Name: _____

Topic 7: Electric and Magnetic Fields Part 2

Date:

Time:

Total marks available:

Total marks achieved: _____

Questions

Q1.

Some mobile phones have a capacitor touch screen made up of a sheet of glass with a thin metallic coating. The screen is charged and when it is touched some of the charge is transferred to the user. This causes a drop in electrical potential at the point where the screen is touched.

A capacitor is charged by connecting it across a battery and then discharged through a resistor. In the case of the touch screen the user provides a discharge resistance of about 900 Ω.

Explain how the capacitor discharges.

(3)

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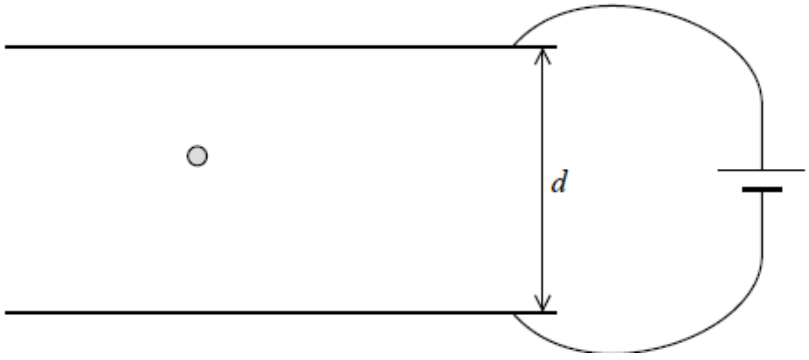
(Total for question = 3 marks)

Q2.

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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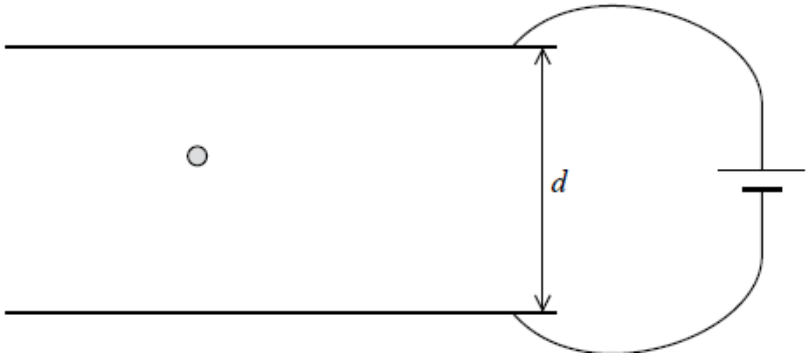
(Total for question = 6 marks)

Q3.

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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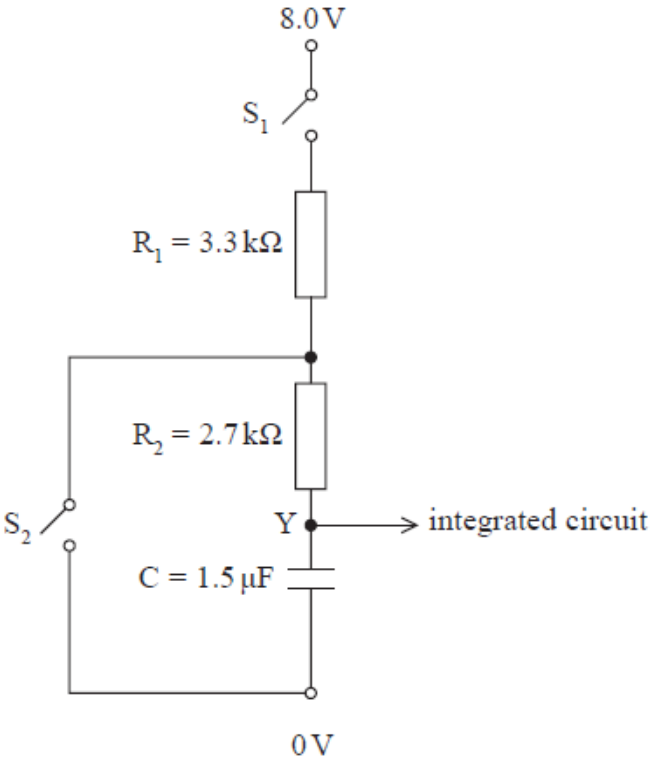
(Total for question = 4 marks)

Q4.

The properties of capacitors make them useful in timing circuits.

The following circuit is used to provide an input Y to an integrated circuit.



When the potential at Y is 8.0 V, the switch S_2 is closed.

(i) Calculate the time taken for the potential at Y to decrease to 2.0 V.

(3)

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Time taken = ...

(ii) Calculate the energy stored on the capacitor when the potential at Y is 2.0 V.

(2)

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Energy stored = ...

(Total for question = 5 marks)

Q5.

Some flowers are negatively charged and surrounded by an electric field. This helps to attract bees.

State what is meant by an electric field.

(1)

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(Total for question = 1 mark)

Q6.

Sketch the electric field around a positive point charge.

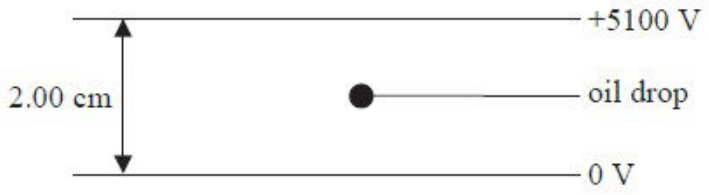
(3)

(Total for question = 3 marks)

Q7. The charge on an electron was originally measured in an experiment called the Millikan Oil Drop experiment.

In a simplified version of this experiment, an oil drop with a small electric charge is placed between two horizontal, parallel plates with a large potential difference (p.d.) across them. The p.d. is adjusted until the oil drop is stationary.

For a particular experiment, a p.d. of 5100 V was required to hold a drop of mass 1.20×10^{-14} kg stationary.



(a) Add to the diagram to show the electric field lines between the plates.

(3)

(b) State whether the charge on the oil drop is positive or negative.

(1)

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(c) Complete the free-body force diagram to show the forces acting on the oil drop. You should ignore upthrust.

(2)

(d) (i) Calculate the magnitude of the charge on the oil drop.

(4)

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Charge = ...

(ii) Calculate the number of electrons that would have to be removed or added to a neutral oil drop for it to acquire this charge.

(2)

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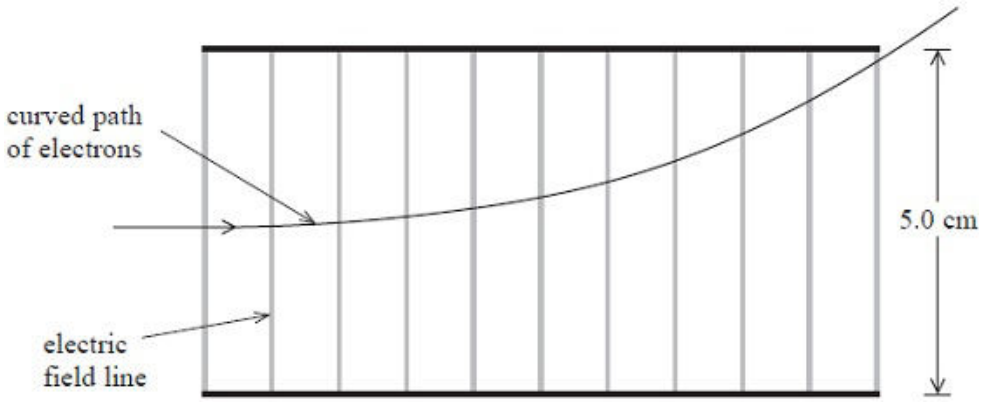
Number of electrons = ...

(Total for Question = 12 marks)

Q8. A teacher uses an electron beam tube to demonstrate the behaviour of electrons in an electric field. The diagram shows the path of an electron in a uniform electric field between two parallel conducting plates.



(a) Mark on the diagram the direction of the electric field.

(1)

(b) The conducting plates are 5.0 cm apart and have a potential difference of 160 V across them.

Calculate the force on the electron due to the electric field.

(3)

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Force = ...

