Magnetic Fields and EM Induction - Mark Scheme

Q1.

Question Number	Answer	Mark
	C	1

Q2.

Question Number	Answer	Mark
(a)	Upward arrow added to diagram (1) **Justification** (From results) there is force downwards / into paper (1) This is the force on the magnet and by N3 the force on the rod is in the opposite direction (1) Reference to LH rule (leads to direction of magnetic field) (1)	**4**
(b)	Refers to $F = BIl$ (1) Calculate weights **Or** uses F = mg (1) Measure (perpendicular) length of rod within the magnetic field (1) Identifies a suitable graph (see below) (1) Determines gradient of graph (1) Correct calculation of B consistent with their graph (see below) (1)	**6**
	Total for question	**10**

y axis	x axis	B =
F	I	gradient/l
I	F	1/(gradient x l)
F	Il	gradient
Il	F	1/gradient
m	I	(gradient x g) / l
I	m	g / (gradient x l)
m	Il	gradient x g
Il	m	g / gradient
m	Il/g	gradient
Il/g	m	1/gradient

Q3.

Question Number	Answer		Mark
(a)	**Either** Use of Pythagoras to find length of wire perpendicular to field [6.1 cm] Use of $F = B \times I \times$length of wire perpendicular to field using $F = 0.0037$ N **Or** Use of $\cos\theta = a/h$ **Or** use of $\sin\theta = o/h$ **Or** measures an angle from diagram as 73°± 1° **Or** measures an angle from diagram as 17°± 1° Use of $F = BIl\sin\theta$ using correct angle $F = 0.0037$ N (accept $F = 0.0040$ N if measured angle of 73° used) <u>Example of calculation</u> $\cos\theta = 3.2$ cm / 6.9 cm $\theta = 62.4°$ $F = 0.074$ T × 0.82 A × 0.069 m × sin 62.4° = 0.074 T × 0.82 A × 0.069 m × 0.89 $F = 0.0037$ N Using measured angle: $\theta = 73°$ $F = 0.074$ T × 0.82 A × 0.069 m × sin 73° = 0.074 T × 0.82 A × 0.069 m × 0.96 $F = 0.0040$ N	(1) (1) (1) (1) (1) (1)	3
(b)	Direction into page Using (Fleming) LHR	(1) (1)	2
	Total for question		**5**

Q4.

Question Number	Answer	Mark
	B	**1**

Q5.

Question Number	Answer		Mark
(a)(i)	(Thermionic) emission of electrons from heated filament **Or** Thermionic emission of electrons from (heated) filament Electrons accelerated by field (between anode and filament) **Or** the electrons gain kinetic energy due to work done by the field	**(1)** **(1)**	**2**
(a)(ii)	Use of $qV = ½ mv^2$ $v = 6.9 \times 10^6$ m s^{-1} Example of calculation 1.60×10^{-19} C × 135 V = ½ × 9.11 × 10^{-31} kg × v^2 $v = 6.89 \times 10^6$ m s^{-1}	**(1)** **(1)**	**2**
(b)(i)	Equates $F = mv^2/r$ and $F = BQv$ Algebra including use of $p = mv$ for conclusion Example of derivation $F = mv^2/r$ and $F = BQv$ $mv^2/r = BQv$ $mv/r = BQ$ $r = mv/BQ$ $p = mv$ so $r = p/BQ$	**(1)** **(1)**	**2**
(b)(ii)	Use of $r=p/BQ$ $B = 1.1 \times 10^{-3}$ T (Allow ecf of v from (a)(ii)) Example of calculation 0.073 m / 2 = 9.11 × 10^{-31} kg × 6.89 × 10^6 m s^{-1} / B × 1.60 × 10^{-19} C $B = 1.1 \times 10^{-3}$ T	**(1)** **(1)**	**2**
(c)	**Max 2** Camera allows magnification **or** camera avoids unsteadiness of hand But as the scale isn't against the object being measured there will be parallax errors **or** as camera cannot 'line up' with both sides at the same time there will be parallax errors difficult to align ruler with maximum distance between sides of circle **or** thickness of path makes it difficult to measure diameter resolution of metre rule is small relative to the measurement **Or** percentage uncertainty in measured value is low		**2**
(d)	Electron collisions decreases E_K / speed / momentum of electrons, reducing radius/diameter **Or** (accelerating) electrons emit (synchrotron) radiation, reducing the E_K / speed / momentum of the electrons, reducing radius/diameter Electrons scattered/absorbed by helium so intensity of beam decreases **Or** There are fewer electrons in the beam so the intensity decreases	**(1)** **(1)**	**2**
	Total for question		**12**

Q6.

