1)

Question			Answers	Marks	Guidance
	(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 speed'.
	(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 × 10^{-3} × 3.2 × 10^{-19} × 0.15 momentum = 9.6 × 10^{-24} (kg m s^{-1})	C1 C1 A1	**Allow** v = 1.45.. × 10^3 (m s^{-1}); p = 1.45.. × 10^3 × 6.6 × 10^{-27}
	(c)		v = 9.6 × 10^{-24}/6.6 × 10^{-27} or v = 1.45... × 10^3 (m s^{-1}) KE = ½ × 6.6 × 10^{-27} × (1.45... × 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 right. 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**	

2)

Question			Answer	Marks	Guidance
	(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)	$BQv = mv^2/r$ $r = \frac{mv}{BQ}$	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 ∝ r^2 ratio = $\frac{4.8^2}{1.2^2}$ ratio = 16	C1 A1	**Allow** full credit for correct alternative approaches **Allow** 16 : 1
			Total	**7**	

3)

Question			Expected Answer	Mark	Additional Guidance
	(a)		Perpendicular out of plane of paper	B1	**Allow**: 'out of paper' **Not**: 'up the paper'
	(b)		$\frac{mv^2}{R} = BQv$ hence $v = \frac{BQR}{m}$	M1 A0	**Allow**: Use of *r* instead of *R* and *e* instead of *Q*
	(c)		speed = $\frac{2\pi \times 0.18}{2.0 \times 10^{-8}}$ or 5.66 × 10^7 (m s^{-1}) $5.66 \times 10^7 = \frac{B \times 1.60 \times 10^{-19} \times 0.18}{1.67 \times 10^{-27}}$ (Any subject) *B* = 3.28 (T)	C1 C1 A1	**Allow** : ecf for incorrect value for speed *v* Alternative : $t = (\frac{2\pi R}{v} =) \frac{2\pi m}{BQ}$ C1 $B = \frac{2\pi \times 1.67 \times 10^{-27}}{2.0 \times 10^{-8} \times 1.60 \times 10^{-19}}$ C1 *B* = 3.28 (T) A1
	(d)		The force / acceleration is perpendicular to the motion / velocity No work is done	B1 B1	**Allow**: 'speed' instead of 'velocity'
			Total	**7**	

4)

Question			Answers	Marks	Guidance
	(a)		torque = one of the forces × perpendicular distance (between the forces)	B1	
	(b)	(i)	Into (plane of) paper	B1	**Not**: 'down'
		(ii)1	force = *BIL* = 0.060 × 0.03 × 0.015 force = 2.7 × 10^{-5} (N)	B1	
		(ii)2	torque = 2.7 × 10^{-5} × 0.015 torque = 4.1 × 10^{-7} (N m) or 4.05 × 10^{-7} (N m)	C1 A1	Possible ecf from **(b)(ii)1** Do not allow 4.0 × 10^{-7} (N m) - rounding error
	(c)	(i)	*F*= *BQv* 2.0 × 10^{-13} = 0.14 × *Q* × 4.5 × 10^6 charge = 3.2 × 10^{-19} (C) or 3.17 × 10^{-19} (C)	C1 A1	**Allow**: Any subject
		(ii)	$F = mv^2 / r$ $2.0 \times 10^{-13} = \frac{2.7 \times 10^{-26} \times (4.5 \times 10^6)^2}{r}$ radius = 2.7 (m) or 2.73 (m)	C1 C1 A1	**Allow**: Any subject
		(iii)	$BQv = mv^2/r$ Hence, radius ∝ mass	B1 B1	**Allow**: $r \propto m$
			Total	**12**	

5)

Question			Answer	Marks	Guidance
	(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 ≠ -14 (POT error)
	(c)		$F = BQv$ $1.37\times10^{-14} = B\times1.60\times10^{-19}\times6.0\times10^7$ *B* = 1.4 × 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) λ = 2.4 × 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**	

6)

Question			Answer	Marks	Guidance
	(a)		(Fleming's) left-hand rule	B1	
	(b)		The force is at right angles to the velocity (hence no work is done on the ions) / no (component of) force in the direction of motion / no (component of) acceleration in the direction of motion (AW)	B1	**Allow**: 'force is right angles to the motion'
	(c)	**(i)**	$F = \frac{mv^2}{r}$ force = $\frac{1.2\times10^{-26}\times(4.0\times10^5)^2}{0.15}$ force = 1.3 × 10^{-14} (N)	C1 A1	**Note**: Answer to 3 sf is 1.28 × 10^{-14} (N)
		(ii)	$F = BQv$ 1.28 × 10^{-14} = *B* × 1.6 × 10^{-19} × 4.0 × 10^5 *B* = 0.20 (T)	C1 A1	Possible ecf from **(c)(i)** **Allow**: 1 sf answer of 0.2 (T)
		(iii)	number per second = $\frac{4.8\times10^{-9}}{1.6\times10^{-19}}$ number per second = 3.0 × 10^{10} (s^{-1})	C1 A1	**Allow**: 1 sf answer of 3 × 10^{10} (s^{-1})
	(d)		(height is smaller) hence less abundance (than lithium-7) position suggests that the ions are less massive / lighter fewer neutrons (than lithium-7)	B1 B1	**Allow**: fewer / less (than lithium-7)
			Total	**10**	