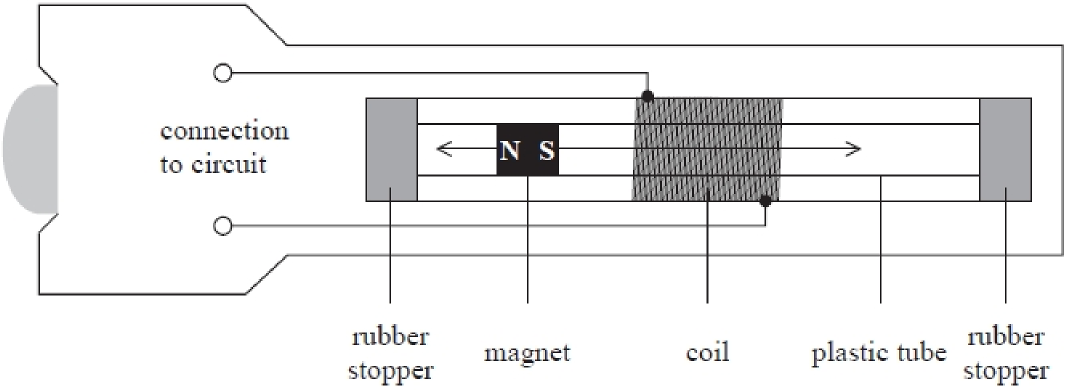
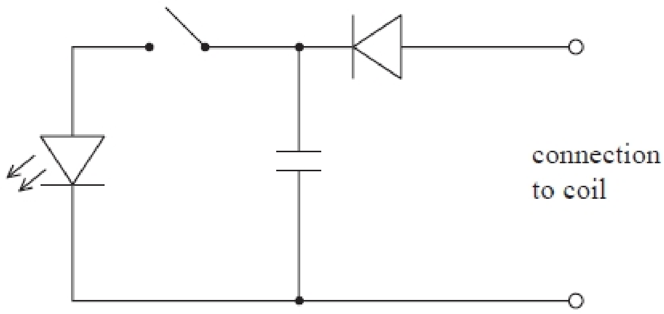
Magnetic Fields and Alternating Current

Q1.

*The diagram shows a 'shaker torch'. When the torch is shaken, a strong magnet moves forwards and backwards through a copper coil, powering a light-emitting diode (LED).



Each time the magnet moves through the coil a current pulse is generated. The coil is connected to a capacitor via a diode, as shown.



Explain how the shaker torch is able to light the LED.

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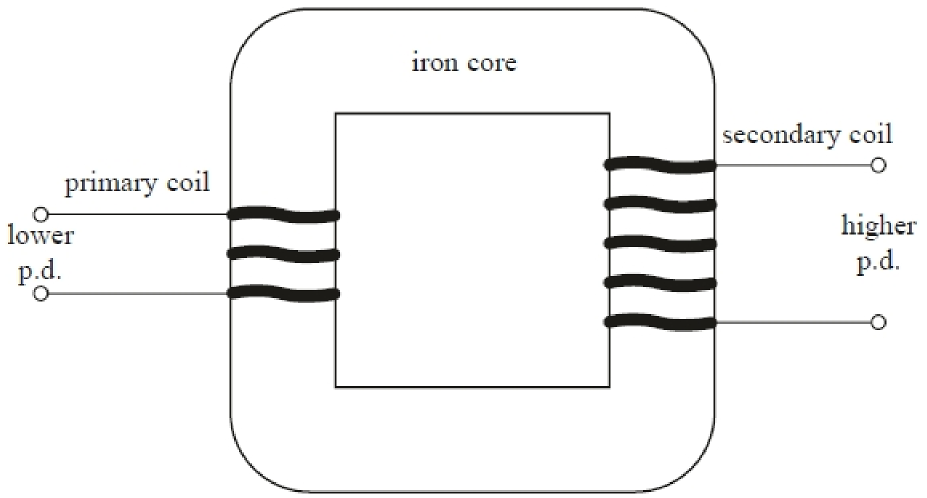
(Total for question = 6 marks)

Q2.

Electrical transmission systems are used to transmit electrical power from place to place. Transformers are used to change potential differences (p.d.) and power transmission cables are used to transmit power.

The diagram shows a step-up transformer.



A step-up transformer is used to convert a lower p.d. to a higher p.d. An alternating p.d. is applied to the primary coil.

Explain how a higher p.d. is produced across the secondary coil.

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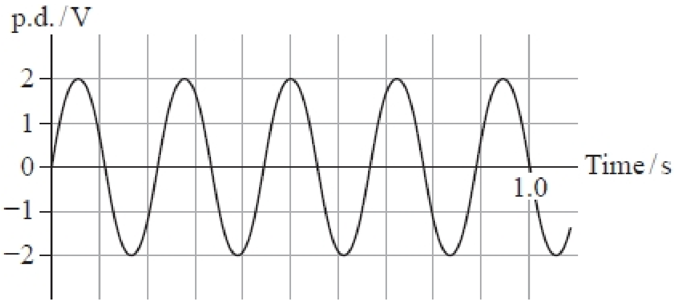
(Total for question = 4 marks)

Q3.

The graph shows how a potential difference (p.d.) varies with time.



Which of the following is correct?

☐ **A** The frequency is 4.5 Hz.

☐ **B** The peak value is 4.0 V.

☐ **C** The period is 0.20 s.

☐ **D** The root mean square value of p.d. is 1.0 V.

(Total for question = 1 mark)

Q4.

Power supplies provide either alternating or direct currents and potential differences.

A power supply produces an alternating potential difference (p.d.). The p.d. has a period of 0.02 s and a peak value of 4.0 V.

(i) Calculate the frequency of the supply.

(1)

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Frequency = ...

(ii) Calculate the root-mean-square p.d.

(1)

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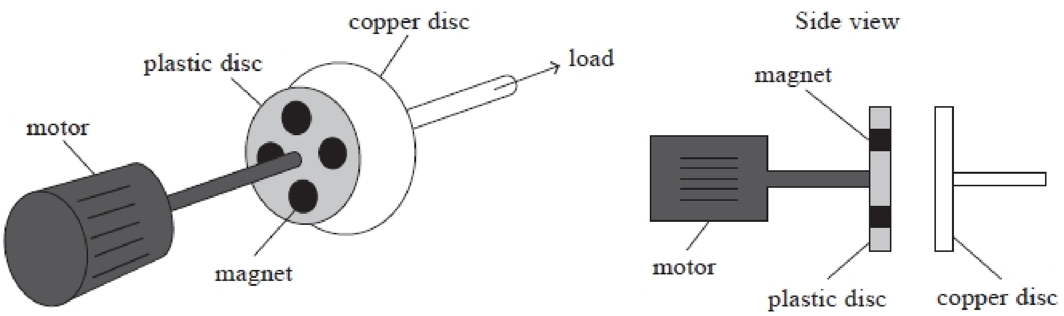
Root-mean-square pd = ...

(Total for question = 2 marks)

Q5.

A device called a clutch can be used to connect a motor to a load. The diagram shows a design called an eddy current clutch.



Several magnets are embedded in the plastic disc and it is rotated by the motor.

(i) Explain why a current is induced in the copper disc when the motor is switched on.

(2)

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(ii) Explain, using Lenz's law, why the copper disc rotates.