Question Number	Answer		Mark
(a)	Use of $f = 1/T$ with 10 or 10×10^{-3} on the denominator f = 100 Hz Example of calculation $f = 1/T = 1/(10 \times 10^{-3}\ \text{s}) = 100$ Hz	(1) (1)	2
(b)	See or use (N)$\Phi = NBA$ B = 0.016 T Example of calculation NΦ = NBA $B = N\Phi/NA = 2 \times 10^{-2}\ \text{Wb} / (500 \times 2.5 \times 10^{-3}\ \text{m}^2)$ B = 0.016 T	(1) (1)	2
(c)	tangent drawn at 2.5, 7.5 or 12.5 ms **Or** linear section of graph used ±0.5 vertical scale Value(s) substituted into $\varepsilon = \Delta(N\Phi)/\Delta t$ ε = (±)12.5 V – 14.0 V [common error is to find average value over half a cycle →8 V scores MP2 only] **Or** Use of $\varepsilon = BNA\omega$ (ecf B from(b) and f from (a)) Use of $\omega = 2\pi f$ ε = 12.6 V	 (1) (1) (1) (1) (1) (1)	3
	Total for Question		7

Q7.

Question Number	Answer	Mark
	B – into the page	**1**
	Incorrect Answers: A – treats direction of electron travel as direction of current C – not perpendicular to page D – not perpendicular to page	

Q8.

Question Number	Answer		Mark
(a)	The induced e.m.f. (in a conductor)	**(1)**	
	Is equal/proportional to the rate of change of (magnetic) flux (linkage) **Or** $\varepsilon = (-)\mathrm{d}(N\Phi)/\mathrm{d}t$ with all symbols defined	**(1)**	**2**
(b)*(i)	(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate)		
	Cables under road produce an alternating/changing (magnetic) field	**(1)**	
	Idea of flux linkage/cutting with the coil (on the bus)	**(1)**	
	(Induced) e.m.f. → (current) → charges batteries (there must be a link to the batteries)	**(1)**	**3**
(b)(ii)	Battery charged repeatedly/often/periodically/frequently	**(1)**	
	The idea that: The bus gains enough charge to travel the distance to next cable **Or** the bus (having been charged) can travel a distance without cables **Or** battery charges quickly. **Or** battery charges completely over one cable section	**(1)**	
	batteries small because they don't need to store much charge	**(1)**	**3**
	Total for Question		**8**

Q9.

Question Number	Answer	Mark
	B	**1**

Q10.

Question Number	Answer		Mark
(a)	See energy = QV **Or** $W=QV$ **Or** $E=QV$ **Or** $F=EQ$ **and** $E=V/d$	(1)	
	Equate QV and $\frac{1}{2}mv^2$ **Or** equate QV and $\frac{p^2}{2m}$	(1)	**2**
* **(b)**	(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate)		
	the (magnetic) field acts at a right angle to the direction of motion **Or** the velocity of the ion is perpendicular to the (magnetic) field	(1)	
	the force is perpendicular to the direction of motion.	(1)	
	the force acts as a centripetal force **Or** this is the condition for circular motion	(1)	**3**

