Question			Answer	Marks	Guidance
1	(a)	(i)	$f = \frac{1}{T} = \frac{1}{10\times10^{-3}}$ frequency = 100 (Hz)	B1	
		(ii)	$2.0\times10^{-2} = B\times1.6\times10^{-3}\times400$ $B = \frac{2.0\times10^{-2}}{1.6\times10^{-3}\times400}$ $B = 3.1 \times 10^{-2}$ (T)	C1 C1 A1	**Allow**: 2 mark for 3.1×10^{n}; $n \neq -2$ (POT error) Answer to 3 sf is 3.13×10^{-2} (T) **Special case**: 12.5 scores 1 mark; number of turns omitted
		(iii)	(e.m.f. = -) rate of change of flux <u>linkage</u> <u>Tangent</u> drawn on Fig. 3.1 at 2.5 (ms) or 7.5 (ms) or 12.5 (ms) Values substituted to determine the gradient. The gradient must be 12.5 $\pm$ 1.0 (V)	B1 B1 B1	**Allow**: $E = (-)\frac{\Delta(N\phi)}{\Delta t}$ or (e.m.f. =) gradient **Alternative**: maximum e.m.f. = $2\pi f \times$ maximum flux linkage C1 maximum e.m.f. = $2\pi \times 100 \times 2 \times 10^{-2}$ C1 maximum e.m.f. = 12.6 (V) or 4π (V) A1
	(b)		$P = \frac{V^2}{R}$ $P = \frac{12^2}{150}$ power = 0.96 (W)	C1 A1	Possible ecf from **(a)(iii)**
			Total	**9**	

Question			Expected Answers	Marks	Additional guidance
2	(a)		Electromotive force is the energy transferred (from one form of energy) to electrical per unit charge	B1	**Allow:** 'electrical energy (gained) per unit charge' **Not:** electrical energy per coulomb
	(b)		Magnetic flux is the product of the (magnetic) flux density and the area (normal to the field)	B1	**Allow:** $\phi = BA$, where B = (magnetic) flux density and A = area. If $\phi = BA\cos\theta$ is used, then θ must be defined as the angle (between the normal to the plane of the area and the magnetic field) **Do not allow** 'field strength' for 'flux density'
	(c)	(i)	A changing (magnetic) flux is produced (in the primary coil / in the iron core) The iron core links this (magnetic) flux /(magnetic) flux density to the secondary coils The changing (magnetic) flux / (magnetic) flux density through secondary induces e.m.f. (in secondary coils)	B1 B1 B1	**Allow:** A changing (magnetic) flux density is produced (in the primary coil) but **not** '*changing (magnetic) field'* **Allow:** The rate of change of (magnetic) flux (linkage) induces an e.m.f. (in the secondary coil)
		(ii)	Any one from: More coils / turns on secondary Less coils / turns on primary Laminate the core	B1	**Not:** Increase frequency of alternating supply
	(d)	(i)	$\frac{n_s}{4200} = \frac{12}{230}$ (Any subject) number of turns = 219 or 220	C1 A1	**Note:** A bald answer 219 or 220 scores 2 marks
		(ii)	current = $(12.0 - 11.8)/0.35$ current = 0.57 (A) --- $P = VI$ or $P = I^2R$ or $P = V^2/R$ $P = 0.2 \times 0.57$ or $P = 0.57^2 \times 0.35$ or $P = 0.2^2/0.35$ power = 0.114 (W) or 0.11 (W)	C1 A1 C1 A1	Possible e.c.f. from **(ii)1**
			Total	**12**	

Question			Expected Answers	Marks	Additional guidance
3	**(a)**		Down(wards)	B1	**Note:** Can be on Fig. 5.1
	(b)		(Fleming's) left-hand rule	B1	**Allow:** Thumb in direction of force, first finger in direction of (magnetic) field and second finger in direction of (conventional) current
	(c)	**(i)**	force = $BIL = 0.080 \times 4.0 \times 5.0 \times 10^{-2}$ force = 0.016 (N)	B1	
		(ii)	reading = 2.500 – 0.016 reading = 2.484 (N) The force on <u>core/magnets</u> is up(wards) (According to Newton's third law) the forces (on the rod and steel core/magnets) are equal <u>and</u> opposite	B1 B1 B1	**Allow:** 'up and down' as equivalent to 'opposite'
	(d)		Resistance increases by a factor of 4 Current decreases by a factor of 4 The force decreases by a factor of 4 force = 0.004 (N)	C1 C1 A1	Possible e.c.f. from **(c)(i)** **Note:** force = **(c)(i)**/4 can score full marks **Special case:** Allow 1 mark for (resistance doubles, current is halved, hence) force = 0.008 (N)
			Total	**9**	

Question			Expected Answers	Marks	Additional Guidance
4	**a**	**(i)**	uniformly spaced, vertical parallel lines must begin and end on the plates with a minimum of three lines arrow in the correct direction down	**B1** **B1**	ignore any edge effects
		(ii)	E = V / d E = 60 / 5 x 10^{-3} = 12000 (V m^{-1})	**A1**	
	b	**(i)**	Use of energy qV and kinetic energy = ½ mv^2 v = $[(2qV)/m]^{1/2}$ v = $[(2 \times 3.2 \times 10^{-19} \times 400)/6.6 \times 10^{-27}]^{1/2}$ v = 1.97 x 10^5 (m s^{-1})	**M1** **M1** **A0**	
		(ii)	a = F / m a = Eq / m a = (12000 x 3.2 x 10^{-19}) / 6.6 x 10^{-27}) = 5.82 x 10^{11} (m s^{-2})	**C1** **A1**	Both required for the mark
		(iii)	**1** t = $\underline{(16 \times 10^{-3}) / 2 \times 10^5}$ = 8 x 10^{-8} (s) **2** s = ½ a x t^2 = ½ [5.82 x10^{11} x (8 x $10^{-8})^2$] = 1.86 x 10^{-3} (m)	**M1** **A0** **C1** **A1**	Answer will depend on number of sf used by candidate. Using u = 2 x 10^5 scores 0/2 Allow slight variation in answers that follow from the candidates working

	c		Eq = Bqv B = E / v = 12000 / 2 x 10^5 = 0.060 (T)	**C1** **C1** **A1**	 Allow one sf unless answer is 0.061 when using v =1.97 x 10^5
	d		velocity (produced by p.d / 400 V) is less force due the magnetic field is reduced / Bqv is less / force due to the electric field is unchanged hence beam deflects <u>down</u>	**B1** **B1**	 Allow the resultant force is downward Allow towards the lower plate
			Total	**[15]**	