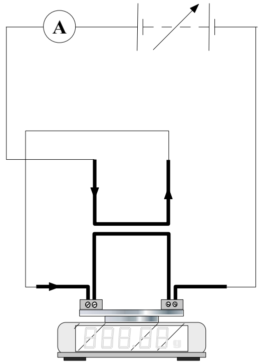
Question	Answers	Additional Comments/Guidelines	Mark
01.1	attempt to apply principle of moments either about pivot or (LH) end of ruler $_1$✓ mass = 127(.04) (g) $_2$✓ assumption is that ruler is uniform / mass evenly distributed **OR** weight acts at the centre/mid-point/middle **OR** centre of mass / gravity is at the centre/mid-point/middle $_3$✓	for $_1$✓ for evidence of moments taken expect clockwise and anticlockwise moment; for moment about pivot expect to see either 29 or 49; for use of LH end of ruler expect 30 or 50 don't insist on seeing masses in kg, distances in m or the inclusion of 9.81 or g in the working; condone g seen on one side only rounding to 127 g earns $_1$✓ and $_2$✓	3
01.2	force on wire is upwards **OR** ↑ $_1$✓ current is from **P** to **Q** **OR** rightwards **OR** (left) to (the) right **OR** →$_2$✓ states direction of force and direction of current (or $_3$✓= 0) and makes a suitably justified deduction, eg using left-hand rule **OR** LH rule **AND** B is into the page **OR** into plane of **Figure 3** **OR** ⊗$_3$✓	for $_1$✓ condone 'motion is upwards' for $_2$✓ 'towards Q' **OR** 'positive to negative' are not enough allow logically correct (using LH rule) $_3$✓ for either downwards force with correct current **AND/OR** upwards force with wrong current increased flux density below wire is acceptable alternative to LH rule	3
01.3	gradient calculated from ΔM divided by ΔI, condone read off errors of ± 1 division; minimum I step ≥ 2.0 A $_1$✓ evidence of g = 9.81 or 9.8 correctly used in working for σ or B $_2$✓ $\|B\|$ in range 1.76 × 10^{-2} to 1.87 × 10^{-2} or 1.8 × 10^{-2} (T) $_3$✓	for $_1$✓ expect (–)0.28 (g A^{-1}); do not penalise for missing – sign for $_2$✓ look for σ = their gradient × 9.81 (× 10^{-3} N) **OR** $B = \dfrac{\text{their gradient} \times 9.81\left(\times 10^{-3}\right)}{15(\times 10^{-2})}$; condone POT errors for $_3$✓CAO by correct method only; ignore – sign if provided; no limit on maximum sf	3

<table>
<tr><th>Question</th><th>Answers</th><th>Additional Comments/Guidelines</th><th>Mark</th></tr>
<tr><td>01.4</td><td>
<table>
<tr><th></th><th>Reduced</th><th>No effect</th><th>Increased</th></tr>
<tr><td>Force acting on wire</td><td></td><td>$_{1}$✓</td><td></td></tr>
<tr><td>Force acting on prism</td><td>$_{2}$✓</td><td></td><td></td></tr>
<tr><td>Gradient of graph</td><td>$_{3}$✓</td><td></td><td></td></tr>
<tr><td>Vertical intercept</td><td>$_{4}$✓</td><td></td><td></td></tr>
</table>
</td><td>
$_{1}$✓ = 1 mark
$_{2}$✓ = 1 mark
$_{3}$✓<u>and</u> $_{4}$✓= 1 mark
allow any distinguishing mark as long as only one per row
for ✓ and × in same row ignore ×
for ✓ and ✓ in same row give no mark
ignore any crossed-out response unless only distinguishing mark on row
</td><td>3</td></tr>
<tr><td>01.5</td><td>
any complete circuit connecting the power supply in Figure 6 to X and to Y that produces currents in X and in Y that travel left to right $_{1}$✓
wiring correct so that X and Y are in series (see below) $_{2}$✓


</td><td>
allow parallel circuit for $_{1}$✓ but reject use of additional power supply
if X and/or Y is/are short-circuited award no marks;
for impractical circuits eg voltmeter added in series, award no marks
ignore any current arrows added to diagram
</td><td>2</td></tr>
</table>

Question	Answers	Additional Comments/Guidelines	Mark
01.6	strategy: states that readings of M (as the dependent variable) will be measured for different values of independent variable, I or d only $_1$✓ clearly identifies the correct control variable, d or I only; condone $\frac{d}{L}$ = constant if I varied **OR** I^2L **OR** IL = constant if d varied; it must be clear how the value of the control variable is known $_2$✓ states that L will be measured or gives value eg L = 5.0 cm $_3$✓ use of g to convert M reading to F; evidence may be found in expression for k $_4$✓	for $_1$✓ condone F identified as the dependent variable or as the balance reading; reject 'measure change in mass / change in F' failure to make M or F the dependent variable cannot score $_1$✓ or $_2$✓ for $_2$✓if d is being varied and I = 5.0 A is stated, this can be taken to mean I is the control variable and the value is known for $_1$✓ and for $_3$✓ insist that M and L are being read **OR** measured **OR** recorded for $_4$✓ 'work out force' is not enough; reject 'acceleration' for g	**MAX 3**
	analysis: suggests a plot with M or F [by itself or combined with another factor] on the vertical axis and some valid manipulation of their independent variable on the horizontal axis $_5$✓ identifies correctly how k can be found using the gradient of their graph; k must be the subject of the expression given $_6$✓ **OR** if suggesting a plot with log M or log F on the vertical axis etc identifying correctly how k can be found from the graph intercept $_6$✓ **OR** suggesting a plot with M or F on the vertical axis etc and identifying correctly how k is found using the area under the line $_{56}$✓ = 1 MAX	the intention to plot M against I^2 is taken to mean that M is the dependent variable and is plotted on the vertical axis examples: plot M against I^2 will earn $_5$✓ and then $k = \frac{g \times d \times \text{gradient}}{L}$ will earn $_6$✓ or plot F against $\frac{1}{d}$ will earn $_5$✓ and then $k = \frac{\text{gradient}}{I^2 \times L}$ will earn $_6$✓ (note that when F is the dependent variable g will not appear in the expression for k)	2