(3)

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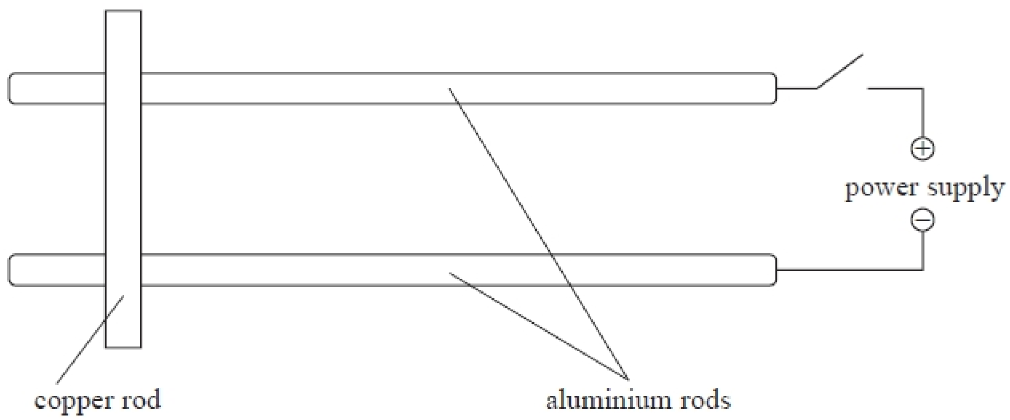
(Total for question = 5 marks)

Q6.

The apparatus shown in the diagram can be used to demonstrate that a force acts on a current-carrying conductor when the conductor is in a magnetic field.



The apparatus is placed in a magnetic field. When the switch is closed, the copper rod rolls along the aluminium rods.

(a) Add to the diagram to indicate the direction of the current in the copper rod.

(1)

(b) State the direction of the magnetic field that will make the copper rod move to the right.

(2)

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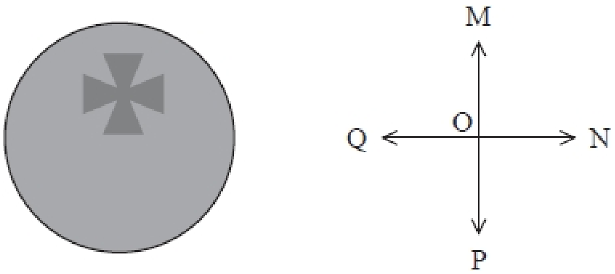
(Total for question = 3 marks)

Q7.

A demonstration is carried out using a beam of electrons in an evacuated tube.

When electrons hit a fluorescent screen, light is emitted. A piece of metal, in the shape of a Maltese cross, stops electrons and produces a shadow on the screen as shown.

The screen is viewed by an observer at point X in the diagram above. A magnetic field is directed at the beam of electrons. This causes the shadow to move upwards on the screen in the direction OM.



In which of the following directions is the magnetic field acting as seen by this observer?

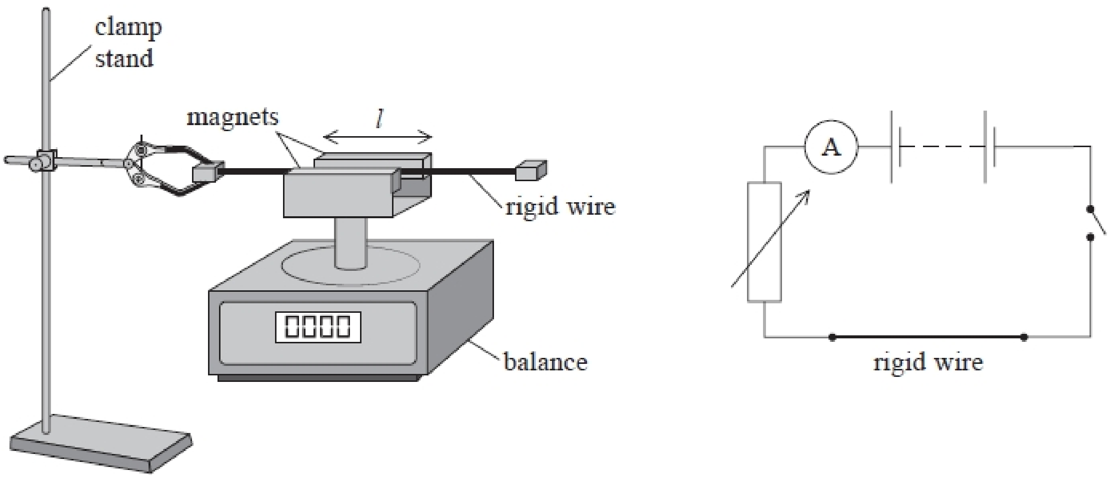
(1)

- ☐ **A** OM
- ☐ **B** ON
- ☐ **C** OP
- ☐ **D** OQ

(Total for question = 1 mark)

Q8.

A student set up the apparatus shown. A length of rigid wire was held horizontally by a clamp in a uniform magnetic field of flux density *B*.
The circuit connected to the rigid wire is also shown.



With the switch open, the balance was set to zero. When the switch was closed a current *I* in the circuit was recorded by the ammeter and the reading on the balance increased.

The length *l* of wire in the magnetic field was 15.5 cm. When the current in the circuit was 4.55 A, the reading on the balance increased by 5.65 g.

Calculate the magnetic flux density *B* in the region of the rigid wire.

(3)

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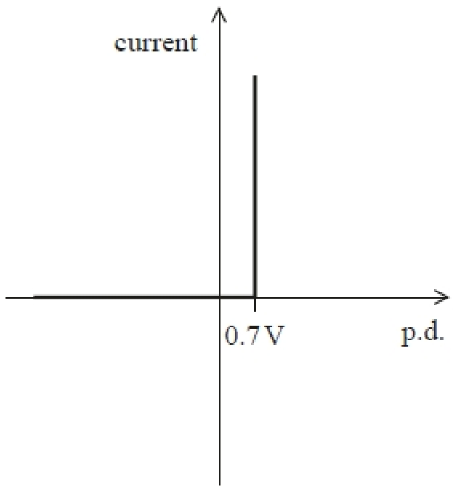
B = ...

(Total for question = 3 marks)

Q9.

The graph shows how current varies with potential difference (p.d.) for an ideal diode.



An alternating p.d. V_{IN} has a peak value of 3.4 V.

(i) Calculate the r.m.s. value.

(2)

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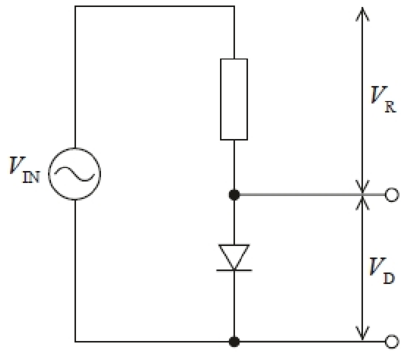
r.m.s. value = ...

(ii) V_{IN} is applied to a diode and resistor as shown.



The p.d. across the resistor is V_R and the p.d. across the diode is V_D. V_D is the output.
Explain why $V_{IN} = V_R + V_D$ at any given time.