(c) Explain why the path of the electron is curved between the plates and straight when it has left the plates.

(3)

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(d) The electron was initially released from a metal by thermionic emission and then accelerated through a potential difference before entering the region of the electric field.

(i) State what is meant by thermionic emission.

(1)

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(ii) In order to be able to just leave the plates as shown, the electron must enter the electric field between the plates with a speed of 1.2×10^7 m s^{-1}.

Calculate the potential difference required to accelerate an electron from rest to this speed.

(3)

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Potential difference = ...

(Total for Question = 11 marks)

Q9.

A potential difference of 50 V is applied between two identical parallel aluminium plates. The plates are separated by a distance of 10 mm.

Which combination of potential difference and separation would double the electric field strength?

	Separation/mm	Potential difference/ V
☐ A	20	100
☐ B	20	25
☐ C	10	100
☐ D	10	25

(Total for question = 1 mark)

Q10.

Some flowers are negatively charged and surrounded by an electric field. This helps to attract bees.

When the bee is collecting nectar from the plant, the electric field strength decreases.
It is thought that this warns other bees that the nectar supply is low.

State the effect of a decreased electric field strength on the equipotential lines.

(1)

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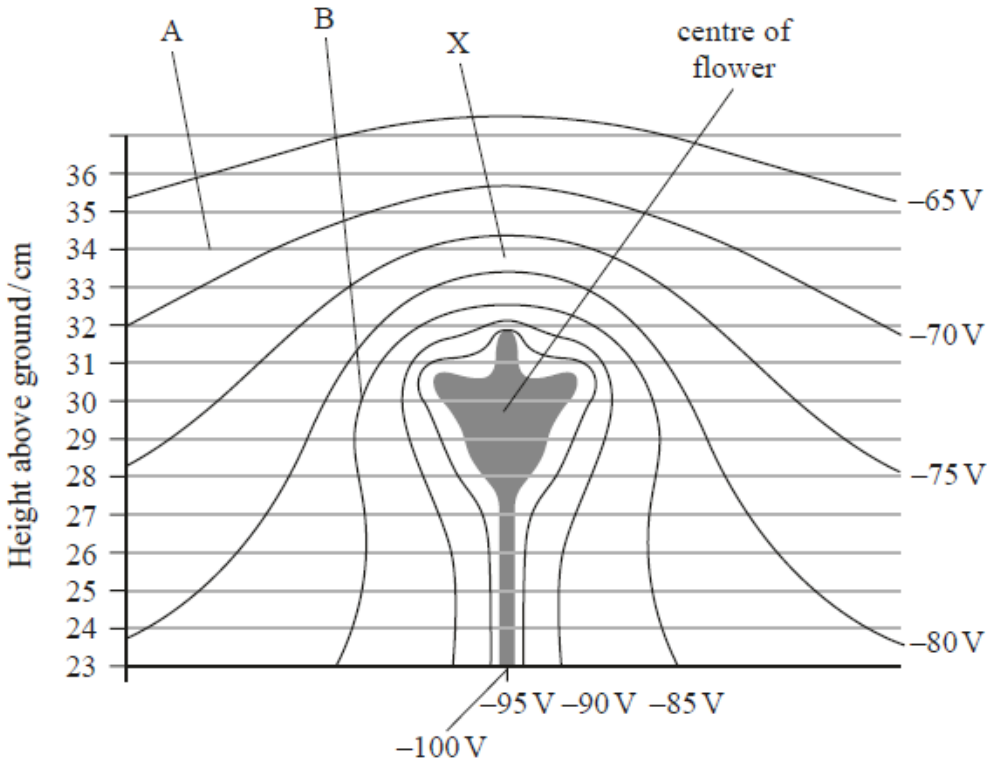
(Total for question = 1 mark)

Q11.

Some flowers are negatively charged and surrounded by an electric field. This helps to attract bees.

The diagram shows lines of equipotential surrounding a flower.



(i) Determine the electric field strength at X.

(3)

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Electric field strength at X = ...

(ii) Draw the electric field line between point A and point B on the diagram.

(2)

(iii) An equation for electric potential V is

$$V = \frac{Q}{4\pi\varepsilon_0 r}$$

This applies to a radial field.

Deduce whether the electric field in the region directly above the flower is radial.
You should take values from the diagram. A graphical method is not required.

(3)

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(Total for question = 8 marks)

Q12.

(a) Explain what is meant by the term electric field strength.

(2)

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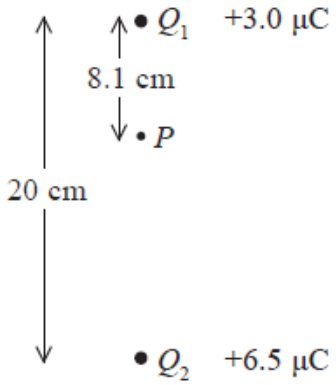
(b) (i) Two point charges Q_1 and Q_2 are placed 20 cm apart. Q_1 has a charge of +3.0 μC and Q_2 has a charge of +6.5 μC.



At point *P*, a distance 8.1 cm from Q_1, the electric field strength is approximately zero.

Demonstrate by calculation that this statement is correct.

(3)

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(ii) A charge of +4.5 μC is placed at point *P*.
State the magnitude of the force acting on this charge.

(1)

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(iii) The + 4.5 μC charge is moved from point *P* to a point half way between Q_1 and Q_2.

Explain qualitatively why energy would be needed for this movement.

(2)

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(Total for question = 8 marks)

Q13.

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 potential difference is applied across two parallel plates. A particle carrying a charge of +0.1 C is placed between the plates and experiences a force *F*.

The distance between the plates is halved. The potential difference remains constant.

Which of the following is now equal to the electric field strength between the plates?

☒ **A** 5*F*

☒ **B** 10*F*

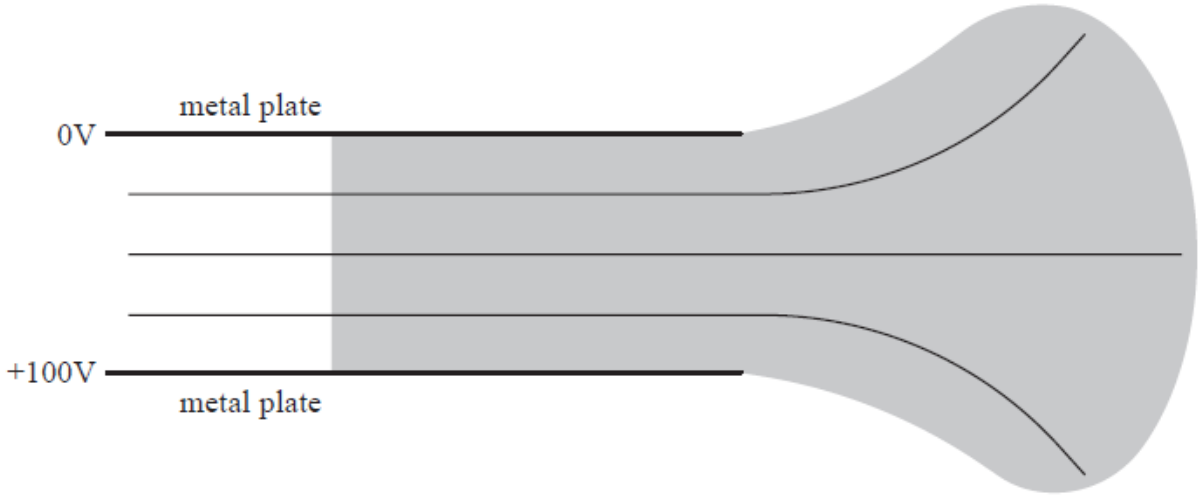
☒ **C** 20*F*

☒ **D** 40*F*

(Total for question = 1 mark)

Q14.

13 The diagram shows two parallel metal plates with a potential difference (p.d.) of 100 V across them. Three equipotential lines are shown.



Draw lines to represent the electric field in the shaded area.