Total			19

Question Number	Acceptable Answer	Additional Guidance	Mark
2(a)	An explanation that makes reference to the following points: • The potential difference creates an electric field **(1)** • An (electric) field/force does work on the electrons (increasing their kinetic energy) **Or** an (electric) field/force accelerates the electrons (increasing their velocity) **(1)**		**2**
2(b)(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**
(b)(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**
(c)(i)	• Use of $F = BQv$ and $F = EQ$ **(1)** • Algebra to show $v = \frac{E}{B}$ **(1)**		**2**
(c)(ii)	• Use of $W = QV$ *and* $E_k = \frac{1}{2}mv^2$ **(1)** • Use of $v = \frac{E}{B}$ **(1)** • $\frac{e}{m} = 1.7 \times 10^{11}\ \text{C kg}^{-1}$ **(1)**	<u>Example of calculation:</u> $v = \frac{E}{B} = \frac{1.4 \times 10^4\ \text{V m}^{-1}}{1.5 \times 10^{-3}\ \text{T}}$ $\frac{e}{m} = \frac{v^2}{2V}$ $\frac{e}{m} = \frac{(9.33 \times 10^6\ \text{m s}^{-1})^2}{2 \times 250\ \text{V}} = 1.74 \times 10^{11}\ \text{C kg}^{-1}$	**3**

(d)	• The hydrogen ion must be (about 2000 times) more massive than the electron **Or** the electron must be (about 2000 times) less massive than the hydrogen ion **(1)**	Accept "proton" for "hydrogen ion"	**1**

(Total for Question 2= 12 marks)

Section B

Q1.

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

Q2.

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

Q3.

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. 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 **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 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 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**

Q4.

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 <u>Example of calculation</u> $mv^2/r = Bqv$ $m = Bqr/v =$(0.673 T × 1.6 × 10^{-19} C × 7.40 × 10^{-2} m) / 1.20 × 10^5 m s^{-1} $m = 6.64 \times 10^{-26}$ kg	(1) (1) (1)	3
(d)	Semicircle drawn starting from same initial point <u>and</u> a smaller radius	(1)	1
	Total for question		**6**

Q5.

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

Q6.

Question Number	Answer		Mark
(a)	The <u>magnetic</u> 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)) <u>Example of calculation</u> $m = 2.7 \times 10^3 \text{ kg m}^{-3} \times 10\times 10^{-3} \text{ m} \times 10\times 10^{-3} \text{ m} \times l$ $m = 0.27 \times l$ $B = (0.27 \times l \times 9.81 \text{ m s}^{-2}) / (5 \text{ A} \times l)$ B = 0.53 T	**(1)** **(1)** **(1)**	**3**
(d)	(Magnetic field is) into paper/page	**(1)**	**1**
	Total for question		**7**

Q7.

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

Question Number	Acceptable Answer		Additional Guidance	Mark
(ii)	• Use of $E = \frac{V}{d}$ • Use of $F_E = EQ$ • Use of $F_M = BQv$ • 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) (1) (1) (1)	Do not award MP4 if incorrect ion charge used <u>Example of calculation:</u> $E = \frac{V}{d} = \frac{135\text{ V}}{2.5\times10^{-2}\text{ m}} = 5400\text{ V m}^{-1}$ $F = EQ = 5400\text{ V m}^{-1} \times 1.6\times10^{-19}\text{ C} = 8.6\times10^{-16}\text{N}$ $F = BQv = 24.5\times10^{-3}\text{T}\times1.6\times10^{-19}\text{C}\times2.2\times10^{5}\text{ms}^{-1}$ $= 8.6\times10^{-16}\text{N}$	4

Q8.

Question Number	Answer		Mark
(i)	Outward spiral from centre in either direction, minimum of two complete loops	(1)	1
(ii)	Direction consistent with diagram: Clockwise path, field out of page Anticlockwise path, field into page	(1)	1
(iii)	Electric field/p.d. between dees causes (resultant) force/acceleration Proton makes half a revolution in half a cycle of the a.c. **Or** facing dee (always) negative when proton reaches gap. **Or** whenever the proton gets to a gap, the p.d. has reversed k.e./speed (only)increases each time the proton crosses the gap **Or** work done by the field in the gap increases the k.e.	(1) (1) (1)	3
(iv)	$Bev=mv^2/r$ **Or** $r=p/Be$ $v=2\pi r/T$ $T=1/f$ (seeing $f=v/(2\pi r)$ scores MP2 & 3) **Or** $Bev=mr\omega^2$ $v=r\omega$ $\omega=2\pi f$ (seeing $v/r=2\pi f$ scores MP2 & 3)	(1) (1) (1) (1) (1) (1)	3
(v)	Use of $B=2\pi fm/e$ with mass of proton $f=1.8\times10^4$ Hz <u>Example of calculation</u> $f=eB/2\pi m$ $f=(1.6\times10^{-19}\text{ C}\times1.2\times10^{-3}\text{ T})/(2\pi\times1.67\times10^{-27}\text{kg})$ $f=1.8\times10^4$ Hz	(1) (1)	2