(2)

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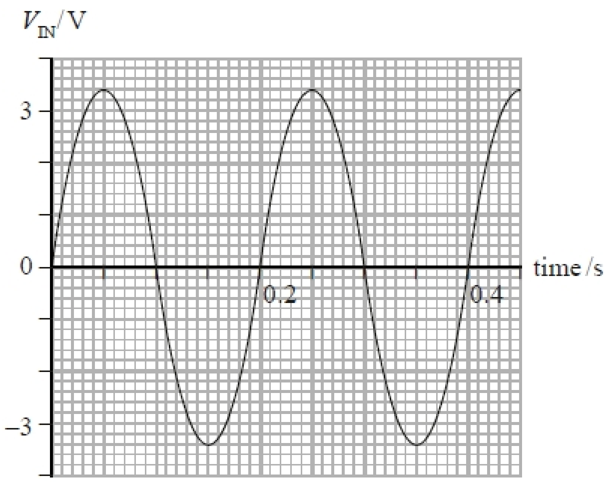
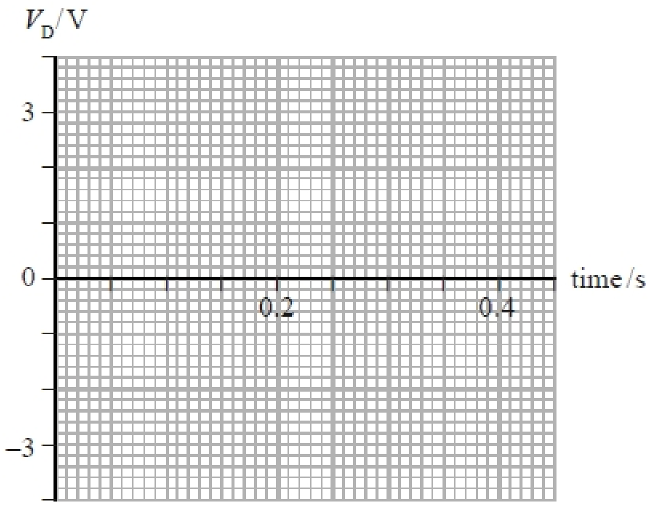
(iii) The graph shows how V_{IN} varies with time.

Sketch a graph of V_D against time using the axes provided below.





(3)

(Total for question = 7 marks)

Q10.

Mains electricity in the UK is 230 V rms.

The peak voltage of the mains supply is given by

☐ **A** $\frac{230}{\sqrt{2}}$ V

☐ **B** $230\sqrt{2}$ V

☐ **C** $\frac{\sqrt{2}}{230}$ V

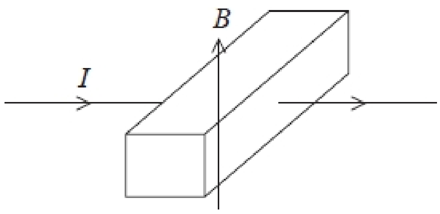
☐ **D** $\frac{230}{2}$ V

(Total for question = 1 mark)

Q11.

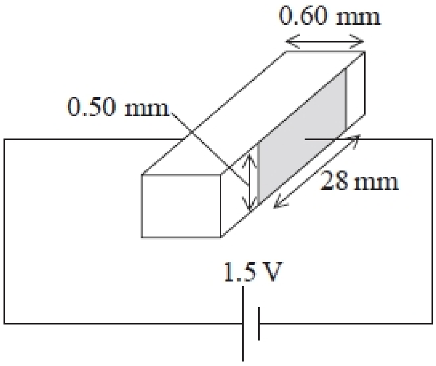
Some liquids conduct electricity. This property can be used to pump these liquids through pipes.

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.



A practical demonstration of this principle used two rectangular electrodes, opposite each other on either side of the pipe, a distance of 0.60 mm apart. The dimensions of the electrodes are shown in the diagram.

The electrodes were connected to a 1.5 V cell.
Salt water was pumped using a magnetic field of magnetic flux density 0.40 T.



(i) Show that the current through the salt water is about 20 mA.

resistivity of salt water = 1.6 Ω m

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(ii) Hence calculate the force on the salt water.

(2)

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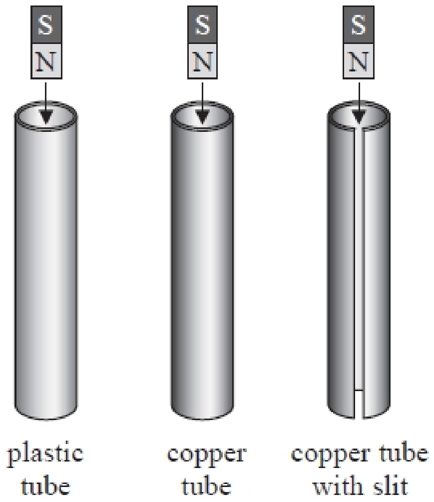
Force = ...

(Total for question = 6 marks)

Q12.

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.

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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.

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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.

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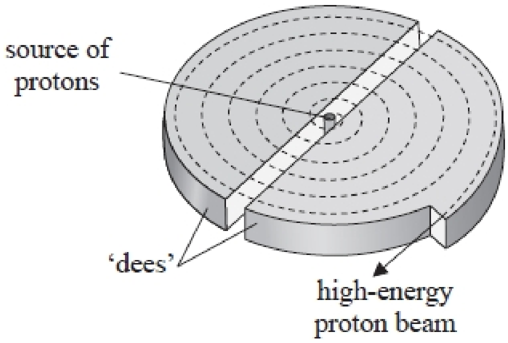
(Total for question = 13 marks)

Q13.

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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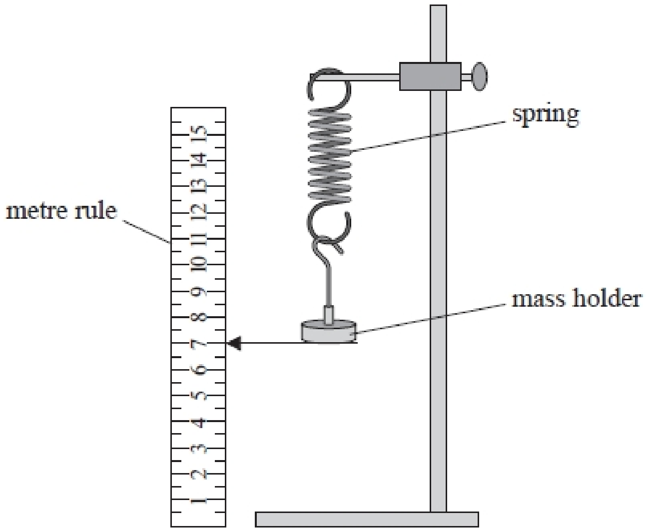
(Total for question = 6 marks)

Q14.

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

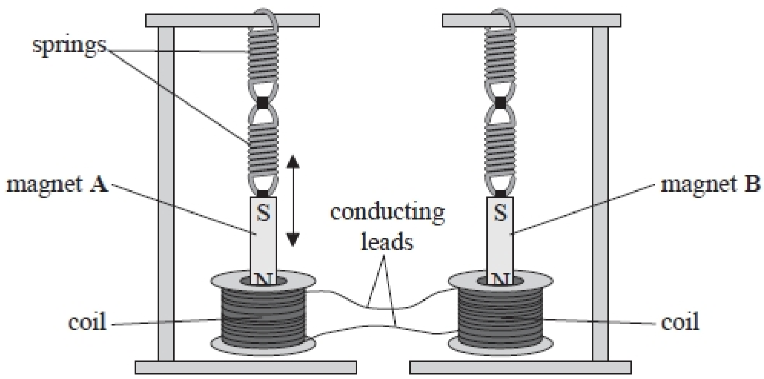


The position of the bottom of the mass holder was recorded. The spring was stretched by adding masses to the mass holder and the new positions were recorded. The extension of the spring each time was calculated.