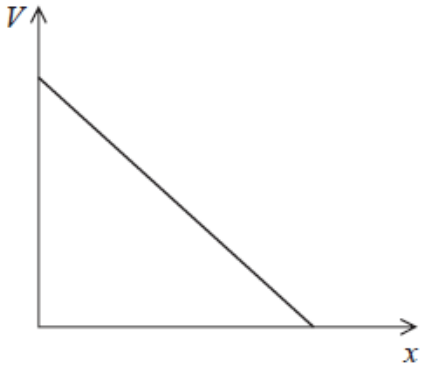
(4)

(Total for question = 4 marks)

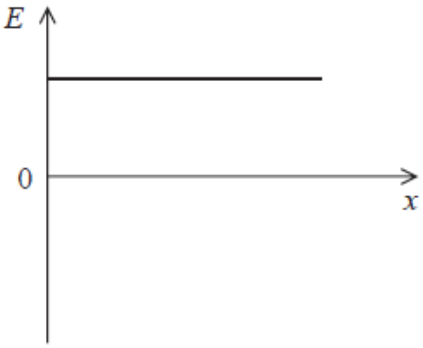
Q15.

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

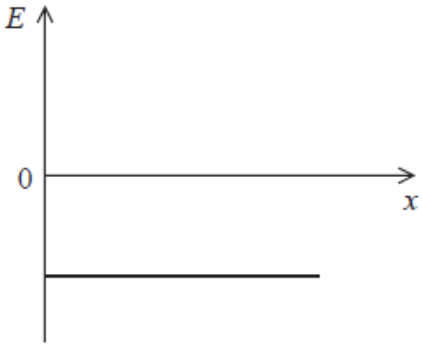
The graph shows how an electric potential V varies with distance x.



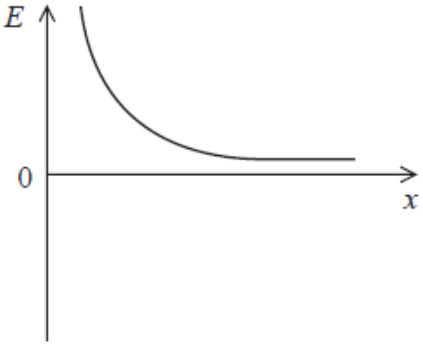
Which of the following shows the corresponding variation of electric field strength E with x?



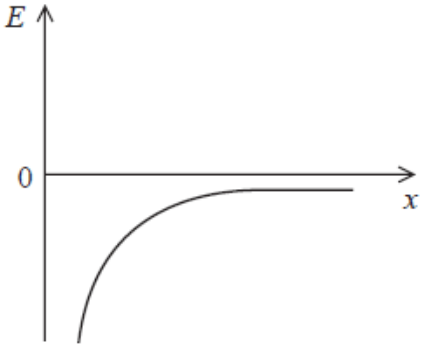
☒ **A**



☒ **B**



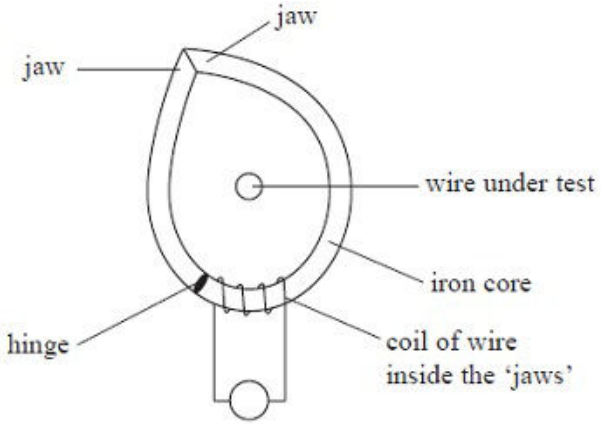
☒ **C**



☒ **D**

(Total for question = 1 mark)

Q16. The photograph shows a digital clamp meter or 'amp-clamp'. This can be used to measure the current in the live wire coming from the mains supply without breaking the circuit.



The 'jaws' of the clamp are opened, placed around the wire carrying the current and then closed. Inside the 'jaws' is an iron core with a coil of wire wrapped around it.

*(a) Explain how an e.m.f. would be produced in the coil of wire inside the amp-clamp when the 'jaws' are placed around a wire carrying an alternating current.

(4)

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(b) State why the amp-clamp cannot be used with a steady direct current.

(1)

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(c) The amp-clamp cannot be used with a cable that is used to plug a domestic appliance like a lamp into the mains supply.

Explain why not.

(2)

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(d) (i) Explain why the amp-clamp can be used to determine the magnitude of different alternating currents with the same frequency.

(2)

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(ii) The amp-clamp may **not** be reliable when comparing alternating currents of different frequencies.

Suggest why not.

(2)

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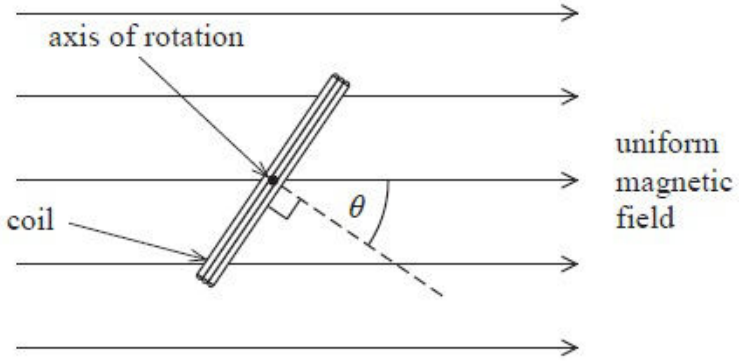
(Total for Question = 11 marks)

Q17. The diagram shows an end view of a simple electrical generator. A rectangular coil of wire is rotated in a uniform magnetic field of magnetic flux density 3.0×10^{-2} T. The axis of rotation is at right angles to the field direction.



(a) The coil has 200 turns and an area of 2.0×10^{-4} m^2.

Calculate the magnetic flux linkage for the coil when $\theta = 0°$.

(2)

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Flux linkage = ...

(b) The coil is rotated at a constant rate of 2 revolutions per second.

(i) Calculate the average e.m.f. induced in the time taken for the coil to rotate from $\theta = 0°$ to $\theta = 90°$

(3)

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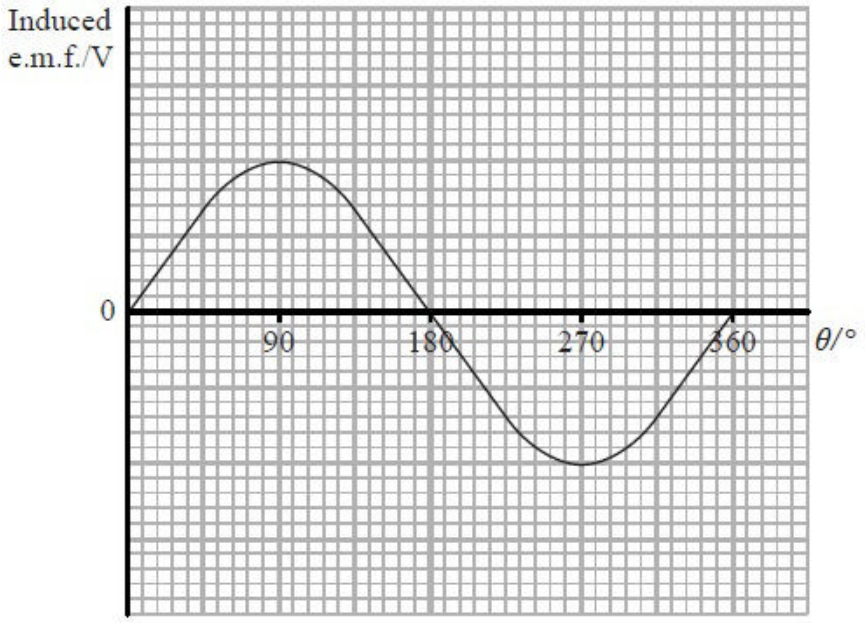
Average e.m.f. = ...

(ii) The graph shows how the induced e.m.f. varies over one cycle of rotation of the coil.



Explain why the magnitude of the e.m.f. is smallest and greatest at the values of θ shown in the graph.

(3)

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(iii) State and explain how the graph would differ if the coil rotated at a slower rate.

