PEARSON EDEXCEL A-LEVEL PHYSICS · 9PH0

PHYSICS



MARK SCHEME

TOPIC 7: ELECTRIC AND MAGNETIC FIELDS

MAGNETIC FIELDS AND ALTERNATING CURRENT

SCORE	PERCENTAGE
/479	%

STEMUP

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Mark Scheme

Q1.

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

Q2.

Question Number	Acceptable Answer	Additional Guidance	Mark
*	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	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 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 Total marks awarded is the sum of marks for indicative content and the marks for structure and lines of reasoning IC points / IC mark / Max linkage mark / 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	6

Q3.

Question Number	Answer	Mark
(c)	Use of area $A = \pi r^2$ (1) Use of $\varepsilon = BA/t$ (1) Use of $I = V/R$ (1) $I = 4.1$ A (1) (accept 4.1 – 4.2 A depending on where rounding is done) (candidates who use a circumference instead of an area can only score MP3) <u>Example of calculation</u> Area of coil = $\pi \times (0.05\ \text{m})^2 = 7.9 \times 10^{-3}\ \text{m}^2$ $\varepsilon = BA/t = 0.035\ \text{T s}^{-1} \times 7.9 \times 10^{-3}\ \text{m}^2 = 2.8 \times 10^{-4}\ \text{V}$ $I = \varepsilon/R = 2.8 \times 10^{-4}\ \text{V} / 6.7 \times 10^{-5}\ \Omega$ $I = 4.1$ A	4

Q4.

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	(1)	
	Reference to the iron core becomes magnetised **Or** increases magnetic field	(1)	
	the idea that the field produced in the core/wire is linked to the coil	(1)	
	(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)	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	(1)	
	Cable carries current in both directions **Or** Magnetic fields will cancel	(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	(1)	
	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)	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	(1)	
	An understanding that there are now two factors (current and frequency) altering (induced) e.m.f/voltage/reading.	(1)	2
	Total for question		11

Q5.

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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**

Q6.

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>
<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>
</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>

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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	(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)**

Q7.

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 $\times 2.4 \times 10^{-2}$ m $\times 74 \times 10^{-3}$ 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 Ω = 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

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Q8.

<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><td>Number of indicative points seen in answer</td><td>Number of marks awarded for indicative points</td></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><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>
Linkage Marks

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

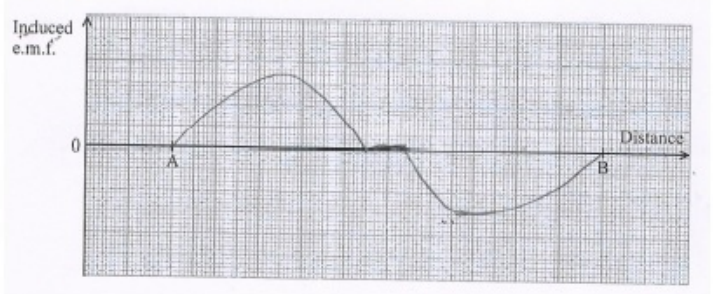
IC points 5 & 6 could score one linkage mark

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

Q9.

Question Number	Answer	Mark
	A	**1**

Q10.

Question Number	Answer		Mark
*(a)	(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate) **Max 6 from** Reference to changing/cutting of field/flux	(1)	
	Induced e.m.f. proportional to rate of change/cutting of flux (linkage) (accept equation)	(1)	
	Initial increase in e.m.f. as the magnet gets closer to the coil	(1)	
	Identifies region of negative gradient with magnet going through the coil	(1)	
	Indication that magnet's speed increases as it falls	(1)	
	Negative (max) value › positive (max) value (this mark is dependent on awarding marking point 5)	(1)	
	Time for second pulse shorter (this mark is dependent on awarding marking point 5)	(1)	
	The areas of the two parts of the graph will be the same (since Nφ constant)	(1)	6
(b)	Two sequential pulses (if **not** two sequential pulses, scores zero)	(1)	
	Pulses same height (+/- 3 mm squares) and width (by eye)	(1)	
	Pulses in opposite directions	(1)	
	Region of zero e.m.f. in the middle	(1)	4
	<u>Example</u> (peaks could be in opposite directions) 		

Q11.