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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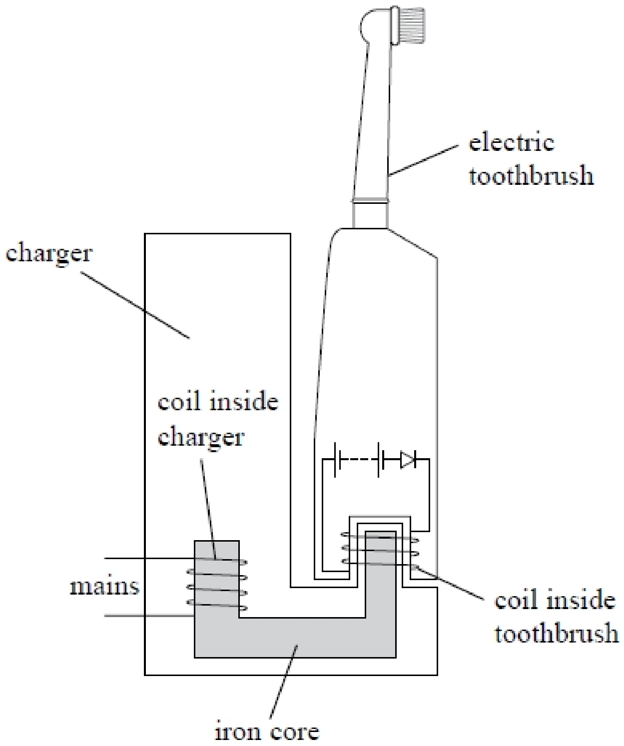
(Total for question = 6 marks)

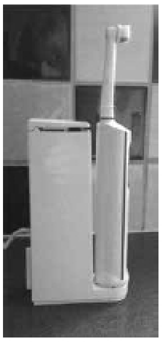
Q15.

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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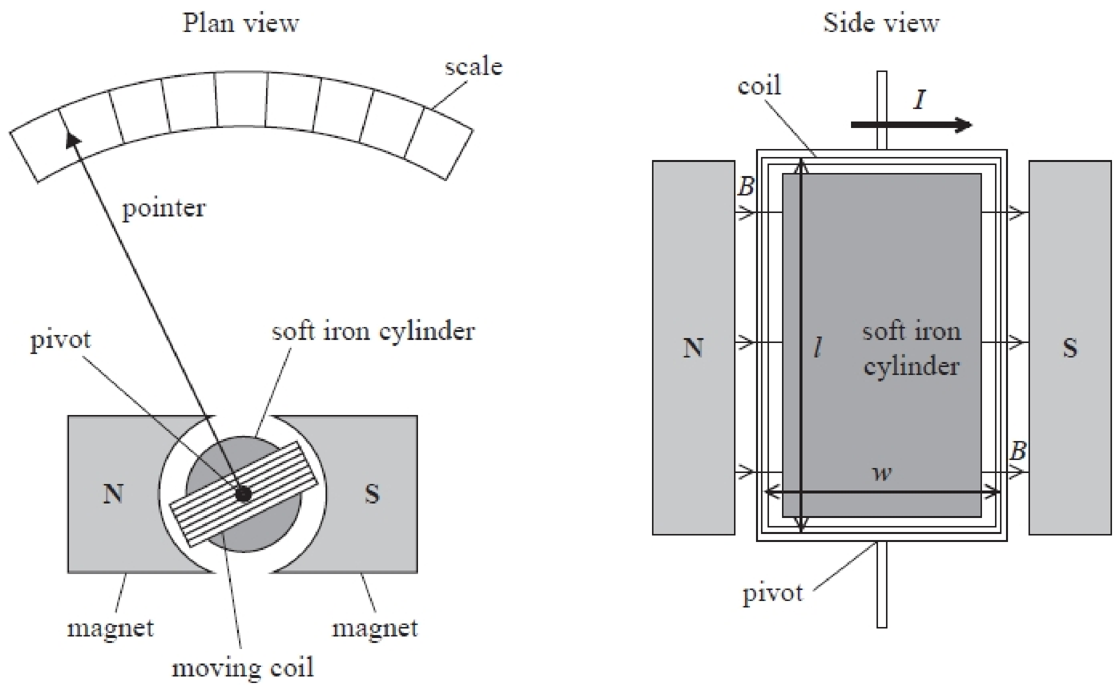
(Total for question = 6 marks)

Q16.

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



The coil within a very sensitive moving coil ammeter can be damaged when the ammeter is transported. The two ends of the coil are connected together when the ammeter is transported. This reduces the movement of the coil and makes it less likely to be damaged.

A student suggests that this is due to Faraday's law and Lenz's law.

Explain how these laws apply to this situation.

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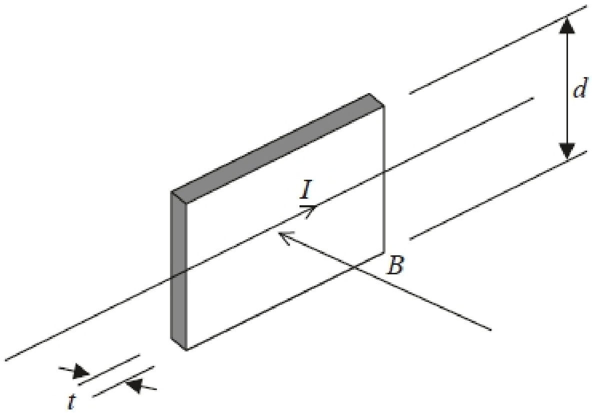
(Total for question = 4 marks)

Q17.

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.

Electrons continue to collect at the top edge of the slice, until the force on a moving electron due to the magnetic field is equal to the force on the electron due to the electric field.

Derive the following equation for V_{HALL}:

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

where *n* is the number of charge carriers per unit volume of the semiconductor.

(4)

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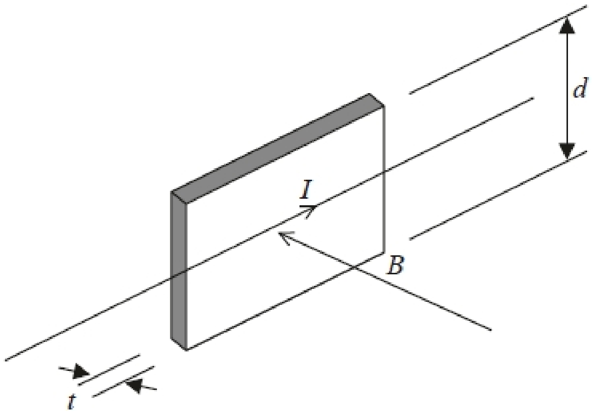
(Total for question = 4 marks)

Q18.

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

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



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

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

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

(3)

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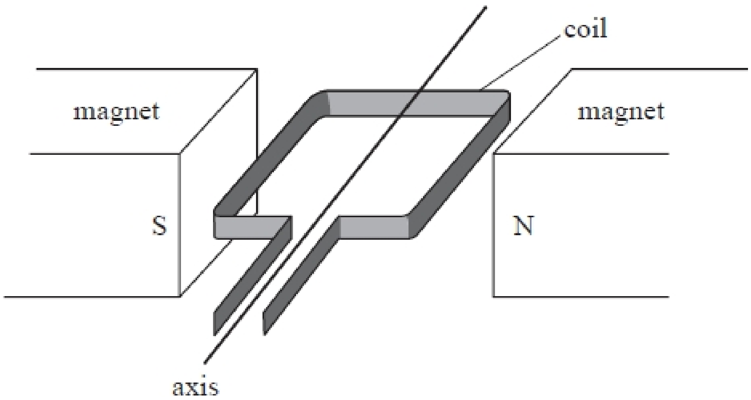
(Total for question = 3 marks)

Q19.

Hybrid electric vehicles (HEV) use the same device both as a generator to charge the car battery and as an electric motor to support the propulsion system. A simplified diagram of the device is shown. The coil can rotate freely around the axis.



Describe how the device can be used as both a generator and an electric motor.