(2)

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(c) Vehicles such as electric cars are driven by electric motors. These vehicles use regenerative braking to reduce the speed of the vehicle. The motor is operated as a generator during braking and the output from the generator is used to recharge the batteries of the car.

(i) Explain how using the motor as a generator slows the car down.

(2)

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(ii) In practice, these vehicles also use friction braking as well as regenerative braking. This is because regenerative braking on its own will not fully stop a car. Suggest why.

(2)

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(Total for Question = 14 marks)

Q18.

(a) State Faraday's law of electromagnetic induction.

(2)

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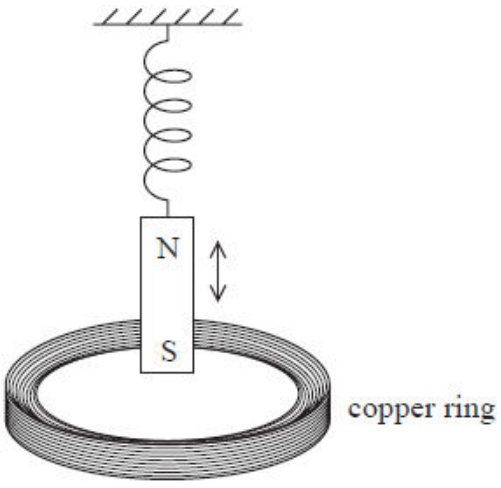
*(b) A magnet is attached to the end of a spring as shown in the diagram.



The magnet is displaced vertically and released so that it oscillates.
Explain why this produces an alternating current in the copper ring.

(4)

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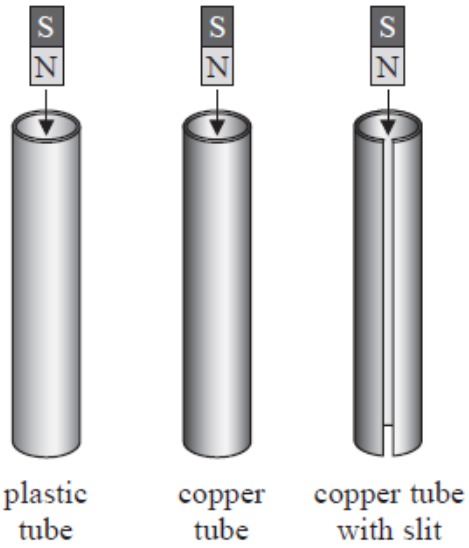
Q19.

A teacher carries out a demonstration to illustrate the laws of electromagnetic induction.
She uses three tubes of identical dimensions. One is made of plastic, one copper and one copper with a slit cut into its length.



(a) The teacher releases a magnet from rest at the top of the plastic tube and it takes 0.45 s to fall through the tube.
Calculate the average acceleration of the magnet as it falls through the tube.

length of tube = 0.75 m

(2)

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Average acceleration = ...

*(b) The teacher suggests that the magnet would take longer to fall through the copper tube as a consequence of the laws of electromagnetic induction.

Assess the validity of this suggestion.

(6)

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(c) Before the teacher releases the magnet through the copper tube with a slit along its length, she asks the class to consider how the time taken will compare with the time for the other copper tube. The class predicts that the time will be the same.

Explain, using electromagnetic induction, whether this prediction is correct.

(3)

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(d) The times for the magnets to fall through the tubes were measured manually using an electronic timer.

Explain how suitable this is as a means of recording these times.

(2)

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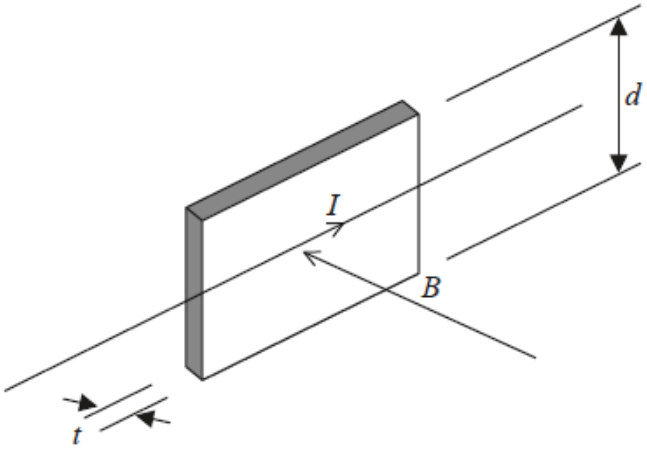
(Total for question = 13 marks)

Q20.

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.

Explain why electrons will collect at the top edge of the slice.

(2)

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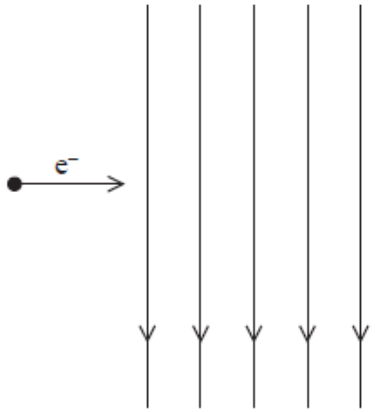
(Total for question = 2 marks)

Q21.

An electron travelling horizontally enters a uniform electric field which acts vertically downwards as shown in the diagram.



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

☒ **A** The electron follows a parabolic path.

☒ **B** The electron accelerates while in the field.

☒ **C** The electric force on the electron acts downwards.

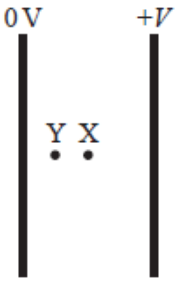
☒ **D** The speed of the electron increases.

(Total for question = 1 mark)

Q22.

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 potential difference *V* is applied across two parallel plates. An electron midway between the two plates at point X experiences an electric force *F*.



The electron moves to point Y which is halfway between point X and the left-hand plate.

Which of the following is the electric force experienced by the electron at Y?

☒ **A** $2F$

☒ **B** F

☒ **C** $\frac{F}{2}$

☒ **D** $\frac{F}{4}$

(Total for question = 1 mark)

Q23.

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

The distance between a proton and an electron is r. The electrostatic force is F.

The distance between the proton and electron is doubled.

Which of the following is equal to the electrostatic force at this separation?

☒ **A** $2F$

☒ **B** $\frac{F}{2}$

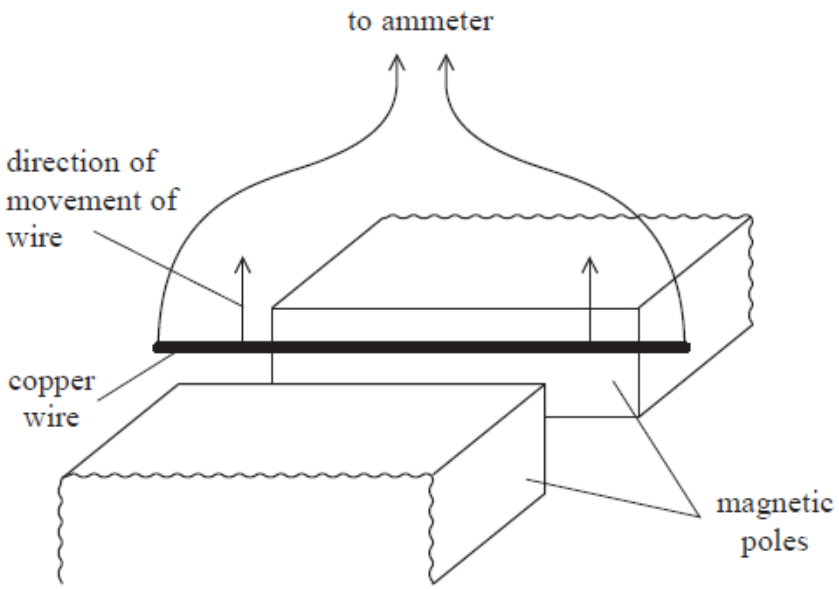
☒ **C** $\frac{F}{3}$

☒ **D** $\frac{F}{4}$

(Total for question = 1 mark)

Q24.