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**

Q12.

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

Q13.

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**

Q14.

Question Number	Answer	Mark
	A	1

Q15.

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

Mark Scheme

Q1.

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**

Q2.

Question number	Acceptable answers	Additional guidance	Mark
	An explanation that makes reference to: • The magnetic force on the electrons acts at right angles to the plane containing B and v **(1)** • Hence the force is always towards the centre of the circle **(1)** So providing a centripetal force on the electron or a centripetal acceleration that maintains circular motion **(1)**		**3**

Q3.

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

Q4.

Question Number	Acceptable answers	Additional guidance	Mark
*	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. **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	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 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 $r = p/BQ$	6

Number of indicative points seen in answer	Number of marks awarded for indicative points
6	4
5-4	3
3-2	2
1	1
0	0

	Number of marks awarded for structure and lines of reasoning
Answer shows a coherent and logical structure with linkage and fully sustained lines of reasoning demonstrated throughout	2
Answer is partially structured with some linkages and lines of reasoning	1
Answer has no linkage between points and is unstructured	0

Number of IC points	Possible linkage marks
0, 1	0
2, 3	1
4, 5, 6	2

Q5.

Question Number	Acceptable answers	Additional guidance	Mark
	• Equates $F=Bev$ and $F=eE$ **(1)** • Substitutes $E = V/d$ **(1)** **Or** $F = eV/d$ seen • Replaces v with I/neA **(1)** • Substitute $A = d \times t$ and leads to given equation **(1)** Alternative: • Equates $F = BIl$ and $F = QE$ with Q identified as total charge **(1)** • 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	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)**

Q6.

Question Number	Answer	Mark
	B	1

Q7.

Question Number	Answer		Mark
(a)	Only (moving) charged particles are deflected by a magnetic field **Or** Only charged particles can be accelerated to produce a beam	(1) (1)	1
(b)	Into the page	(1)	1
(c)	Use of $F = mv^2/r$ **Or** use of $r = p/BQ$ Use of $F = Bqv$ **Or** use of $p = mv$ $m = 6.64 \times 10^{-26}$ kg Example of calculation $mv^2/r = Bqv$ $m = Bqr/v = (0.673\ T \times 1.6 \times 10^{-19}\ C \times 7.40 \times 10^{-2}\ m) / 1.20 \times 10^{5}\ m\ s^{-1}$ $m = 6.64 \times 10^{-26}$ kg	(1) (1) (1)	3
(d)	Semicircle drawn starting from same initial point and a smaller radius	(1)	1
	Total for question		6

Q8.

Question Number	Answer		Mark
(a)	The idea that electron(s) have been removed/added from an atom/molecule/particle.	(1)	1
(b)	Flemings left hand (rule) **Or** FLHR	(1)	1
(c)	**Max 5** Only charged particles leave a trail so photon is neutral **Or** the two particles produced are charged because they leave a track Particles are oppositely charged because they curve/spiral in opposite directions **Or** Particles are oppositely charged to conserve charge (Applying FLHR) , top particle is positive and bottom one negative. Because they have the same curvature/radius on the spirals **Or** because the paths have identical shape Particles have the same momentum The photon enters from the left because the (resultant) momentum afterwards is to the right.	(1) (1) (1) (1) (1) (1)	5
	Total for question		7

Q9.

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

Q10.

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

Q11.

Question Number	Acceptable answers	Additional guidance	Mark
	• measures radius (allow between 4 cm and 6 cm) (1) • Use of $p = Bqr$ (1) • $B = 1.1$ T (range 0.95 T – 1.42 T) (1) • direction: out of page (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

Q12.

Question Number	Answer	Mark
	C	**1**

Q13.