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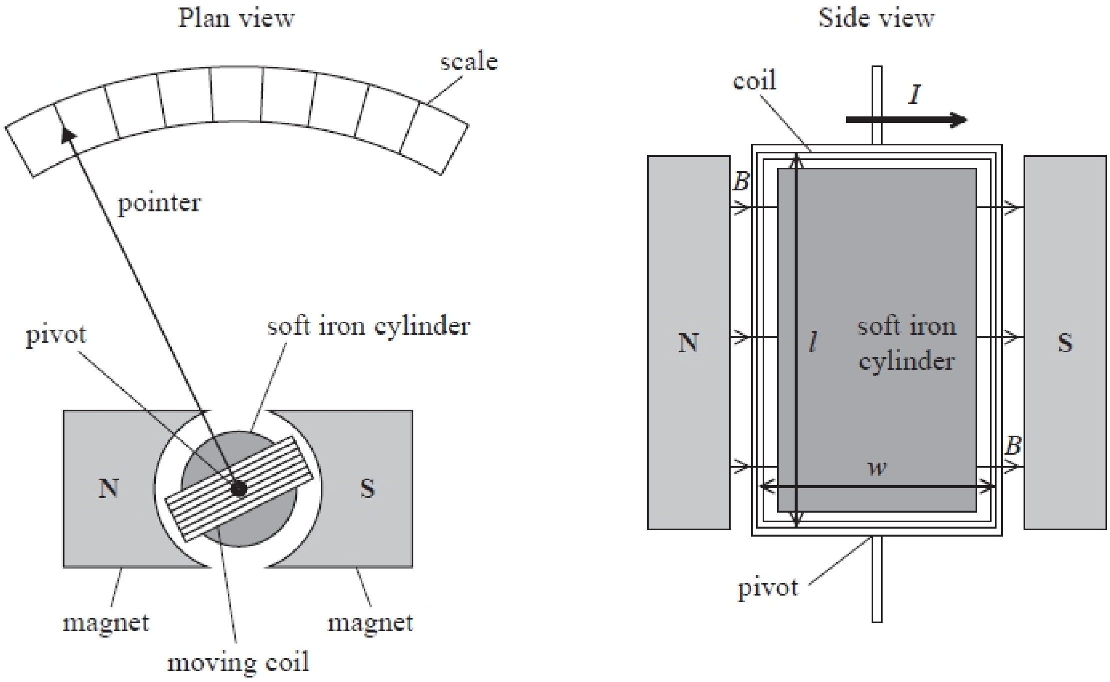
(Total for question = 6 marks)

Q20.

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



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

(i) Explain which way the coil will rotate.

(2)

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

$$M = BAIN$$

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

(4)

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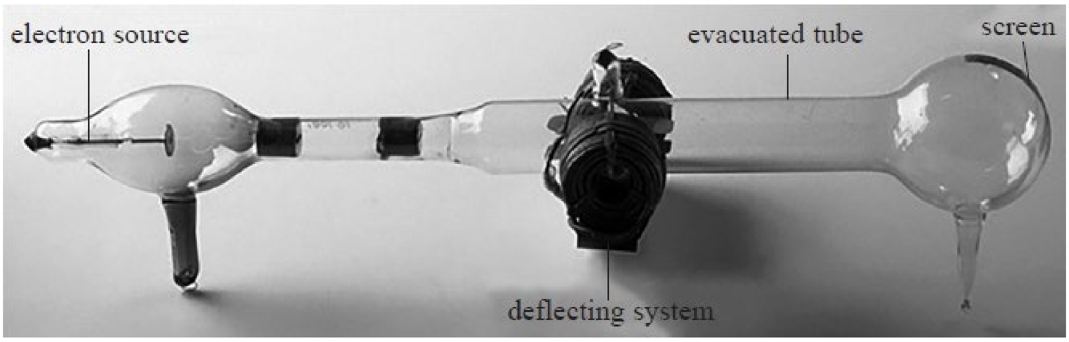
(Total for question = 6 marks)

Q21.

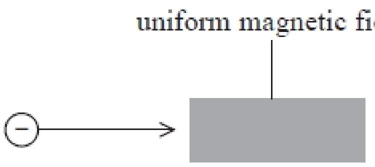
At the end of the 19th century, J.J. Thompson used electric and magnetic fields to deflect beams of charged particles. A photograph of his apparatus is shown.



© Science Museum London

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

An electron is travelling left to right and enters a region of uniform magnetic field as shown below. The direction of the magnetic field is perpendicular to the direction of travel of the electron.



(i) The magnetic field deflects the electron in the direction up the page.

Explain the direction of the magnetic field that would produce this deflection.

(2)

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(ii) Explain why the electron would travel in a circular path if no other forces acted on it.

(2)

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(Total for question = 4 marks)

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 ☒.

Which of the following is a unit of magnetic flux?

☐ **A** $N\ C^{-1}$

☐ **B** $T\ m^{-2}$

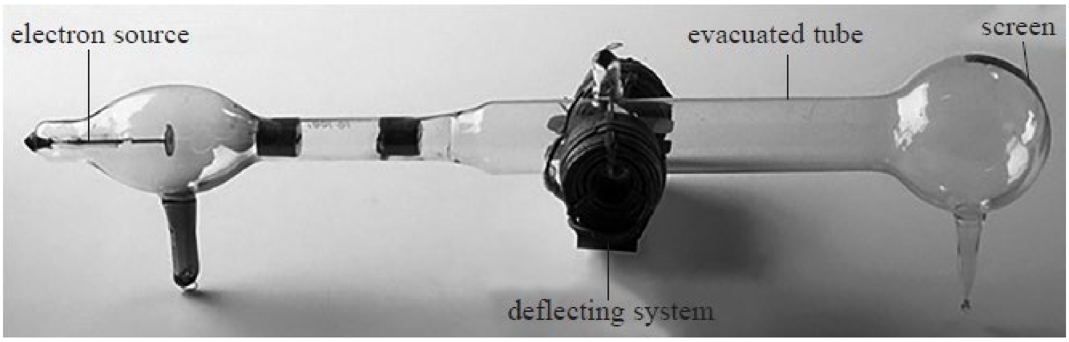
☐ **C** V s

☐ **D** $Wb\ m^{2}$

(Total for question = 1 mark)

Q23.

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.

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

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

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

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

(2)

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

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

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

(3)

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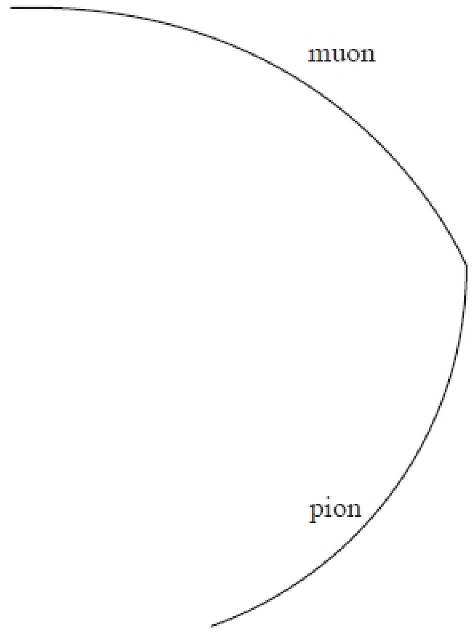
e/*m* = ...

(Total for question = 5 marks)

Q24.

A negatively charged pion decays into a muon and an antineutrino. The diagram shows tracks in a particle detector formed in such an event.



The momentum of the pion just before it decays is 9.1×10^{-20} N s.

Determine the magnetic flux density of the magnetic field which acts in the detector and state its direction.

Scale of diagram 1 cm represents 10 cm

pion charge = -1.6×10^{-19} C

(4)

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Magnetic flux density = ...