(c)	See mass of ion = $80 \times 1.66 \times 10^{-27}$ (kg) in velocity/p calculation **Or** 1.328×10^{-25} (kg) in velocity/p calculation	(1)	
	Use of $m/Q = 2V/v^2$ with $Q = (-)\ 1.6\text{x}10^{-19}$ (C)	(1)	
	Use of $BQv = \frac{mv^2}{r}$ **Or** use of $r = \frac{p}{BQ}$ **and** $p = mv$ (do not award this mark if speed of light is used)	(1)	
	$r = 0.47$ m	(1)	**4**
	Example of calculation $m/Q = 2V/v^2$ $v = \sqrt{(2VQ/m)}$ $v = \sqrt{\frac{2 \times 3000\ \text{V} \times 1.6 \times 10^{-19}\ \text{C}}{80 \times 1.66 \times 10^{-27}\text{kg}}}$ $v = 8.5 \times 10^4$ (ms^{-1}) $r = mv/BQ$ $r = \frac{80 \times 1.66 \times 10^{-27}\text{kg} \times 8.5 \times 10^4\text{m s}^{-1}}{0.15\ \text{T} \times 1.6 \times 10^{-19}\text{C}}$ $r = 4.7 \times 10^{-1}$ m		
	Total for question		**9**

Q11.

Question Number	Answer		Mark
*(a)	(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate)		
	Induced e.m.f. is equal to the rate of change of flux (linkage) **Or** Induced e.m.f. is proportional to the rate of change of flux (linkage)	(1)	
	Maximum e.m.f. when coil is horizontal **Or** e.m.f. zero when coil is vertical	(1)	
	When the coil is horizontal; (The side of the coil) is cutting the flux at maximum rate. **Or** the flux linkage is zero so any movement will lead to decrease/increase	(1)	
	When the coil is vertical; The (side of the) coil is moving parallel to the flux **Or** (The side of the coil) is not cutting the magnetic field lines **Or** the flux linkage is maximum and slight movement of the coil will lead to very little change.	(1)	**(4)**

Question Number	Answer		Mark
(b)(i)	$\varepsilon\, dt = d(N\varphi)$	(1)	
	where area = $\varepsilon\, dt$ **and** $d(N\varphi)$ = change in flux linkage	(1)	(2)
(b)(ii)	Attempt to determine an area from graph	(1)	
	Use Flux Linkage = BAN	(1)	
	$B = 0.010$ T	(1)	
	Accept: Use of $f = 1/T$ **and** $\omega = 2\pi f$	(1)	
	Use of $\varepsilon = BAN\omega$	(1)	
	$B = 0.010$ T	(1)	
	<u>Example of calculation</u> area of square = 1 ms × 2 V = 2 × 10^{-3} Vs 6.5 squares in a quarter turn of coil so maximum flux linkage = 0.013 Wb $B = \frac{0.013\text{Wb}}{2.5 \times 10^{-3}\text{m}^2 \times 500}$ $B = 0.010$ T		(3)

Question Number	Answer		Mark
(c)	Amplitude is halved / peak value = 4 V	(1)	
	Time period is doubled	(1)	(2)
(d)	There is a complete circuit so there is a current (in the coil)	(1)	
	$F = BIl$ so there is a force acting that opposes the motion (increasing the force) (dependent mark) **Or** There is a magnetic force acting that opposes the motion (increasing the force) (dependent mark) **Or** This produces a magnetic field that opposes the motion (increasing the force) (dependent mark)	(1)	
	Or		
	Energy transferred to lamp (from generator)	(1)	
	So, extra work is done (which requires an increase in force) (dependent mark)	(1)	(2)
	Total for question 16		**13**

Q12.

Question Number	Answer		Mark
(a)	Lines of magnetic flux cut through coil of wire **Or** this causes a change in flux (linkage) for the coil	(1)	
	Reference to electromagnetic induction, e.g. This induces an <u>emf</u>	(1)	
	There is a complete/closed circuit (so there is a current in the coil)	(1)	**3**
(b)	Statement of Lenz's law in terms of induced e.m.f. or current	(1)	
	The (induced) current in the coil produces a magnetic field to oppose motion	(1)	
	So there is a force on the magnet in the opposite direction to its motion	(1)	
	As work = force × distance, work is done as the magnet moves	(1)	**4**
(c)	The current changes direction **Or** an alternating current is produced	(1)	
	So without diode the battery charges and discharges **Or** the diode cuts out alternate half cycles so preventing the discharge **Or** a battery needs d.c. to charge and the diode produces d.c.	(1)	**2**
	Total for question		**9**