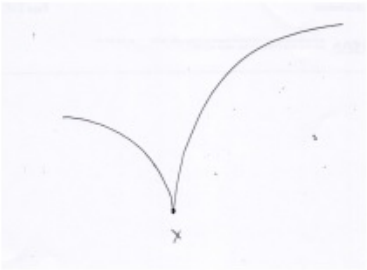
Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	• Electric field vertically downwards (from top plate to bottom plate) **(1)** • Magnetic field into paper **(1)**		**2**

Question Number	Acceptable Answer	Additional Guidance	Mark
(ii)	• Use of $E = \frac{V}{d}$ **(1)** • Use of $F_E = EQ$ **(1)** • Use of $F_M = BQv$ **(1)** • Show that these forces are equal (if v is 2.2 x 10^5 m s^{-1}) and hence state that B is suitable **(1)**	Do not award MP4 if incorrect ion charge used Example of calculation: $E = \frac{V}{d} = \frac{135\,\text{V}}{2.5\times10^{-2}\,\text{m}} = 5400\,\text{V m}^{-1}$ $F = EQ = 5400\,\text{V m}^{-1} \times 1.6\times10^{-19}\,\text{C} = 8.6\times10^{-16}\,\text{N}$ $F = BQv = 24.5\times10^{-3}\,\text{T}\times1.6\times10^{-19}\,\text{C}\times2.2\times10^{5}\,\text{ms}^{-1}$ $= 8.6\times10^{-16}\,\text{N}$	**4**

Q14.

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

Q15.

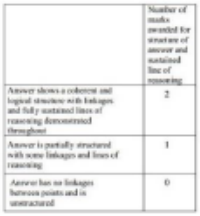
Question Number	Answer	Mark
	Diagram: Path curves in opposite sense **(1)** With a greater radius of curvature **(1)** [For Mp2 drawn line must start at X , upwards at less than 45° to vertical and go above printed line. Look at curvature close to X, do not penalise if later it curves more/less.]  **Explanation: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

Mark Scheme

Q1.

<table>
<tr><th>Question Number</th><th>Acceptable Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr>
<td>*</td>
<td>
<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>
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<tr><td>0</td><td>0</td><td>0</td><td>0</td></tr>
</table>
Indicative content:
IC1 Alternating p.d. causes an alternating current in the coil
IC2 Current carrying conductor in a magnetic field experiences a force
IC3 Current is alternating, so force changes direction with current (same frequency)
Or the alternating current drives the cone at the frequency of the p.d.
</td>
<td>
This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully sustained reasoning.

Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.

The table shows how the marks should be awarded for indicative content and structure and lines of reasoning.
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<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>

Alternative to first 3 indicative content points:
IC1 Current in coil causes a magnetic field

IC2 Current is alternating so field changes direction with current (same frequency)

IC3 Field interacts with permanent magnet's field so coil experiences oscillating force
</td>
<td></td>
</tr>
</table>

	IC4 The loudspeaker forces the box into oscillation IC5 (At certain frequencies) the frequency of oscillation equals the natural frequency of oscillation of the air in the box IC6 Maximum energy is transferred and the amplitude of vibration of the box increases	IC6 Resonance occurs and the amplitude of vibration of the box increases	6

Q2.

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

Q3.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• Use of $F = BIl \sin\theta$ (1) • Use of $F = mg$ (1) • $B = 0.0786$ T (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

Q4.

Question number	Acceptable answers	Additional guidance	Mark
(i)	• Use of ½ $mv^2 = mgh$ **(1)** • $v = 2.43$ m s^{-1} **(1)**	Example of calculation: $v = \sqrt{2gh} = \sqrt{2 \times 9.81 \times 0.30} = 2.43$ m s^{-1}	**2**
(ii)	• Use of impulse = change in momentum **(1)** • Recognises initial velocity is zero **(1)** • Hence $F = 0.923$ N **(1)** • Use of $l = \pi d$ **(1)** • Equates calculated value of F with BIl **(1)** • Hence I = 191 A **(1)**	Example of calculation: $Ft = mv - mu$ where $u = 0$ So $F = (0.019 \text{ kg} \times 2.43 \text{ m s}^{-1})/0.05 \text{ s} = 0.923$ N $l = \pi \times 0.048 \text{ m} = 0.151$ m $I = 0.923 \text{ N}/(0.032 \text{ T} \times 0.151 \text{ m}) = 191$ A	**6**

Q5.