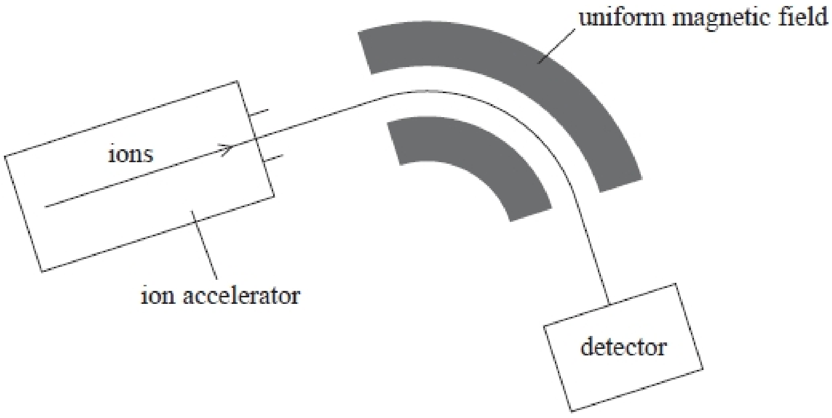
Direction of magnetic field = ...

(Total for question = 4 marks)

Q25.

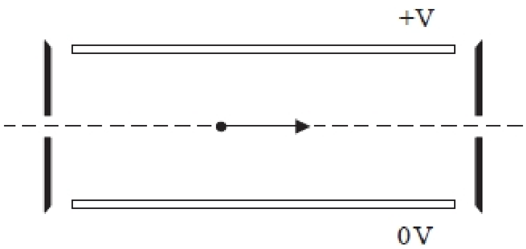
Mass spectrometry is a technique used to separate ions based on their charge to mass ratio.

The atoms in a sample are ionised and then accelerated and formed into a fine beam.
This beam is passed into a region of uniform magnetic field and the ions are deflected by different amounts according to their mass.



Analysis of mass spectrometer data shows that chlorine exists in nature as two isotopes, chlorine-35 and chlorine-37.

In most mass spectrometers the ions are passed through a velocity selector, after being accelerated, to produce a beam of ions of a particular velocity.
The velocity selector consists of a pair of parallel plates, across which a potential difference (p.d.) is applied to create an electric field.



In one mass spectrometer the plates are 2.5 cm apart and a p.d. of 135 V is applied.

A magnetic field is also applied to produce a force on the ions in the opposite direction to the force from the electric field. For one particular speed the ions travel in a straight line and emerge from the selector.

(i) Add to the diagram to indicate the directions of the electric field and the magnetic field.

(2)

(ii) The magnetic flux density applied to the velocity selector is 24.5 mT.

Deduce whether this magnetic flux density is suitable to produce a beam of chlorine-35 ions of speed 2.2×10^5 m s^{-1}.

(4)

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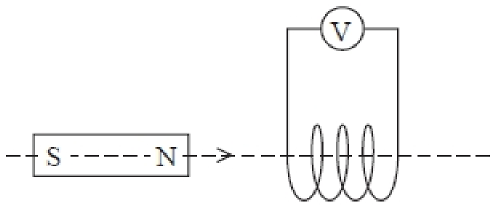
(Total for question = 6 marks)

Q26.

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

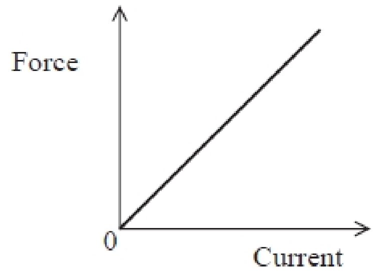
☐ **C** increasing the speed of the magnet

☐ **D** reversing the polarity of the magnet

(Total for question = 1 mark)

Q27.

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** $\frac{1}{B}$

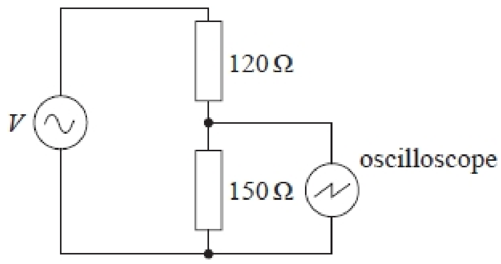
☒ **D** $\frac{B}{l}$

(Total for question = 1 mark)

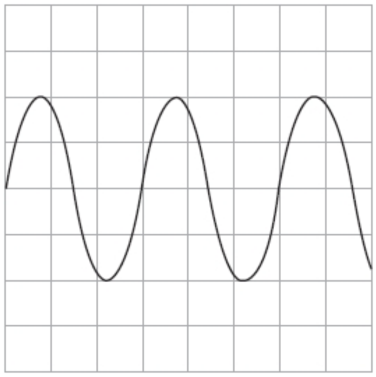
Q28.

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)

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....

Peak p.d. across 150 Ω resistor = ...

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

(3)

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

(iii) Calculate the power dissipated in the circuit.

(3)

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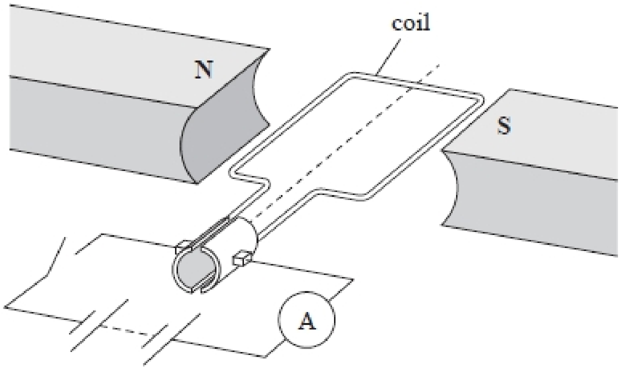
Power dissipated in circuit = ...

(Total for question = 8 marks)

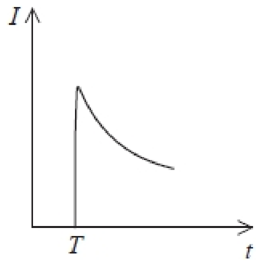
Q29.

* 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)

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(Total for question = 6 marks)

Q30.

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

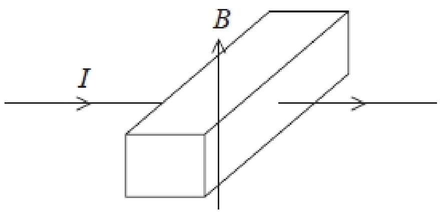
☐ **D** 9.0 A

(Total for question = 1 mark)

Q31.

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.



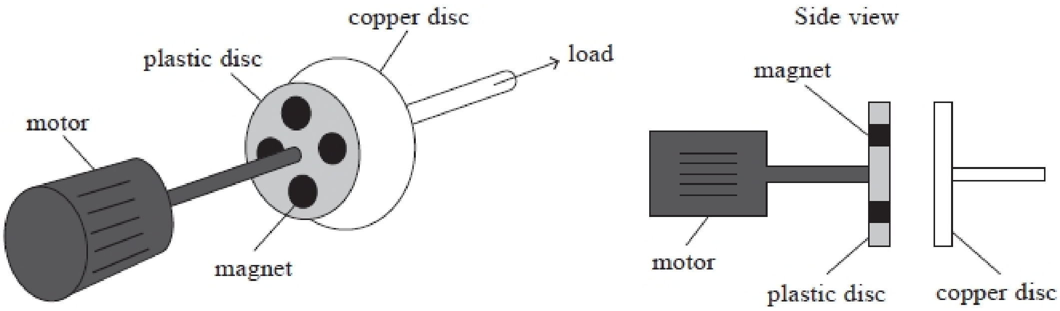
Add an arrow to the diagram above to show the direction in which the liquid will move.

(1)

(Total for question = 1 mark)

Q32.

A device called a clutch can be used to connect a motor to a load. The diagram shows a design called an eddy current clutch.



Several magnets are embedded in the plastic disc and it is rotated by the motor.

The table shows how the turning effect exerted on a load varies with ω for a particular distance between the copper disc and the plastic disc.

