
</table>

Q19.

Question Number	Acceptable answers	Additional guidance	Mark
	The only correct answer is B A *is not correct because it is 3 divided by 2* C *is not correct because it is 3 x root 2* D *is not correct because it is* 3^2	2.1 A	1

Q20.

Question Number	Answer		Mark
(a)(i)	Straight through, zero deflection, direction fired in. (Do not accept 'through' or 'directly behind' on its own)	**(1)**	**1**
(a)(ii)	(Atom consists) mainly/mostly of <u>empty space</u> **Or** Volume of atom very much greater than volume of nucleus. (do not credit if part of a list)	**(1)**	**1**
(b)	Most of the mass is in the nucleus/centre [it is not enough to say that the nucleus is dense/concentrated. Looking for idea that nearly all of the atom's mass is in the nucleus] Nucleus/centre is <u>charged</u> [ignore references to the charge being positive. Just saying the nucleus is positive does not get the mark.]	**(1)** **(1)**	**2**
(c)(i) E	Electrostatic/electromagnetic/electric/coulomb	**(1)**	**1**
(c)(ii)	Arrow starting on the path at closest point to the nucleus Arrow pointing radially away from nucleus (correct direction starting on the nucleus scores 2nd mark only)	**(1)** **(1)**	**2**
(c)(iii)	Deflection starts earlier Final deflection is greater (paths should diverge)	**(1)** **(1)**	**2**
	Total for question		**9**

Q21.

Question Number	Answer		Mark
(a)	The capacitor stores charge **Or** capacitor charges from the supply The idea that the capacitor doesn't fully discharge before being recharged.	(1) (1)	**2**
(b)(i)	$(6.4 + 4.4)/2 = 5.4$ V	(1)	**1**
(b)(ii)	Use of $V = IR$ Average $I = 5.4$ V/$(2.2 \times 10^3 \Omega) = 2.5\times 10^{-3}$ A ecf value form (b)(i)	(1) (1)	**2**
(b)(iii)	Time = 17 ms or 17.5 ms	(1)	**1**
(b)(iv)	Use of $Q = It$ Use of $C = Q/V$ Use of $\Delta V = 2.0$ V $C = 21$ µF (ecf values of I and t from above) Example of calculation $Q = 2.5\times 10^{-3}$ A $\times 17 \times 10^{-3}$ s $= 4.25 \times 10^{-5}$ C $C = 4.25 \times 10^{-5}$ C / 2.0 V $C = 21$ µF	(1) (1) (1) (1)	**4**
(c)	Uses a larger capacitance Because a larger time constant is needed **Or** stores more charge **Or** less $\Delta V \rightarrow \Delta Q/C$	(1) (1)	**2**
	Total for question		**12**

Q22.

Question Marks	Acceptable Answers		Additional guidance	Mark
i	• Use of $W = \frac{1}{2}CV^2$ • $W = 45$ µJ	(1) (1)	Example of calculation $W = \frac{1}{2} 40\mu F \times (1.5\ V)^2$ $W = 45$ µJ Alt: Use $Q = CV$ then $E = QV/2$ for MP1	2
ii	• Use of $V = V_o e^{-t/RC}$ • Time = 0.14 (s)	(1) (1)	Example of calculation $0.5 = e^{-t/5000\times 40\times 10^{-6}}$ $\ln 0.5 = -t/0.2$ $t = 0.14$s	2
iii	• Use of speed = d/t • Speed = 3.6 ms^{-1} Allow ecf from ii	(1) (1)	Show that value gives 5.0 ms^{-1} Example of calculation $v = 0.5\text{m}/0.14\text{s}$ $= 3.6$ ms^{-1}	2
iv	• use of $s = \frac{at^2}{2}$ • s = 9 cm + comment that foil is not broken at its centre (comment consistent with calculation) Allow ecf from ii	(1) (1)	Show that value gives 0.049 m Example of calculation $s = \frac{9.81\ ms^{-2} \times 0.14^2\ s}{2} = 0.094$ m	2

Q23.

Question Number	Acceptable answers	Additional guidance	Mark
	Direction out of page (1)	The arrow needs to be parallel to the length of the pipe by eye.	1

Q24.

Question Number	Acceptable Answer	Additional Guidance	Mark
	An explanation that makes reference to the following points: • The potential difference creates an electric field (1) • An (electric) field/force does work on the electrons (increasing their kinetic energy) **Or** an (electric) field/force accelerates the electrons (increasing their velocity) (1)		2

Q25.

Question Number	Answer	Mark
	A	1

Q26.

Question Number	Answer	Mark
	C	1

Q27.

Question Number	Answer	Mark
	A	**1**

Q28.

Question Number	Answer	Mark
	D	**1**

Q29.

Question number	**Acceptable answers**	**Additional guidance**	**Mark**
	• Use of $F = BIl$ or use of $F = Bqv$ **(1)** • Converts N to kg m s^{-2} **(1)**	Example $B = \frac{F[\text{kg m } s^{-2}]}{I[\text{A}]\ l[\text{m}]}$ So units are kg A^{-1} s^{-2}	**2**

Q30.

Question Number	Answer		Mark
	Use of $F_E = kQ_1Q_2/r^2$	(1)	
	Use of $W = mg$	(1)	
	Resolve vertically $T\cos\theta = mg$ **and** Resolve horizontally $T\sin\theta = F_E$	(1)	
	Attempt to combine components to give tan θ ($\tan\theta = F_E/mg$)	(1)	
	$\theta = 41°$ to $42°$	(1)	
	$T = 0.035$ N	(1)	
	Or		
	Use of $F_E = kQ_1Q_2/r^2$	(1)	
	Use of $W = mg$	(1)	
	Use of Pythagoras to find tension force	(1)	
	Tan $\theta = F_E/mg$ **Or** $\cos\theta = mg/T$ **Or** $\sin\theta = F_E/T$	(1)	
	$\theta = 41°$ to $42°$	(1)	
	$T = 0.035$ N	(1)	6
	(if they halve the separation or halve the electric force they can still get MP1 and so could score MP1,2, 3 & 4)		
	<u>Example of calculation</u> Weight of sphere = 0.0027 kg × 9.81 N kg^{-1} = 0.026 N Electric force $F_E = kQ_1Q_2/r^2$ $= 8.99 \times 10^9 \text{ N m}^2 \text{ C}^{-2} \times (4.0 \times 10^{-7} \text{ C})^2 / 0.25^2 \text{ m}^2 = 0.023$ N Vertically $T\cos\theta = mg$ Horizontally $T\sin\theta = F_E$ Tan $\theta = F_E/mg = 0.023$ N/ 0.026 N $\theta = 41°$ sub into vertical equation $T = mg/\cos\theta = 0.026$ N /cos 41 $T = 0.034$ N		