Question Number	Acceptable answers	Additional guidance	Mark
(i)	• Use of $R=\rho l/A$ (1) • Using $A=0.5\times28$ ($\times10^{-6}$ m^2) (1) • Use of $V=IR$ (1) • $I = 22$ (mA) (1)	Example of calculation $R = \dfrac{1.6\Omega\text{m} \times 0.6\times10^{-3}\text{m}}{0.5\times10^{-3}\text{m} \times 28\times10^{-3}\text{m}}$ $R = 68.6\Omega$ $1.5V = I \times 68.6\Omega$ $I = 1.5\text{V} / 68.6\Omega$ $I = 0.022\text{A} = 22\text{mA}$	**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 $F = 0.40\text{T} \times 0.022\text{A} \times 0.6\times10^{-3}\text{m}$ $F = 5.3\times10^{-6}\text{N}$	**2**

Q6.

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

Q7.

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

Q8.

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	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**	**6**

Q9.

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**

Q10.

Question Number	Answer	Mark
	C	**1**

Q11.

Question Number	Answer		Mark
(a)	The magnetic field (must be) at right angles to the current	**(1)**	**1**
(b)	All three units for force, length and current clearly identified (The unit of force is kg m s^{-2} , the unit of current is A, the unit of length is m) T = kg A^{-1} s^{-2}	**(1)** **(1)**	**2**
(c)	*Use* of $\rho = m/V$ Use of $mg = BIl$ B = 0.53 (T) (no u.e. as given in question for part (b)) Example of calculation $m = 2.7 \times 10^3$ kg $m^{-3} \times 10 \times 10^{-3}$ m $\times 10 \times 10^{-3}$ m $\times l$ $m = 0.27 \times l$ $B = (0.27 \times l \times 9.81$ m $s^{-2})/ (5$ A $\times l)$ B = 0.53 T	**(1)** **(1)** **(1)**	**3**
(d)	(Magnetic field is) into paper/page	**(1)**	**1**
	Total for question		7

Q12.

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

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 logically structured answer with linkages and fully-sustained reasoning.

Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.

The following table shows how the marks should be awarded for indicative content.

Indicative content:
• (Maximum/Initial) current is equal to battery emf divided by R
Or current as switch closed
Or current as complete circuit
Or current due to battery
• Coil rotates
• (movement of) coil "cuts/changes" (magnetic) flux (linkage) / field
• Which induces an emf (according to Faraday's law)
• Opposes original emf/current according to Lenz's law
Or current reduced as effect opposes change
• The faster the coil rotates the larger this (back) emf/effect the smaller the current</td><td><table><tr><th>IC points</th><th>IC mark</th><th>Max linkage mark available</th><th>Max final mark</th></tr><tr><td>6</td><td>4</td><td>2</td><td>6</td></tr><tr><td>5</td><td>3</td><td>2</td><td>5</td></tr><tr><td>4</td><td>3</td><td>1</td><td>4</td></tr><tr><td>3</td><td>2</td><td>1</td><td>3</td></tr><tr><td>2</td><td>2</td><td>0</td><td>2</td></tr><tr><td>1</td><td>1</td><td>0</td><td>1</td></tr><tr><td>0</td><td>0</td><td>0</td><td>0</td></tr></table>
ic3 needs a link to coil moving
ic4 depends on ic3</td><td>6</td></tr>
</table>

Q14.

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

Q15.

Question Number	Answer	Mark
	A	1

Mark Scheme

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 e.m.f. 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.

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<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>
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</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>
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</table>
</td>
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</tr>
</table>

Q2.

<table>
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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>
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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>

Q3.

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**

Q4.

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	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**	**6**

Q5.

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

Q6.