ω / rad s^{-1}	Turning effect / N cm
52.4	1.0
104.7	2.0
157.1	2.8

Explain the trend shown by the data.

(4)

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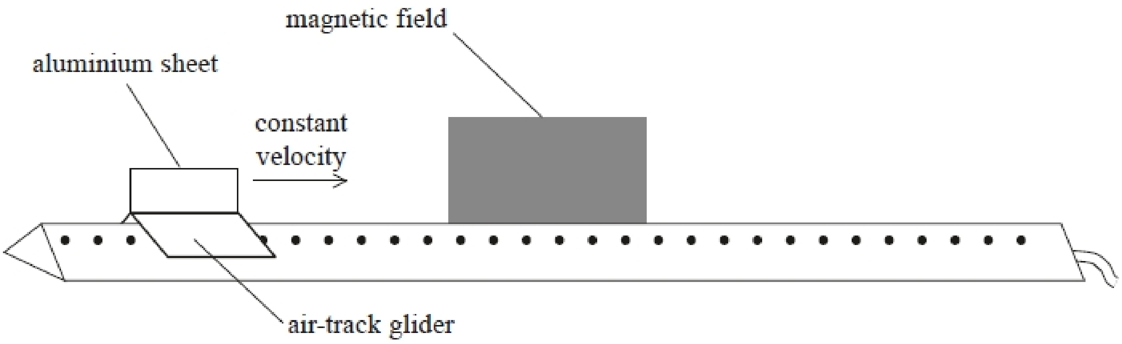
(Total for question = 4 marks)

Q33.

A rectangular sheet of aluminium is attached to an air-track glider as shown.

The glider moves towards a region of uniform magnetic field at a constant velocity. When the glider enters the magnetic field, the magnetic flux is perpendicular to the aluminium sheet.



Which row of the table describes the velocity of the glider as it enters the magnetic field, when it is completely within the magnetic field and as it leaves the magnetic field?

	Enters the magnetic field	Within the magnetic field	Leaves the magnetic field
☐ **A**	constant	decreasing	constant
☐ **B**	decreasing	constant	increasing
☐ **C**	decreasing	constant	decreasing
☐ **D**	decreasing	decreasing	decreasing

(Total for question = 1 mark)

Mark Scheme – Magnetic Fields and Alternating Current

Q1.

<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

Indicative content:

IC1 As the magnet moves through the coil there is a change in magnetic flux linkage (with coil)
Or as the magnet moves through the coil the coil cuts (lines of) magnetic flux
Or as the magnet moves through the coil the coil cuts magnetic field lines

IC2 An <u>e.m.f.</u> is induced across the coil

IC3 This generates a current in the (capacitor) circuit

IC4 The diode only allows current in one direction

IC5 So capacitor is charged (repeatedly)

IC6 When switch is closed capacitor discharges through the LED</td>
<td>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>

<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>

Total marks awarded is the sum of marks for indicative content and the marks for structure and lines of reasoning
<table>
<tr><th>IC points</th><th>IC mark</th><th>Max linkage mark</th><th>Max final mark</th></tr>
<tr><td>6</td><td>4</td><td>2</td><td>6</td></tr>
<tr><td>5</td><td>3</td><td>2</td><td>5</td></tr>
<tr><td>4</td><td>3</td><td>1</td><td>4</td></tr>
<tr><td>3</td><td>2</td><td>1</td><td>3</td></tr>
<tr><td>2</td><td>2</td><td>0</td><td>2</td></tr>
<tr><td>1</td><td>1</td><td>0</td><td>1</td></tr>
<tr><td>0</td><td>0</td><td>0</td><td>0</td></tr>
</table>
</td>
<td>6</td>
</tr>
</table>

Q2.

Question Number	Acceptable answers	Additional guidance	Mark
	• Alternating current/a.c. (in primary) produces changing/alternating magnetic flux/field **(1)** • The magnetic flux/field is linked to the secondary coil by the iron core **(1)** • The changing magnetic flux/field induces an emf in the secondary coil **(1)** • More turns on the secondary (will increase the rate of change of flux linkage according to Faraday's law). **(1)**	alt. to changing magnetic flux is $\Delta N\phi$ alt. quote of $V_1/V_2 = N_1/N_2$	**(4)**

Q3.

Question Number	Acceptable answers	Additional guidance	Mark
	The only correct answer is A B is not correct as the peak value is 2 V C is not correct as the period is 0.22 s D is not correct as r.m.s. value of p.d. is 1.4 V		**1**

Q4.

Question Number	Acceptable answers	Additional guidance	Mark
(i)	• Frequency = 50 Hz **(1)**	<u>Example of calculation</u> $f = \frac{1}{0.02\ \text{s}} = 50\ \text{Hz}$	**1**
(ii)	• Root mean square potential difference = 2.8 V **(1)**	<u>Example of calculation</u> $V_{rms} = \frac{4}{\sqrt{2}} = 2.83\ \text{V}$	**1**

Q5.

Question Number	Acceptable answers	Additional guidance	Mark
(i)	• change in magnetic flux (linkage as motor rotates) **Or** (copper disc is) cutting magnetic flux/field **(1)** • therefore there is an <u>induced</u> <u>e.m.f.</u> (according to Faraday's law) **(1)**	Accept flux linkage for magnetic flux	**2**
(ii)	• copper disc rotates in the same direction **(1)** • because it reduces the rate of magnetic flux change **(1)** • so as to oppose the change that produces it **(1)**	Accept induced current produces magnetic fields **Or** force on current in a magnetic field for MP2 Accept alternatives to flux as in (i)	**3**

Q6.

Question Number	Answer		Mark
	Arrow added to diagram downwards on or near the copper rod An indication that the field is at right angles to the page or copper rod Magnetic field into page (Upward arrow for current →magnetic field out of page. If no arrow on rod MP2 &3 can still be scored)	(1) (1) (1)	3
	Total for question		**3**

Q7.

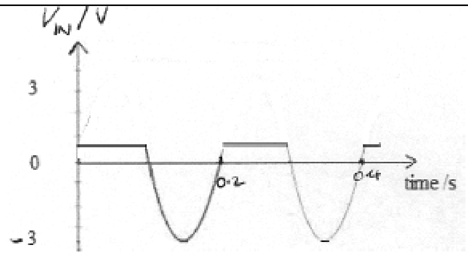
Question Number	Acceptable answers	Additional guidance	Mark
	The only correct answer is D *A is not correct because FLHR gives the direction as OQ* *B is not correct because FLHR gives the direction as OQ* *C is not correct because FLHR gives the direction as OQ*		1

Q8.

Question Number	Acceptable Answer		Additional Guidance	Mark
	• Use of $F = BIl \sin\theta$ • Use of $F = mg$ • $B = 0.0786$ T	(1) (1) (1)	Example of calculation: $BIl = mg$ $\therefore B = \frac{5.65 \times 10^{-3}\ \text{kg} \times 9.81\ \text{N kg}^{-1}}{4.55\ \text{A} \times 15.5 \times 10^{-2}\ \text{m}}$ $= 0.07859\ T$	3

Q9.

Question Number	Acceptable answers		Additional guidance	Mark
(i)	• Use of $V_{rms} = \frac{V_0}{\sqrt{2}}$ • $V_{rms} = 2.4$ V	(1) (1)	Example of calculation: $V_{rms} = \frac{3.4}{\sqrt{2}} = 2.4$ V	(2)

Question Number	Acceptable answers	Additional guidance	Mark
(ii)	• Energy is conserved **Or** Kirchoff's law **Or** potential difference is energy per unit charge (1) • So the sum of p.d.s in a series circuit must equal the e.m.f. applied (1) (MP2 is dependent on MP1)	accept work done for energy accept V_{in} for emf Alternative: Current is the same in both components (1) $IV_{IN} = IV_R + IV_D$ and I cancels (1)	**(2)**
(iii)	• Alternate half cycles of sine curve (with peak about 3 V) (1) • Horizontal line in 1st half cycle and negative half cycle of a sine curve in 2nd half cycle (1) • horizontal lines/spaces at a value of potential difference of 0.6 V to 0.8 V (1)		**(3)**

Q10.

