**M1.** (a) force due to electric field acts (vertically) downwards on electrons ✓

vertical (component) of velocity of each electron increases ✓

horizontal (component of) velocity unchanged (so angle to initial direction increases) ✓

3

(b) (i) magnetic flux density should be reversed and adjusted in strength (gradually until the beam is undeflected) ✓

1

(ii) magnetic (field) force = *Bev*

and electric (field) force = *eV / d* ✓

(Accept *Q* or *q* as symbol for *e* (charge of electron)

*Bev* = *eV/d* (for no deflection) gives *v* = *V / Bd* ✓

2

(c) (gain of) kinetic energy of electron = work done by anode pd or $\frac{1}{2} m v^2 = e V_{(A)}$ ✓

$$\frac{e}{m}\left(=\frac{v^2}{2V_{(A)}}\right)=\frac{(3.9\times10^7)^2}{2\times4200}$$ ✓

$= 1.8 \times 10^{11}$ C kg$^{-1}$.

3

**[9]**

**M2.** (a) (i) diffraction ✓

1

(ii) the electrons in the beam must have the same wavelength ✓

otherwise electrons of different wavelengths (or speeds/velocities/energies/momenta) would diffract by different amounts (for the same order) [owtte] ✓

**2**

(b) (i) (eV = ½ $m$ $\mathbf{v}^2$ gives) **either v =** $\sqrt{\frac{2eV}{m}}$

**or** $1.6 \times 10^{-19} \times 25000 = ½ \times 9.1 \times 10^{-31} \times \mathbf{v}^2$ ✓

$v = \sqrt{\frac{2 \times 1.6 \times 10^{-19} \times 25000}{9.1 \times 10^{-31}}} = 9.4 \times 10^7$ m s$^{-1}$ ✓

$p$ or $mv$ (= $9.1 \times 10^{-31} \times 9.4 \times 10^7$) = $8.5 \times 10^{-23}$ ✓

kg m s$^{-1}$ (or N s) ✓

**alternatives for first two marks**

$p$ or $mv = \sqrt{2meV}$ ✓ =

$\sqrt{2 \times 9.1 \times 10^{-31} \times 1.6 \times 10^{-19} \times 25000}$ ✓

**4**

(ii) **any two of the first three mark points**

increase of pd increases the speed (or velocity/energy/ momentum) of the electrons ✓

(so) the electron wavelength would be smaller ✓

(and) the electrons would diffract less (when they pass through the lenses) ✓

**and**

the image would show greater resolution (or be more detailed) ✓

**max 3**

**[10]**

**M3.** (a) (i) The number of electrons (per second) in the beam will increase **(1)**

because the filament will become hotter and will emit more electrons (per 2 second) **(1)**

**2**

(ii) the speed (or kinetic energy) of the electrons will increase **(1)**

because the electrons (from the filament) are attracted towards the anode with a greater acceleration (or force) **(1)**

(or gain more kinetic energy in crossing a greater pd)

**2**

(b) (i) (magnetic) force on each electron in the beam is perpendicular to velocity **(1)**

no work is done on each electron by (magnetic) force so ke (or speed) is constant **(1)**

magnitude of (magnetic) force is constant because speed is constant **(1)**

(magnetic) force is always perpendicular to velocity so is centripetal **(1)**

**max 3**

(ii) rearranging $r = \frac{mv}{Be}$ gives $\frac{e}{m} = \frac{v}{Br}$ **(1)**

$\frac{e}{m} = \frac{7.4 \times 10^6}{6.0 \times 10^{-4} \times 68 \times 10^{-3}}$ = $1.81 \times 10^{11}$ **(1)** C $kg^{-1}$ **(1)**

for correct answer to 2 sf **(1)**

**4**

(iii) specific charge for the electron ≈ 2000 × specific charge of $H^+$ **(1)**

*(accept = and accept any value between 1800 and 2000)*

which was the largest known specific charge before the specific charge of the electron was determined/measured **(1)**

(or which could be due to a much greater charge or a much smaller mass of the electron)

**2**

**[13]**

**M4.** (a) (i) emission of (conduction) electrons from a heated metal (surface) or filament/cathode **(1)**
work done on electron = *eV* **(1)**

(ii) gain of kinetic energy (or ½ $mv^2$) = $eV$; rearrange to give required equation **(1)** 3

(b) (i) work done = force × distance moved in direction of force **(1)**
force (due to magnetic field) is at right angles to the direction of motion/velocity
[or no movement in the direction of the magnetic force
∴ no work done] **(1)**
electrons do not collide with atoms **(1)**

any two **(1)(1)**

[alternative for 1st and 2nd marks
(magnetic) force has no component along direction of motion **(1)**
no acceleration along direction of motion **(1)**
or acceleration perpendicular to velocity]

$$r = \frac{mv}{Be}\left(\text{or } Bev = \frac{mv^2}{r}\right)$$ **(1)**

$$v^2 = \frac{2eV}{m}$$ **(1)**

$$\therefore r^2\left(= \frac{m^2v^2}{B^2e^2}\right) = \frac{m^2}{B^2e^2} \times \frac{2eV}{m} = \frac{2mV}{B^2e}$$ **(1)**

(iii) (rearranging the equation gives) $\frac{e}{m} = \frac{2V}{B^2r^2}$ **(1)**

$$\frac{e}{m} = \frac{2 \times 530}{(3.1 \times 10^{-3})^2 \times (25 \times 10^{-3})^2} = 1.7(6) \times 10^{11}$$ $C\,kg^{-1}$ **(1)**

**7**

**[10]**

**M5.** (a) (i) metal wire emits electrons when heated **(1)**
conduction electrons in metal gain kinetic energy when wire is heated **(1)**

(ii) electrons from wire would be absorbed/scattered/stopped by gas atoms
or collide with gas atoms and lose kinetic energy or speed **(1)**

(iii) electrons carry negative charge so anode needs to be positive (to attract them) **(1)**

**4**

(b) (i) $E_k$ (or $\frac{1}{2}mv^2$) (= work done or eV) = $1.6 \times 10^{-19} \times 2500$ **(1)**
= $4.0 \times 10^{-16}$ J **(1)**

(ii) $$v\left(= \left(\frac{2E_k}{m}\right)^{1/2}\right) = \left(\frac{2 \times 4.0 \times 10^{-16}}{9.11 \times 10^{-31}}\right)^{1/2}$$ **(1)**

= $3.0 \times 10^{7}$ m s$^{-1}$ **(1)**

(allow C.E. for value of $E_k$ from (i))

**4**

**[8]**