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: • (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	<table><tr><th>IC points</th><th>IC mark</th><th>Max linkage mark available</th><th>Max final mark</th></tr><tr><td>**6**</td><td>4</td><td>2</td><td>**6**</td></tr><tr><td>**5**</td><td>3</td><td>2</td><td>**5**</td></tr><tr><td>**4**</td><td>3</td><td>1</td><td>**4**</td></tr><tr><td>**3**</td><td>2</td><td>1</td><td>**3**</td></tr><tr><td>**2**</td><td>2</td><td>0</td><td>**2**</td></tr><tr><td>**1**</td><td>1</td><td>0</td><td>**1**</td></tr><tr><td>**0**</td><td>0</td><td>0</td><td>**0**</td></tr></table> ic3 needs a link to coil moving ic4 depends on ic3	6

Q7.

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**

Mark Scheme

Q1.

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)**

Q2.

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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>
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Q3.

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<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>

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<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.
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</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**

Q4.

<table>
<tr><th>Question Number</th><th>Answer</th><th>Mark</th></tr>
<tr><td>(a)(i)</td><td>Max 2
Inconsistent number of significant figures or decimal places
Or results recorded to different precision /resolution (1)
No repeat readings (1)
More readings needed up to <u>1.5</u> cm (1)</td><td>2</td></tr>
<tr><td>(a)(ii)(1)</td><td>Attempt to use Vr= constant (1)
Correctly finds two values of Vr from values in table and makes comment
Or uses Vr value with another r or V to confirm corresponding value and makes comment (1)

<u>Example of calculation</u>

<table><tr><th>r/cm</th><th>V/V</th><th>rV/ cmV</th></tr><tr><td>1.0</td><td>0.725</td><td>0.725</td></tr><tr><td>1.5</td><td>0.483</td><td>0.725</td></tr><tr><td>2.0</td><td>0.363</td><td>0.726</td></tr><tr><td>2.5</td><td>0.29</td><td>0.725</td></tr><tr><td>3.0</td><td>0.242</td><td>0.726</td></tr><tr><td>3.5</td><td>0.21</td><td>0.735</td></tr></table></td><td>2</td></tr>
<tr><td>(a)(ii)(2)</td><td>The graph would be a straight line graph through the origin. (1)
(accept a sketch of a straight line graph going through the origin graph)</td><td>1</td></tr>
<tr><td>(b)(i)</td><td>An e.m.f. is (induced) when there is a changing (magnetic) field/flux. (1)

Because the <u>current</u> is constant there is a constant magnetic field. Or Because the <u>current</u> is constant there isn't a changing magnetic field. (1)</td><td>2</td></tr>
<tr><td>(b)(ii)</td><td>Movement of either the coil or the wire (1)
Use an alternating current/signal/supply/AC (1)
Switch the current on/off Or change current e.g. use of variable resistor (1)</td><td>3</td></tr>
<tr><td></td><td>Total for question</td><td>10</td></tr>
</table>

Q5.

Question number	Acceptable answers	Additional guidance	Mark
	An explanation that makes reference to the following points: • The current produces a magnetic field around the aluminium ring **(1)** • The direction of the ring field opposes the change producing it **(1)** • The fields repel, producing a force **(1)** • The electromagnetic force is equal and opposite to the weight of the ring so it remains in position shown **(1)**		**4**

Mark Scheme

Q1.

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

Q2.

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

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<tr><td>5 - 4</td><td>3</td></tr>
<tr><td>3 - 2</td><td>2</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>

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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	(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)**

Q3.

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**

Q4.

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

Q5.

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

Q6.

<table>
<tr><th>Question Number</th><th>Acceptable Answers</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>*</td><td>This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning.

Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.

The following table shows how the marks should be awarded for indicative content.

Indicative content:
• (Maximum/Initial) current is equal to battery emf divided by R
Or current as switch closed
Or current as complete circuit
Or current due to battery
• Coil rotates
• (movement of) coil "cuts/changes" (magnetic) flux (linkage) / field
• Which induces an emf (according to Faraday's law)
• Opposes original emf/current according to Lenz's law
Or current reduced as effect opposes change
• The faster the coil rotates the larger this (back) emf/effect the smaller the current</td><td><table><tr><th>IC points</th><th>IC mark</th><th>Max linkage mark available</th><th>Max final mark</th></tr><tr><td>6</td><td>4</td><td>2</td><td>6</td></tr><tr><td>5</td><td>3</td><td>2</td><td>5</td></tr><tr><td>4</td><td>3</td><td>1</td><td>4</td></tr><tr><td>3</td><td>2</td><td>1</td><td>3</td></tr><tr><td>2</td><td>2</td><td>0</td><td>2</td></tr><tr><td>1</td><td>1</td><td>0</td><td>1</td></tr><tr><td>0</td><td>0</td><td>0</td><td>0</td></tr></table>
ic3 needs a link to coil moving
ic4 depends on ic3</td><td>6</td></tr>
</table>

Mark Scheme

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

Q3.

