Question			Answer	Marks	Guidance
1	**(a)**	**(i)**	(weight = *BIL*) $6.8\times10^{-5}=0.070\times I\times0.01$ (Any subject) I = 0.097 (A)	C1 A1	
		(ii)	The force on the cables will keep changing direction	B1	
	(b)	**(i)**	$BQv=mv^2/r$ $r=\dfrac{mv}{BQ}$	M1 A1	**Allow** *e, q* instead of *Q* **Note**: *r* must be the subject of this equation
		(ii)	($p = mv = BQr$; KE = ½ p^2/m) KE $\propto r^2$ ratio = $\dfrac{4.8^2}{1.2^2}$ ratio = 16	C1 A1	**Allow** full credit for correct alternative approaches **Allow** 16 : 1
			Total	**7**	

Question			Answers	Marks	Guidance
2	(a)	(i)	A (constant) force acts at right angles to the velocity / motion (of the helium nucleus).	B1	**Note**: The answer must be in terms of force and not acceleration. **Allow** 'force is towards the centre of the circle'. **Not** 'there is a *centripetal* force' - unless explained. **Not** 'force is right angles to <u>speed</u>'.
	(a)	(ii)	No work done (by the force) / no acceleration in the direction of motion / no force in direction of motion	B1	**Allow** force / acceleration is at right angles to velocity / motion.
	(b)		$BQv = \frac{mv^2}{r}$ or $mv = BQr$ momentum = $0.20 \times 10^{-3} \times 3.2 \times 10^{-19} \times 0.15$ momentum = 9.6×10^{-24} (kg m s^{-1})	C1 C1 A1	**Allow** $v = 1.45.. \times 10^3$ (m s^{-1}); $p = 1.45.. \times 10^3 \times 6.6 \times 10^{-27}$
	(c)		$v = 9.6 \times 10^{-24}/6.6 \times 10^{-27}$ or $v = 1.45... \times 10^3$ (m s^{-1}) KE = $\frac{1}{2} \times 6.6 \times 10^{-27} \times (1.45... \times 10^3)^2$ KE = 7.0×10^{-21} (J)	C1 A1	Possible ecf from **(b)** **Allow** 1 sf answer **Alternative**: ($E = p^2/2m$); KE = $\frac{(9.6\times10^{-24})^2}{2\times6.6\times10^{-27}}$ C1 KE = 7.0×10^{-21} (J) A1
	(d)		The helium nucleus moves to the <u>right.</u> The path is a clockwise curve / looped (in the plane of the paper).	B1 B1	**Not** if the path is shown as a straight line. **Allow** 2 marks for clockwise curve / loop to the right. **Allow** 1 mark for a sketch showing an 'upward curve to the right'
			Total	**9**	

Question			Answers	Marks	Guidance
3	**(a)**		The induced e.m.f. is (directly) proportional / equal to the rate of change of (magnetic) flux linkage.	B1	**Allow** $E = \frac{\Delta\Phi}{\Delta t}$ with all terms defined; *E* = induced e.m.f., Φ = (magnetic) flux linkage and *t* = time.
	(b)		North / N (pole). There is a repulsive force (between magnet and coil and the work done against this repulsive force is transferred to electrical energy in the coil).	B1	**Allow -** A south (pole) would cause attraction (between the coil and magnet) or there is gain in KE (of magnet which cannot happen hence it must be north pole).
	(c)	**(i)**	There is no change in (magnetic) flux (linkage) or there is no change in the (magnetic) flux density.	B1	**Allow** 'no change in (magnetic) field strength'.
		(ii)	*E* = 0 between 0 to 3 cm, 5 – 8 cm and 10 - 12 cm. Two 'pulses' where *B* is changing. The pulses have opposite signs.	B1 M1 A1	Tolerance: ± ¼ large square **Note**: The pulses must have *E* = 0 at 3 cm, 5 cm, 8 cm and 10 cm; tolerance ± ¼ large square.
			Total	**6**	