A student is investigating electromagnetic induction using a U-shaped magnet. The magnetic flux density between the poles of the magnet is 74 mT. The magnetic field outside the region of the poles is negligible.
She places a stiff copper wire between the poles of the magnet as shown in the diagram.
The wire is connected to an ammeter of resistance 0.25 Ω



(a) The rectangular poles measure 6.0 cm × 2.4 cm.

Show that the magnetic flux between the poles of the magnet is about 1×10^{-4} Wb.

(3)

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(b) The student holds the wire as shown in the diagram and moves it vertically upwards at a constant speed of 1.2 m s^{-1}
Calculate the e.m.f. induced in the wire when it is moving.

(3)

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Induced e.m.f. = ...

(c) According to Lenz's law, a force will act on the wire to oppose the motion of the wire.

Calculate the magnitude of the force that opposes the motion and comment on this value.

(4)

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Magnitude of force = ...

Comment

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(Total for question = 10 marks)

Q25.

A capacitor of 50 μF is charged to a potential difference of 12 V.

The energy stored on the charged capacitor in joules is given by

☒ **A** $0.5 \times 50 \times 10^{-6} \times 12^{2}$

☒ **B**

$\frac{0.5 \times 50 \times 10^{-6}}{12^2}$

☒ **C** $\frac{0.5 \times 12^2}{50 \times 10^{-6}}$

☒ **D** $0.5 \times (50 \times 10^{-6})^2 \times 12$

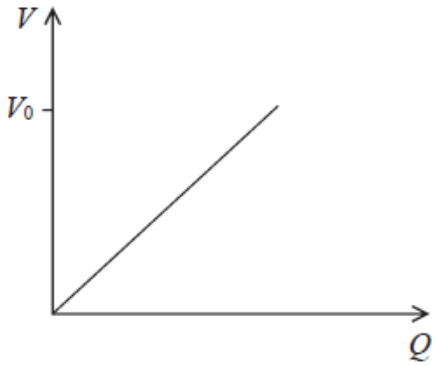
(Total for question = 1 mark)

Q26.

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 capacitor is connected to a power supply and charged to a potential difference V_0.

The graph shows how the potential difference V across the capacitor varies with the charge Q on the capacitor.



At a potential difference V_0 a small charge ΔQ is added to the capacitor. This results in a small increase in potential difference ΔV across the capacitor.

Which of the following gives the approximate increase in energy stored on the capacitor due to this extra charge?

☒ **A** $\Delta V \times \Delta Q$

☒ **B** $\frac{\Delta V \times \Delta Q}{2}$

☒ **C** $V_0 \times \Delta Q$

☒ **D** $\frac{V_0 \times \Delta Q}{2}$

(Total for question = 1 mark)

Q27.

A capacitor of capacitance *C* has a potential difference *V* across it. The energy stored on the capacitor is Z joules. A second capacitor of capacitance *C*/2 has a potential difference 2*V* across it.
The energy stored on the second capacitor is

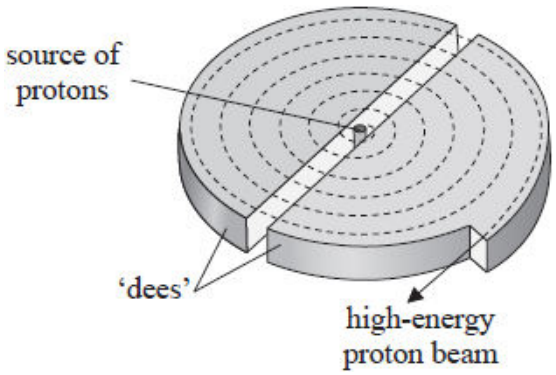
- **A** Z
- **B** 2Z
- **C** 4Z
- **D** 8Z

(Total for question = 1 mark)

Q28.

Proton beam therapy is being introduced in the UK as a new cancer treatment.

A beam of protons is accelerated by a cyclotron to an energy of 23 MeV and is then focused onto a tumour.



* Explain how the cyclotron produces the high-energy proton beam.

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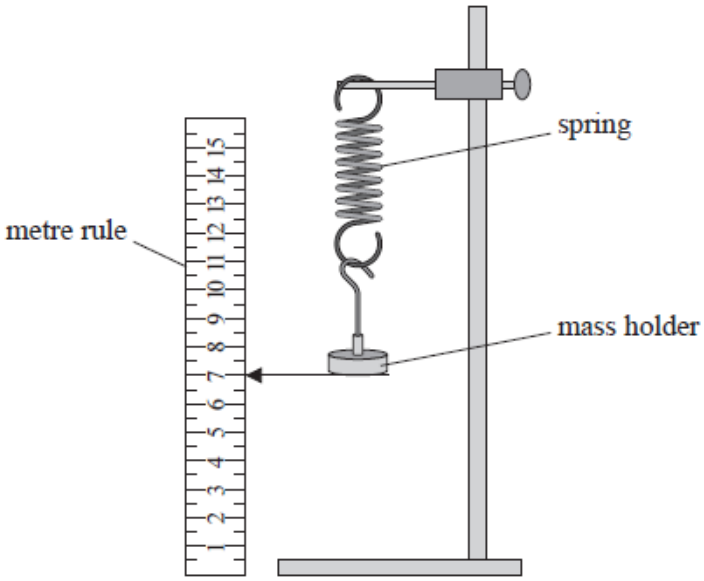
(Total for question = 6 marks)

Q29.

A student investigated the behaviour of a spring under tension. The spring was hung vertically with a mass holder attached.

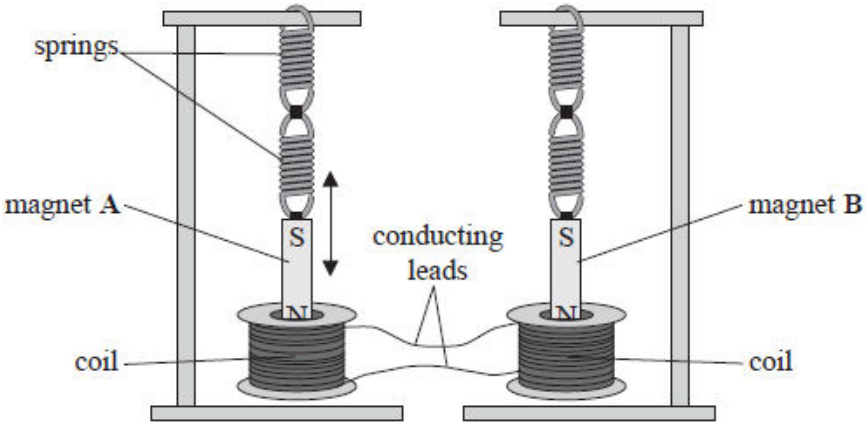


The position of the bottom of the mass holder was recorded. The spring was stretched by adding masses to the mass holder and the new positions were recorded. The extension of the spring each time was calculated.

The student produced the following table.

Mass added / g	Extension / cm	Stretching force / N
50	1.9	0.49
70	3	0.69
90	3.5	0.9
110	4.5	1.08
130	5.3	1.28
150	5.8	1.47

* Identical bar magnets are suspended from identical springs, with the North pole of each magnet inside a coil of wire as shown. The two coils are connected together with conducting leads.



Magnet A is displaced so that it oscillates vertically. The North pole of magnet A moves into and out of the coil of wire with simple harmonic motion. As this motion continues, magnet B starts to oscillate. The amplitude of oscillation of magnet B increases over time.

Explain why magnet B starts to oscillate with an increasing amplitude.

