Mark schemes

1 (a) (i) current heats the wire **(1)**
electrons (in filament) gain (sufficient) k.e. (to leave the filament) **(1)**

(ii) electrons would collide with gas atoms / molecules **(1)**

3

(b) (i) k.e. = (eV = $1.6 \times 10^{-19} \times 3600$) = 5.8×10^{-16} (J) **(1)**

(ii) $\frac{1}{2} mv^2 = eV$ **(1)**

$v = \left(\sqrt{\frac{2eV}{m}}\right) = \sqrt{\frac{2 \times 1.6 \times 10^{-19} \times 3600}{9.1 \times 10^{-21}}}$ **(1)** = 3.6×10^7 m s^{-1} **(1)**

4

[7]

2 (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 ½mv^2) (= work done or eV) = $1.6 \times 10^{-19} \times 2500$ **(1)**
= 4.0×10^{-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)**
= 3.0×10^7 m s^{-1} **(1)**

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

4

[8]

3 (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 $\frac{1}{2} m v^2 = e V_{(A)}$ ✓

$$\frac{e}{m}\left(= \frac{v^2}{2V_{(A)}}\right) = \frac{(3.9 \times 10^7)^2}{2 \times 4200}$$ ✓

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

3

[9]

4 (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 $\frac{1}{2} mv^2) = eV$; 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]

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

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

7

[10]

5 (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* **v**² gives) **either v** = $\sqrt{\frac{2eV}{m}}$

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

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

p or *mv* (= $9.1 \times 10^{-31} \times 9.4 \times 10^7$) = 8.5×10^{-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]

6 (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)**

$\frac{e}{m} = \frac{7.4 \times 10^6}{6.0 \times 10^{-4} \times 68 \times 10^{-3}}$ = 1.81×10^{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]

7 (a) (i) filament heated by an electric current [or metal heated by nearby hot wire filament] **(1)**
(conduction) electrons in the metal gain sufficient kinetic energy to leave the metal / cathode / filament **(1)**

(ii) temperature of filament depends on the current or low current so small heating effect] **(1)**
kinetic energy of electrons depends on temperature of filament **(1)**
electrons must do work (or overcome work function) to leave metal **(1)**
electrons have insufficient (kinetic) energy to leave metal / cathode / filament (or overcome work function) if the current is too low **(1)**

4

(b) (i) E_k (= eV = 1.6 × 10^{-19} × 4200) = 6.7 × 10^{-16} (J) **(1)**

(ii) (use of $E_k = ½mv^2$ gives) $½mv^2$ = 6.7 × 10^{-16} (J) **(1)**

(allow C.E. for value of E_k)

$$v = \left(\frac{2 \times 6.7 \times 10^{-16}}{9.1 \times 10^{-31}}\right)^{1/2}$$ **(1)**

= 3.8 × 10^7 m s^{-1} **(1)**

4

[8]

8

(a) (i) $V\left(=\frac{W}{Q}\right) = \frac{6.0 \times 10^{-16}}{1.60 \times 10^{-19}}$ **(1)** = 3750 V **(1)**

(ii) heats the filament [or cathode or wire] **(1)**
to enable electrons to gain (sufficient) k.e. to leave filament
[or cause thermionic emission] **(1)**

(4)

(b) (i) electron moves towards positive plate
curve in field **(1)**
and straight beyond **(1)**

(ii) $t\left(=\frac{l}{v} = \frac{0.060}{3.6 \times 10^7}\right)$ = 1.67 ns **(1)**

(iii) $y = -\frac{1}{2}at^2$ **(1)**

$a = \frac{eV_p}{md}$ **(1)**

combine to give $\frac{e}{m} = \frac{2yd}{V_p t^2}$ **(1)** = $\frac{2 \times 12.5 \times 10^{-3} \times 25 \times 10^{-3}}{1250 \times (1.67 \times 10^{-9})^2}$ **(1)**

= 1.8 × 10^{11} C kg^{-1} **(1)**

(max 8)

[12]