Question			er	Marks	Guidance
4	**(a)**		Arrow to the left	B1	
	(b)	**(i)**	1500 (eV)	B1	**Note**: 2.4×10^{-16} (J) on the answer line scores zero
		(ii)	(KE =) $1500 \times 1.6 \times 10^{-19}$ (= 2.4×10^{-16} J) $2.4\times10^{-16} = \frac{1}{2}\times 9.11\times10^{-31}\times v^2$ (Allow any subject) $v = 2.3 \times 10^7$ (m s^{-1})	C1 C1 A1	Possible ecf from **(b)(i)** **Allow**: 2 marks for 5.3×10^{14} (answer not square-rooted) **Note**: $v = \sqrt{\dfrac{2\times1500}{9.11\times10^{-31}}} = 5.74\times10^{16}$ (m s^{-1}) does not score
	(c)	**(i)**	$F_{(E)} = Eq$ and $F_{(M)} = Bqv$ $Eq = Bqv$ (This mark is for equating the two equations) (Hence) $v = \dfrac{E}{B}$	 M1 A1	 **Allow** an equivalent approach **Allow** any subject
		(ii)	Force due to magnetic field > force due to electric field Electrons drift 'downwards'	B1 B1	**Allow**: magnetic force > electric force or $F_M > F_E$ or $Bqv > Eq$ or magnetic force is bigger <u>and</u> electric force is the same **Note**: This mark can be scored on Fig. 3.2
			Total	**9**	

Question			er	Marks	Guidance
5	**(a)**		magnetic flux = magnetic flux density × area <u>normal</u> to the field	B1	**Allow**: $\phi = BA$, with terms defined; B = magnetic flux density or magnetic field strength and A = area <u>normal</u> to the field **Note**: If angle is used in the definition then it must be defined correctly
	(b)	**(i)**	$R = \dfrac{1.7\times10^{-8}\times130}{\pi\times(4.6\times10^{-4})^2}$ (Any subject) R = 3.3(2) (Ω) current = $\dfrac{24}{3.32}$ current = 7.2 (A)	C1 C1 A1	 **Allow**: Possible ecf if value for R is incorrect after attempted use of the equation $R = \dfrac{\rho L}{\pi r^2}$.
		(ii)	e.m.f. = rate of change of magnetic flux linkage (initial ϕ =) $0.090 \times 1.3 \times 10^{-3}$ or 1.17×10^{-4} $150 = \dfrac{1100\times0.090\times1.3\times10^{-3}}{t}$ (Any subject) time = 8.6×10^{-4} (s)	 C1 C1 A1	 **Allow**: (initial $N\phi$ =) $0.090 \times 1.3 \times 10^{-3} \times 1100$ or 0.129 **Allow**: 2 marks for 7.8×10^{-7} (s) if 1100 turns omitted
			Total	**7**	

Question			Answer	Marks	Guidance
6	(a)	(i)	Correct direction of force at **A** (and marked **F**)	B1	
		(ii)	The force is perpendicular to velocity / motion (hence no work done on the electron) or No (component of) acceleration / force in direction of velocity / motion (hence no work done on electron) or No distance moved in the direction of the force	B1	
	(b)		$F = \frac{mv^2}{r}$ force = $\frac{9.11\times10^{-31}\times(6.0\times10^7)^2}{0.24}$ force = 1.4×10^{-14} (N)	C1 A1	**Note**: Answer to 3sf is 1.37×10^{-14} (N) **Allow**: 1 mark for 1.4×10^n; $n \neq -14$ (POT error)
	(c)		$F = BQv$ $1.37\times10^{-14} = B\times1.60\times10^{-19}\times6.0\times10^7$ $B = 1.4 \times 10^{-3}$ (T)	C1 A1	Possible ecf from **(b)** **Note**: Answer to 3 sf is 1.43×10^{-3} (T) for 1.37×10^{-14} (N) **Note**: Using 1.4×10^{-14} (N) gives 1.46×10^{-3} (T) **Note**: Using $B = mv/Qr$ gives 1.42×10^{-3} (T)
	(d)		Using $(E =) mc^2$ and $(E =)\frac{hc}{\lambda}$ **(QWC)** $2\times mc^2 = 2\times\frac{hc}{\lambda}$ or $mc^2 = \frac{hc}{\lambda}$ or $mc = \frac{h}{\lambda}$ Correct substitution (any subject) $\lambda = 2.4 \times 10^{-12}$ (m)	B1 C1 A1	Eg: $2\times9.11\times10^{-31}\times(3.0\times10^8)^2 = 2\times\frac{6.63\times10^{-34}\times3.0\times10^8}{\lambda}$ Answer to 3 sf is 2.43×10^{-12} (m) **Allow**: 1 mark for 1.21×10^{-12} (m) or 4.86×10^{-12} (m) for the C1A1 marks
			Total	**9**	