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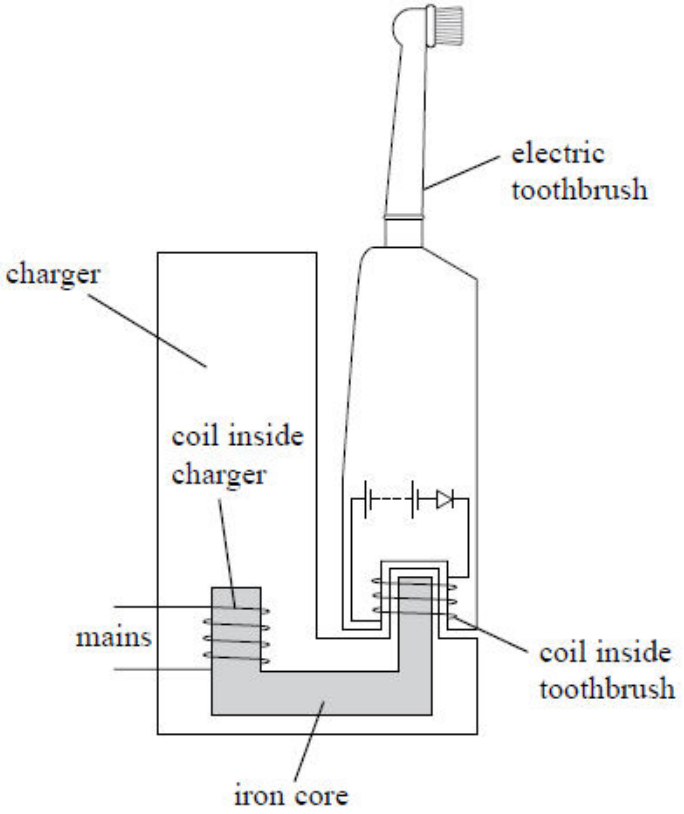
(Total for question = 6 marks)

Q30.

The diagram shows the inside of an electric toothbrush and a charger.

The charger contains a coil wrapped around an iron core. The coil is plugged into the mains a.c. supply.

The toothbrush also contains a coil that sits around the iron core when the toothbrush is placed on the charger to recharge the battery of the toothbrush.



* Describe how the charger is able to charge the low-voltage battery.

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(Total for question = 6 marks)

Mark Scheme

Q1.

Question number	Acceptable answers	Additional guidance	Mark
	An explanation that makes reference to: • Electrons/charge transferred from negatively charged plate to positively charge plate through the resistor **(1)** • Hence the charge on capacitor decreases (exponentially) **(1)** • Until the charge on the capacitor equals 0/negligible **(1)**		**3**

Q2.

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. 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	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).	

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**

Q3.

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**

Q4.

Question Number	Acceptable answers	Additional guidance	Mark
i	• Use of $\ln V = \ln V_o - \frac{t}{RC}$ **(1)** • Substitution $V = 2.0$ V and $V_o = 8.0$ V **(1)** • $t = 5.6(1)$ ms **(1)**	Alternative use of $V = V_o e^{-\frac{t}{RC}}$ Rearrange to $\ln 4 = t / 2700\ \Omega \times 1.5 \times 10^{-6} F$ Example of calculation $t = 2700\ \Omega \times 1.5 \times 10^{-6}$ F $(\ln 8 - \ln 2)$ $t = 5.61$ ms	**3**
ii	• Use of $W = ½\ CV^2$ **(1)** • $W = 3.0 \times 10^{-6}$ J **(1)**	Example of calculation $W = \frac{1}{2} 1.5 \times 10^{-6}$F $\times 2^2$ V$^2 = 3.0 \times 10^{-6}$ J	**2**

Q5.

Question Number	Acceptable answers	Additional guidance	Mark
	• A region where a charged particle experiences a force/acceleration **(1)**		**(1)**

Q6.

Question number	Acceptable Answers		Additional guidance	Mark
	• At least 4 radial lines	(1)	Ignore dotted lines	3
	• arrow pointing outwards	(1)		
	• straight, symmetrical and equally distributed	(1)		

Q7.

Question Number	Answer		Mark
(a)	At least three vertical lines spread over symmetrically over more than half of the plate length and touching both plates. (ignore edge ones that might curve) All equispaced and parallel [don't allow gaping to avoid oil drop] Arrow pointing downwards	**(1)** **(1)** **(1)**	**3**
(b)	Negative / - / -ve (negative and/or positive does not get the mark)	**(1)**	**1**
(c)	Upward force labelled: Electric (force) **Or** Electrostatic (force) **Or** force due to electric field **Or** electromagnetic (force) [do not accept repulsive/attractive force. If EQ used, the symbols must be defined] Downward force labelled: mg, weight, W, gravitational force (for both marks the lines must touch the drop and be pointing away from it. Ignore upthrust if drawn but one mark lost for each extra force added)	**(1)** **(1)**	**2**
(d)(i)	E = 5100 V/ 2 cm Conversion of cm to m Use of $QE = mg$ (1.18×10^{-13} kg) $Q = 4.6 \times 10^{-19}$ C (E = 255 000 (V m^{-1}) scores MP1 & 2. unit conversion missed → $Q = 4.62 \times 10^{-17}$ C scores MP1 & 3 if V is halved → $Q = 9.23 \times 10^{-19}$ C scores MP1 ,2 & 3) <u>Example of calculation</u> $E = V/d$ $F = EQ = mg$ $Q = mg / E = mgd/V$ Q = (1.20×10^{-14} kg × 9.81m s^{-2}× 0.02 m) / (5100 V) Q = 4.62×10^{-19} C	**(1)** **(1)** **(1)** **(1)**	**4**
(d)(ii)	Answer to (d)(i) divided by e 3 electrons **Or** sensible integer number less than 500 (answers with very large numbers of electrons can get MP1 only) <u>Example of calculation</u> Number of electrons = 4.62×10^{-19} C / 1.6×10^{-19} C Number = 2.9 i.e. 3 electrons.	**(1)** **(1)**	**2**
	Total for question		**12**

Q8.

Question Number	Answer		Mark
(a)	Arrow(s) downwards	**(1)**	**1**
(b)	Use of $E = V/d$ Use of $F = EQ$ $F = 5.1 \times 10^{-16}$ N Example of calculation $F = (160\ \text{V} \times 1.6 \times 10^{-19}\ \text{C}) / 5.0 \times 10^{-2}\ \text{m}$ $F = 5.12 \times 10^{-16}$ N	**(1)** **(1)** **(1)**	**3**
(c)	Between the plates there is an acceleration/force which is vertical/upwards Constant horizontal velocity Outside the plates no (electric) field /force acts **Or** Outside the plates speed so large that gravitational effect negligible	**(1)** **(1)** **(1)**	**3**
(d)(i)	Release of (surface) electrons due to heating	**(1)**	**1**
(d)(ii)	Use of $E_k = \frac{1}{2}mv^2$ Use of $V = W/Q$ p.d. = 410 V Example of calculation $E_k = 9.11 \times 10^{-31}\ \text{kg} \times (1.2 \times 10^{7}\ \text{m s}^{-1})^2/2$ $E_k = 6.56 \times 10^{-17}$ J p.d. $= (6.56 \times 10^{-17}\ \text{J})/(1.6 \times 10^{-19}\ \text{C})$ p.d. = 410V	**(1)** **(1)** **(1)**	**3**
	Total for question		**11**

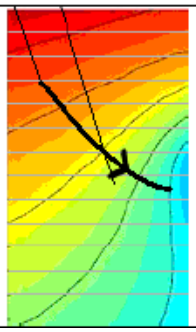
Q9.

Question Number	Answer	Mark
	C	1

Q10.

Question Number	Acceptable answers	Additional guidance	Mark
	• Equipotential lines would be further apart **(1)**		(1)

Q11.