Question Number	Answer		Mark
(c)	Use of area $A = \pi r^2$	(1)	
	Use of $\varepsilon = BA/t$	(1)	
	Use of $I = V/R$	(1)	
	$I = 4.1$ A	(1)	4
	(accept 4.1 – 4.2 A depending on where rounding is done)		
	(candidates who use a circumference instead of an area can only score MP3)		
	<u>Example of calculation</u>		
	Area of coil = $\pi \times (0.05\ \text{m})^2 = 7.9 \times 10^{-3}\ \text{m}^2$		
	$\varepsilon = BA/t = 0.035\ \text{T s}^{-1} \times 7.9 \times 10^{-3}\ \text{m}^2 = 2.8 \times 10^{-4}\ \text{V}$		
	$I = \varepsilon/R = 2.8 \times 10^{-4}\ \text{V} / 6.7 \times 10^{-5}\ \Omega$		
	$I = 4.1$ A		

Q4.

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	(1)	
	Reference to the iron core becomes magnetised **Or** increases magnetic field	(1)	
	the idea that the field produced in the core/wire is linked to the coil	(1)	
	(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)	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	(1)	
	Cable carries current in both directions **Or** Magnetic fields will cancel	(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	(1)	
	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)	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	(1)	
	An understanding that there are now two factors (current and frequency) altering (induced) e.m.f/voltage/reading.	(1)	2
	Total for question		11

Q5.

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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**

Q6.

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**

Q7.

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)**

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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	(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)**

Q8.

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 Ω = 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

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Q9.

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**

Q10.

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	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**	**6**

Q11.

Question Number	Answer	Mark
	A	1

Q12.

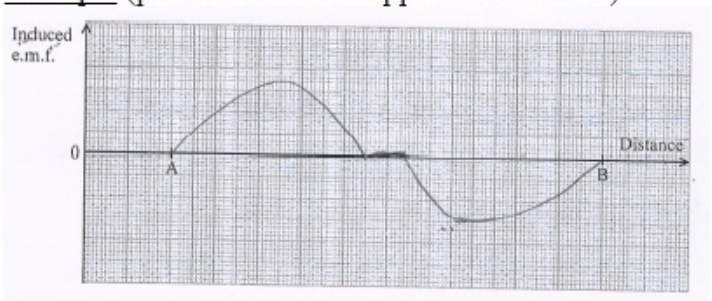
Question Number	Answer	Mark
(a)(i)	**Max 2** Inconsistent number of significant figures or decimal places **Or** results recorded to different precision /resolution (1) No repeat readings (1) More readings needed up to 1.5 cm (1)	2
(a)(ii)(1)	Attempt to use Vr= constant (1) Correctly finds two values of Vr from values in table **and** makes comment **Or** uses Vr value with another r or V to confirm corresponding value **and** makes comment (1) Example of calculation r/cm | V/V | rV/ cmV 1.0 | 0.725 | 0.725 1.5 | 0.483 | 0.725 2.0 | 0.363 | 0.726 2.5 | 0.29 | 0.725 3.0 | 0.242 | 0.726 3.5 | 0.21 | 0.735	2
(a)(ii)(2)	The graph would be a straight line graph through the origin. (1) (accept a sketch of a straight line graph going through the origin graph)	1
(b)(i)	An e.m.f. is (induced) when there is a changing (magnetic) field/flux. (1) Because the current is constant there is a constant magnetic field. **Or** Because the current is constant there isn't a changing magnetic field. (1)	2
(b)(ii)	Movement of either the coil or the wire (1) Use an alternating current/signal/supply/AC (1) Switch the current on/off **Or** change current e.g. use of variable resistor (1)	3
	Total for question	10

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Q13.