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

Q11.

Question Number	Acceptable answers	Additional guidance	Mark
(i)	• Use of $R=\rho l/A$ (1) • Using A=0.5×28 (×10^{-6} m^2) (1) • Use of $V=IR$ (1) • I = 22 (mA) (1)	Example of calculation $R = \frac{1.6\Omega m \times 0.6 \times 10^{-3} m}{0.5 \times 10^{-3} m \times 28 \times 10^{-3} m}$ $R = 68.6\Omega$ $1.5V = I \times 68.6\Omega$ $I = 1.5V / 68.6\Omega$ $I = 0.022A = 22mA$	**4**

Question Number	Acceptable answers	Additional guidance	Mark
(ii)	• Use of $F=BIL$ ecf values from (i) (1) • Force = 5.3×10^{-6} N (1)	Use of show that values gives 4.8×10^{-6} N Example of calculation $F = 0.40\text{T} \times 0.022\text{A} \times 0.6 \times 10^{-3}\text{m}$ $F = 5.3 \times 10^{-6}\text{N}$	2

Q12.

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)

Question Number	Acceptable Answer	Additional Guidance	Mark
* (b)	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

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	0

(1)

(1)

(1)

(1)

(1)

(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 • hence a smaller force will oppose the motion of the magnet • so the time taken to fall will be less	(1) (1) (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 • the shorter the time being measured the greater the effect that reaction time will have	(1) (1)		(2)

Q13.

<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 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.
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<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><td></td><td>Number of marks awarded for structure and lines of reasoning</td></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>

Q14.

<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 <u>flux</u> (linkage)
The change in magnetic flux linkage <u>induces an emf</u> 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>

Q15.

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** • 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 • $E = -N\,d\varphi/dt$ 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**

Q16.

Question Number	Acceptable answers	Additional guidance	Mark
	An explanation that makes reference to the following points: • This is because there is a change of flux (linkage) as the meter is moved (1) • An emf is induced which will produce a current in the coil (as both ends of the coil are connected) (1) • Current-carrying conductor within a magnetic field experiences a force (1) • These forces oppose the coil's motion (reducing it) (1)		**4**

Q17.

Question Number	Acceptable answers		Additional guidance	Mark
	• Equates $F=Bev$ and $F=eE$ • Substitutes $E = V/d$ **Or** $F = eV/d$ seen • Replaces v with I/neA • Substitute $A = d \times t$ and leads to given equation Alternative: • Equates $F = BIl$ and $F = QE$ with Q identified as total charge • Substitutes $E = V/d$ **Or** $F = QV/d$ seen • Substitutes $Q = neAl$ and cancels l • Substitute $A = d \times t$ and leads to given equation	(1) (1) (1) (1) (1)	Example of derivation: $Bev = eE$ $Bev = eV/d$ $\frac{BI}{neA} = \frac{V_H}{d}$ $V_H = \frac{BI}{net}$ Alternative: $BIl = QE$ Total charge $Q = neAl$ $BIl = neAlE$ $BI = neAV_H/d$ $V_H = BI/net$	(4)

Q18.

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

Q19.

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. Indicative content: Generator: • coil has to be rotated • cuts magnetic flux **Or** rate of change of flux linkage • induces an emf Motor: • current provided to coil • Force on sides of coil that are perpendicular to magnetic field • rotate coil as forces provide a moment	(see table below)	6

IC points	IC mark	Max linkage mark available	Max final mark
6	4	2	**6**
5	3	2	**5**
4	3	1	**4**
3	2	1	**3**
2	2	0	**2**
1	1	0	**1**
0	0	0	**0**

Q20.

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

Q21.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	• (Perpendicularly) out of the page (1) • The force is perpendicular to the magnetic field and the direction of (conventional) current **Or** an application of Fleming's Left-Hand Rule (1)	Accept movement of electrons for current	2
(ii)	An explanation that makes reference to the following points: • There would be a force (of constant magnitude) on the electron perpendicular to its direction of motion (1) • Causing an acceleration towards the centre of a circle (1)	Accept reference to centripetal force for MP1	2

Q22.

Question Number	Acceptable answers	Additional guidance	Mark
	The only correct answer is C A is not correct as this is a unit of electric field strength B is not correct as units T m^2 could be used as a unit of flux D is not correct as Wb is a unit of flux		1

Q23.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	• Use of $F = BQv$ and $F = EQ$ (1) • Algebra to show $v = \frac{E}{B}$ (1)		2
(ii)	• Use of $W = QV$ *and* $E_k = \frac{1}{2}mv^2$ (1) • Use of $v = \frac{E}{B}$ (1) • $\frac{e}{m} = 1.7\times10^{11}$ C kg^{-1} (1)	Example of calculation: $v = \frac{E}{B} = \frac{1.4\times10^4 \text{ V m}^{-1}}{1.5\times10^{-3}\text{ T}}$ $\frac{e}{m} = \frac{v^2}{2V}$ $\frac{e}{m} = \frac{(9.33\times10^6 \text{ m s}^{-1})^2}{2\times250\text{ V}} = 1.74\times10^{11}$ C kg^{-1}	3

Q24.

Question Number	Acceptable answers		Additional guidance	Mark
	• measures radius (allow between 4 cm and 6 cm) • Use of $p = Bqr$ • $B = 1.1$ T (range 0.95 T – 1.42 T) • direction: out of page	(1) (1) (1) (1)	Allow use of their measured radius in MP2 Example of calculation: 9.1×10^{-20} N s $= B \times 1.6 \times 10^{-19}$ C $\times 0.52$ m $B = 1.09$ T	4

Q25.

Question Number	Acceptable Answer		Additional Guidance	Mark
(i)	• Electric field vertically downwards (from top plate to bottom plate) • Magnetic field into paper	(1) (1)		2

Question Number	Acceptable Answer		Additional Guidance	Mark
(ii)	• Use of $E = \frac{V}{d}$ • Use of $F_E = EQ$ • Use of $F_M = BQv$ • Show that these forces are equal (if v is 2.2×10^5 m s^{-1}) and hence state that B is suitable	(1) (1) (1) (1)	Do not award MP4 if incorrect ion charge used Example of calculation: $E = \frac{V}{d} = \frac{135\,V}{2.5 \times 10^{-2}\,m} = 5400\,V\,m^{-1}$ $F = EQ = 5400\,V\,m^{-1} \times 1.6 \times 10^{-19}\,C = 8.6 \times 10^{-16}\,N$ $F = BQv = 24.5 \times 10^{-3}\,T \times 1.6 \times 10^{-19}\,C \times 2.2 \times 10^5\,m\,s^{-1} = 8.6 \times 10^{-16}\,N$	4

Q26.

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

Q27.

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

Q28.

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

Q29.

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

Q30.

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

Q31.

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

Q32.

Question Number	Acceptable answers	Additional guidance	Mark
	• The relationship between ω and turning effect is (approximately) proportional **(1)** • As speed increases rate of change/cut of magnetic flux increases **(1)** • this increases the induced current in the copper disc **(1)** • this will lead to an increase in force (on the copper disc as it is within a magnetic field/flux) **(1)**	Accept attempt to find a constant ratio and relevant conclusion Accept alternatives to flux accept ref. to emf rather than current Dependent on MP2 or 3	4

Q33.

Question Number	Acceptable answers	Additional guidance	Mark
	C		1