Question Number	Acceptable answers		Additional guidance	Mark
(i)	• States a value of ΔV	(1)	Example of calculation: $E = \frac{(80-75)\text{V}}{0.009\text{m}} = 556\ \text{V m}^{-1}$ (Alt: 5.6 V cm^{-1})	(3)
	• Uses $\Delta V/\Delta d$ with a difference in distance	(1)		
	• $E = 560\ \text{V m}^{-1}$ allow range 500-560 V m^{-1}	(1)		
(ii)	• Line perpendicular to a least 2 equipotential lines	(1)		(2)
	• Arrow pointing towards flower	(1)		
(iii)	• States $V \times r$ = constant	(1)	Example of calculation: Using $V = 95$ and $r = 2.0 - 2.2$: $Vr = 190 - 209$ $V = 90$ and $r = 2.1 - 2.5$: $Vr = 189 - 225$ $V = 85$ and $r = 2.5 - 2.8$: $Vr = 212 - 238$ $V = 80$ and $r = 3.5 - 3.8$: $Vr = 280 - 304$ $V = 75$ and $r = 4.3 - 4.7$: $Vr = 323 - 353$ $V = 70$ and $r = 5.8 - 6.2$: $Vr = 406 - 434$ Using $r = 3$ and $V = 82-83$: $Vr = 246-249$ $r = 4$ and $V = 77-78$: $Vr = 308-312$ $r = 5$ and $V = 72-73$: $Vr = 360-365$	(3)
	• One corresponding pair of values of V and r	(1)		
	• At least two pairs of values used to show that the product is not constant therefore not radial (MP3 dependent on MP2)	(1)		

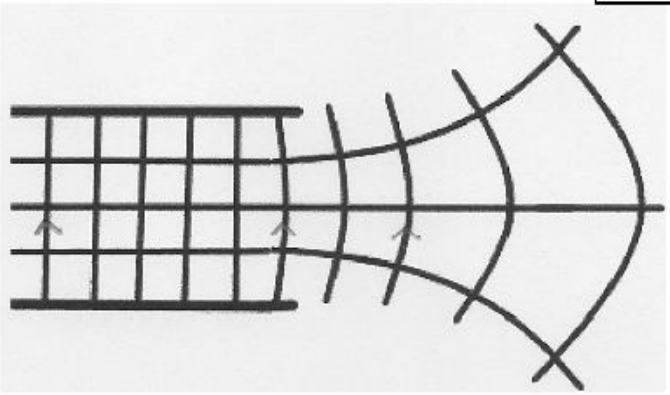
Q12.

Question Number	Answer		Mark
(a)	(Electric field strength (at a point in a field) is) the force per unit charge (accept force per coulomb of charge) Acting on a (small) positive charge.	(1) (1)	2
(b)(i)	Use of $E = kQ/r^2$ Electric field due to $Q_1 = 4.1(1) \times 10^6$ (N C^{-1}) Use of 11.9 cm to find field due to Q_2 **Or** Use of $E = kQ/r^2$ Use of $E1/E2 = Q1\ r22/\ Q2\ r12$ $E_1/E_2 = 1$ <u>Example of calculation</u> Electric field due to Q_1 $= (8.99 \times 10^9$ N m^2 $C^{-2}) \times (3 \times 10^{-6}$ C) / $(8.1 \times 10^{-2})^2$ $= 4.11 \times 10^6$ N C^{-1} Electric field due to Q_2 $= (8.99 \times 10^9$ N m^2 $C^{-2}) \times (6.5 \times 10^{-6}$ C) / $(11.9 \times$ $10^{-2})^2 = 4.13 \times 10^6$ N C^{-1}	(1) (1) (1) (1) (1) (1)	3
(b)(ii)	(Force on charge is) zero/negligible/approx zero (Allow values less than 0.1 N)	(1)	1
(b)(iii)	At midpoint repulsive force due to Q_2 > repulsive force due to Q_1 **Or** the <u>resultant</u> field/force is repulsive <u>Work</u> must be done against the repulsive force/field to move the charge to this position.	(1) (1)	2
	Total for question		8

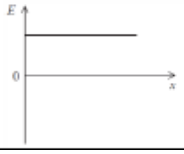
Q13.

Question Number	Acceptable answers	Additional guidance	Mark
	The only correct answer is C A is not correct as $E_{initial} = F/Q = 10F$, if d halved then $E_{after} = 20F$ B is not correct as $E_{initial} = F/Q = 10F$, if d halved then $E_{after} = 20F$ D is not correct as $E_{initial} = F/Q = 10F$, if d halved then $E_{after} = 20F$		1

Q14.

Question Number	Acceptable answers	Additional guidance	Mark
	• Arrow upwards on at least one line. (1) Uniform section: • at least 3 parallel, perpendicular straight lines, equispaced (1) Non-uniform: • at least 2 lines perpendicular to equipotentials (1) • spacing getting larger (1)		4

Q15.

Question Number	Acceptable answers	Additional guidance	Mark
	The only correct answer is A 	B,C and D are not the negative potential gradient	1

Q16.

Question Number	Answer		Mark
*(a)	(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate) A clear statement that an alternating/changing current produces an alternating/changing magnetic field/flux Reference to the iron core becomes magnetised **Or** increases magnetic field the idea that the field produced in the core/wire is linked to the coil (e.m.f. produced) due to EM induction **Or** reference to induced e.m.f. **Or** Faraday's law in words (do not accept induced current/voltage on its own) [be careful not to credit the random use of words/phrases like, there is flux linkage, flux cutting takes place or the field lines are cut by the coil. Also watch out for candidates who think there is a current in the coil creating the flux linkage]	**(1)** **(1)** **(1)** **(1)**	**4**
(b)	(Constant current means) no change of flux (linkage) **Or** no changing (magnetic) field **Or** flux/ field is constant [do not credit 'flux won't be changing direction' or 'no flux linkage being cut' or alternating]	**(1)**	**1**
(c)	More than one wire in cable Cable carries current in both directions **Or** Magnetic fields will cancel	**(1)** **(1)**	**2**
(d)(i)	The larger the current the greater the (magnetic) flux/field (produced) **Or** the larger the change in current the larger the change in the (magnetic) flux/field gives a greater rate of change of flux **Or** bigger change in flux in the same time **Or** a greater (induced) e.m.f./voltage/reading	**(1)** **(1)**	**2**
(d)(ii)	the idea that frequency changes the value of (induced) e.m.f/voltage/reading **Or** the idea that the frequency changes the rate of change of (magnetic)flux An understanding that there are now two factors (current and frequency) altering (induced) e.m.f/voltage/reading.	**(1)** **(1)**	**2**
	Total for question		**11**

Q17.

Question Number	Answer		Mark
(a)	Use of $N\Phi = NBA$ $\Phi = 1.2 \times 10^{-3}$ Wb (accept T m^2) Example of calculation $\Phi = 200 \times 3.0 \times 10^{-2}$ T$\times$ 2.0×10^{-4} m s^{-1} $\Phi = 1.2 \times 10^{-3}$ Wb	**(1)** **(1)**	**2**
(b)(i)	Time = 0.125 (s) **Or** Time = 1/8 (s) Use of $\varepsilon = (-)d(N\Phi)/dt$ $\varepsilon = (-)9.6 \times 10^{-3}$ V (ecf $N\Phi$ from (a)) Example of calculation $\varepsilon = 1.2 \times 10^{-3}$ Wb /0.125 s $\varepsilon = 9.6$ mV	**(1)** **(1)** **(1)**	**3**
(b)(ii)	Maximum values when coil is horizontal **Or** maximum values when the coil is parallel to the magnetic field **Or** minimum value when coil vertical **Or** minimum value when the coil is perpendicular to the magnetic field e.m.f. determined by rate of change of flux **Or** see $\varepsilon = (-)d(N\Phi)/dt$ Greatest rate of change of flux as coil goes through horizontal **Or** greatest rate of change of flux occurs when $\theta=90°$ **Or** least rate of change of flux as it goes through vertical **Or** least rate of change of flux occurs when $\theta=0°$	**(1)** **(1)** **(1)**	**3**
(b)(iii)	Peaks would be smaller amplitude **Or** maximum e.m.f. smaller Rate of change of flux (linkage/cutting) less	**(1)** **(1)**	**2**
(c)(i)	Energy required to turn generator Transferred from kinetic energy of the car	**(1)** **(1)**	**2**
(c)(ii)	Greater rate of kinetic energy transfer/loss at high(er) speeds At slower/low speeds there is less/negligible braking effect (so car would not fully stop)	**(1)** **(1)**	**2**
	Total for question		**14**

Q18.

Question Number	Answer		Mark
(a)	The induced e.m.f. Is equal/proportional to the rate of change of (magnetic) flux (linkage) **Or** $\varepsilon = (-)\ d(N\Phi)/\Delta t$ with symbols defined	**(1)** **(1)**	**2**

Question Number	Answer	Mark
*(b)	(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate) the idea that due to the magnet moving there is a changing field around the ring (1) An e.m.f. induced (in a closed circuit hence a current flows) (1) Change in direction of magnet, changes the direction of e.m.f./current (1) Magnitude of e.m.f. (and current) depends on the rate of change of flux linkage **Or** magnitude of e.m.f. (and current) depends on position/ speed of magnet (1)	**4**

Q19.