Question number	Acceptable answers	Additional guidance	Mark
	An explanation that makes reference to the following points: • The current produces a magnetic field around the aluminium ring **(1)** • The direction of the ring field opposes the change producing it **(1)** • The fields repel, producing a force **(1)** • The electromagnetic force is equal and opposite to the weight of the ring so it remains in position shown **(1)**		**4**

Q14.

Question Number	Answer		Mark
*(a)	(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate) **Max 6 from**		
	Reference to changing/cutting of field/flux	(1)	
	Induced e.m.f. proportional to rate of change/cutting of flux (linkage) (accept equation)	(1)	
	Initial increase in e.m.f. as the magnet gets closer to the coil	(1)	
	Identifies region of negative gradient with magnet going through the coil	(1)	
	Indication that magnet's speed increases as it falls	(1)	
	Negative (max) value › positive (max) value (this mark is dependent on awarding marking point 5)	(1)	
	Time for second pulse shorter (this mark is dependent on awarding marking point 5)	(1)	
	The areas of the two parts of the graph will be the same (since $N\varphi$ constant)	(1)	6
(b)	Two sequential pulses (if **not** two sequential pulses, scores zero)	(1)	
	Pulses same height (+/- 3 mm squares) and width (by eye)	(1)	
	Pulses in opposite directions	(1)	
	Region of zero e.m.f. in the middle	(1)	4
	<u>Example</u> (peaks could be in opposite directions) 		

Q15.

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**

Mark Scheme

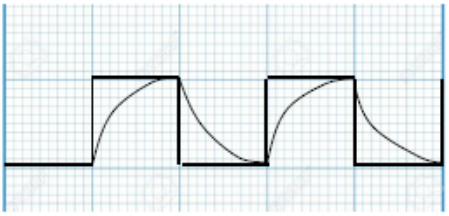
Q1.

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**

Q2.

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

Q3.

Question Number	Acceptable answers	Additional guidance	Mark
	• Time axis: one cycle = 50 OR two cycles =100 (1) • Use of time constant = RC (1) • Charging curve, from 25 ms to 50 ms, just about reaching 5V as shown (ecf from their T) (1) • One corresponding discharge curve (1) • Curve should look exponential (1)	Example of calculation $T = 1/f = 1/20\ \text{Hz} = 0.050\ \text{s}$ Two cycles $= 2 \times 0.050\ \text{s} = 0.10\ \text{s} = 100\ \text{ms}$ Time Constant $= 100 \times 50 \times 10^{-6} = 0.005\ \text{s}$ In half a cycle (0.025 s) there are 0.025 s / 0.005 s = 5 Time constants Ignore anything drawn in the first half cycle  Time period should be marked 50 ms or equivalent	5

Q4.

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

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

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

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

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

Q5.

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

Q6.

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**

Mark Scheme

Q1.

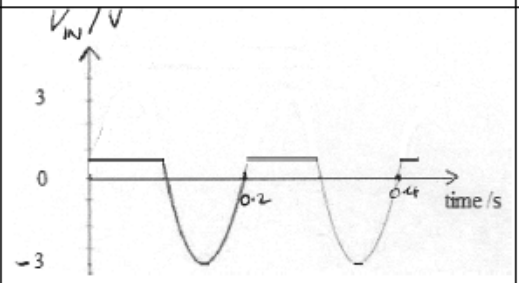
Question Number	Acceptable answers	Additional guidance	Mark
	The only correct answer is A B is not correct as the peak value is 2 V C is not correct as the period is 0.22 s D is not correct as r.m.s. value of p.d. is 1.4 V		**1**

Q2.

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

Q3.

Question Number	Acceptable answers	Additional guidance	Mark
(i)	• Use of $V_{rms} = \frac{V_o}{\sqrt{2}}$ **(1)** • $V_{rms} = 2.4$ V **(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)

Q4.

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

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

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

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

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

Q5.

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

Q6.

Question Number	Answer	Mark
	C	1

Q7.

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

Q8.

Question Number	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