Question Number	Acceptable Answer	Additional Guidance	Mark
(a)	• use of $s = ut + \frac{1}{2}at^2$ (1) • a = 7.4 m s^{-2} (1)	Example of calculation: $s = ut + \frac{1}{2}at^2 \quad \therefore a = \frac{2 \times 0.75\text{m}}{(0.45\text{s})^2} = 7.41\text{ms}^{-2}$	**(2)**

<table>
<tr><th>Question Number</th><th>Acceptable Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr>
<td>* (b)</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.

<table>
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<tr><td>6</td><td>4</td></tr>
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</table>
</td>
<td>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).</td>
<td></td>
</tr>
</table>

1	1
0	0

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	(1)
Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout	2	(1) (1) (1)
Answer is partially structured with some linkages and lines of reasoning	1	(1)
Answer has no linkages between	0	(1)

	points and is unstructured		

Indicative content:

- when the magnet falls there is a rate of change of magnetic flux linked with the tube
- the change in flux linkage for the copper tube induces an emf (Faraday's law)
- the induced emf causes a current to flow in the tube
- the induced emf (and current) are in such a direction as the oppose the change in flux linkage (Lenz's law)
- a force is exerted on the magnet opposing its motion
- plastic is not a conductor so no current is induced, shorter time to fall through the tube so teacher is correct

(6)

Question Number	Acceptable Answer		Additional Guidance	Mark
(c)	An explanation that makes reference to the following:			
	• the slit will limit the size of the induced current	(1)		
	• hence a smaller force will oppose the motion of the magnet	(1)		
	• so the time taken to fall will be less	(1)		**(3)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(d)	An explanation that makes reference to the following: • manual timing will be affected by reaction time (1) • the shorter the time being measured the greater the effect that reaction time will have (1)		**(2)**

Q20.

Question Number	Acceptable answers	Additional guidance	Mark
	• The current and magnetic field are perpendicular (1) • By (Flemings) left hand rule the force on the electrons is upwards (1)	alt. force results from current not parallel to a magnetic field	(2)

Q21.

Question Number	Answer	Mark
	C	1

Q22.

Question Number	Acceptable answers	Additional guidance	Mark
	The only correct answer is B **A** *is not correct because this is a uniform field so F constant* **C** *is not correct because this is a uniform field so F constant* **D** *is not correct because this is a uniform field so F constant*	*F*	**1**

Q23.

Question Number	Acceptable answers	Additional guidance	Mark
	The only correct answer is D $\frac{F}{4}$	A,B and C do not show an inverse square	**1**

Q24.

Question Number	Answer		Mark
(a)	Use of $\Phi = BA$ Converts cm to m Or mT to T $\Phi = 1.1 \times 10^{-4}$ Wb Example of calculation $\Phi = 6.0 \times 10^{-2}$ m $\times$ 2.4×10^{-2} m $\times$ 74×10^{-3} T $\Phi = 1.07 \times 10^{-4}$ Wb	(1) (1) (1)	3
(b)	Use of $\mathcal{E} = \Delta\Phi/\Delta t$ Use of time = distance/speed $\mathcal{E} = 5.3$ mV (5.0 mV or 5.5 mV depending on value of Φ used, ecf value of Φ from (a)) **Or** Quotes $\mathcal{E} = Blv$ $l = 6.0 \times 10^{-2}$m used $\mathcal{E} = 5.3$ mV Example of calculation Time = 0.024 m / 1.2 m s^{-1} $t = 0.020$ s $\mathcal{E} = 1.1 \times 10^{-4}$ Wb / 0.02 s = 5.5 mV	(1) (1) (1) (1) (1) (1)	3
(c)	Use of $I = V/R$ Use of $F = BIl$ $F = 9.8 \times 10^{-5}$ N (ecf value of $\mathcal{E}$ from (b)) This force is too small to be felt. (this comment must be consistent with their value of force) Example of calculation $I = 5.5$ mV/ /0.25 $\Omega = 0.022$ A $F = 74 \times 10^{-3}$ T $\times$ 0.022 A $\times$ 0.060 m $F = 9.8 \times 10^{-5}$ N	(1) (1) (1) (1)	4
	Total for question		10

Q25.

Question number	Acceptable answers	Additional guidance	Mark
	A		1

Q26.

Question Number	Acceptable answers	Additional guidance	Mark
	The only correct answer is C A is not correct as the increase in energy is the change in the area under the graph line : rectangle area $V_0 \times \Delta Q$ B is not correct as the increase in energy is the change in the area under the graph line : rectangle area $V_0 \times \Delta Q$ D is not correct as the increase in energy is the change in the area under the graph line : rectangle area $V_0 \times \Delta Q$		**1**

Q27.

Question Number	Answer	Mark
	B	1

Q28.

<table>
<tr><th>Question Number</th><th>Acceptable answers</th><th>Additional guidance</th><th>Mark</th></tr>
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<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

There is an alternating p.d./E-field
P.d./E-field accelerates protons between dees
Magnetic field perpendicular to plane of dees
Proton path curved by magnetic field
As velocity of protons increases radius of path in dees increases
The time for which a proton is in a dee remains constant
Or the frequency of p.d./E-field is constant

</td>
<td>
Guidance on how the mark scheme should be applied: The mark for 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>
</table>
<table>
<tr><th>Number of IC points</th><th>Possible linkage marks</th></tr>
<tr><td>0, 1</td><td>0</td></tr>
<tr><td>2, 3</td><td>1</td></tr>
<tr><td>4, 5, 6</td><td>2</td></tr>
</table>
IC2 accept 'in the gap' for between dees. Accept increases E_k for accelerates

IC3 accept vertical or upwards for perpendicular to plane.

IC5 accept reference to $r = p/BQ$
</td>
<td>6</td>
</tr>
</table>

Q29.

<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:

As magnet A moves, its coil experiences a change of magnetic flux (linkage)
The change in magnetic flux linkage induces an emf in the coil
The (induced) emf causes a current in both coils
The current in the second coil causes a force to act on magnet B, driving magnet B into oscillation
Because both mass-spring systems have the same period/frequency
Resonance occurs (and magnet B oscillates with increasing amplitude)

</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>
</table>
Linkage Marks

IC points 1 – 4
Three of these points could score one linkage mark

IC points 5 & 6 could score one linkage mark</td>
<td>6</td>
</tr>
</table>

Q30.

<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.

<table>
<tr><th>Number of indicative marking points seen in answer</th><th>Number of marks awarded for indicative marking points</th></tr>
<tr><td>6</td><td>4</td></tr>
<tr><td>5–4</td><td>3</td></tr>
<tr><td>3–2</td><td>2</td></tr>
<tr><td>1</td><td>1</td></tr>
<tr><td>0</td><td>0</td></tr>
</table>
</td><td>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).</td><td></td></tr>
</table>

<table>
<tr><th>Question number</th><th>Acceptable answers</th><th>Additional guidance</th><th>Mark</th></tr>
<tr><td>* (continued)</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 of answer and sustained line of reasoning</th></tr>
<tr><td>Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout</td><td>2</td></tr>
<tr><td>Answer is partially structured with some linkages and lines of reasoning</td><td>1</td></tr>
<tr><td>Answer has no linkages between points and is unstructured</td><td>0</td></tr>
</table>
</td><td></td><td></td></tr>
</table>

Question number	Acceptable answers	Additional guidance	Mark
* (continued)	**Indicative content** • The supply creates a changing magnetic field in the iron core • Rate of change of flux in toothbrush coil is equal to rate of change of flux in charger coil (for an ideal transformer) • The changing flux linkage in the coil of the toothbrush induces an e.m.f. according to Faraday's law • $E = -N \, d\phi/dt$ so to step down the e.m.f. there must be fewer turns in the toothbrush coil • The e.m.f. in the toothbrush coil must be larger than the toothbrush battery • Diode is included so battery is not discharged by the alternating e.m.f.	Allow provides dc to charge battery or similar.	**6**