M1. (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 $1.6 \times 10^{-19} \times 25000 = ½ \times 9.1 \times 10^{-31} \times \mathbf{v}^2$ ✓

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

M2. (a) electrons have a wave-like nature **(1)**
there is a (small) probability that an electron can cross the gap
[or an electron can tunnel across the gap] **(1)**
transfer is from - to + only **(1)**

3

(b) constant height mode:

gap width varies as tip scans across at constant height **(1)**
current due to electron transfer is measured **(1)**
current decreases as gap width increases (or vice versa) **(1)**
variation of current with time is used to map surface **(1)**

[or constant current mode:

current due to electron transfer is measured **(1)**
feedback used to keep current constant
by changing height of probe tip **(1)**
height of probe tip changed to keep gap width constant **(1)**
variation of height of probe tip with time
used to map surface **(1)**]

3

[6]

M3. (a) force on an electron in a magnetic field depends on speed **(1)**
electrons at different speeds would be focussed differently so image would be blurred **(1)**
[or electrons at different speeds would have different (de Broglie) wavelengths
therefore resolution would be reduced]

2

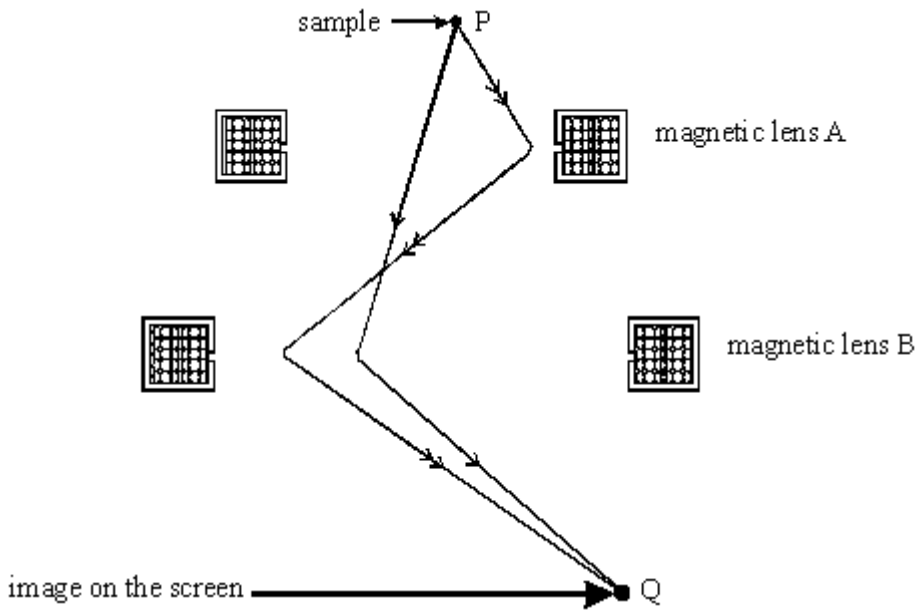
(b) increase in pd increases speed **(1)**
increase in speed/momentum/E_k causes reduction of (de Broglie) wavelength **(1)**
reduced (de Broglie) wavelength gives better resolution **(1)**

3

[5]

M4. (a) (i) straight paths outside the lenses **(1)**
correct direction of deflection on passing through A **(1)**
path through B correct for path drawn through A **(1)**

for examples
(only one required)



(ii) lens A: magnifies (or forms an intermediate image before B) **(1)**
lens B: magnifies and focuses (or forms an enlarged image on the screen) **(1)**

max 4

(b) increase of voltage causes increase of speed (of the electrons) **(1)**
hence a reduced de Broglie wavelength **(1)**
less diffraction for reduced wavelength **(1)**

better resolution if less diffraction **(1)**

max 3

[7]

M5.(a) (i) wave-like nature allows an electron (to transfer) **(1)**
a wave can penetrate thin barriers (or gaps) **(1)**
(probability of) transfer of an electron (or tunnelling effect) negligible if gap is too wide **(1)**

(ii) with a p.d., electrons transfer from - to + only **(1)**
with zero p.d., equal transfer in either direction **(1)**
[or so a current can flow for **(1)** (only)]

4

(b)

(use of $\lambda = \frac{h}{mv}$ gives) $v\ (= \frac{h}{mv}) = \frac{6.6 \times 10^{-34}}{9.1 \times 10^{-31} \times 1.0 \times 10^{-9}} = 7.3 \times 10^{+5}$ m s^{-1}

(1)

2

[6]

M6.(a) (i) $E_k = eV = 1.6 \times 10^{-19} \times 20 \times 10^3 = 3.2 \times 10^{-15}$ (J) **(1)**

$$v = \left(\frac{2E_k}{m}\right)^{1/2} = \left(\frac{2 \times 3.2 \times 10^{-15}}{9.11 \times 10^{-31}}\right)^{1/2}$$ $= 8.4 \times 10^7$ m s^{-1} **(1)**

(ii) (use of $\lambda = \frac{h}{p}$ gives) $\lambda = \frac{6.63 \times 10^{-34}}{9.11 \times 10^{-11} \times 8.4 \times 10^7}$ **(1)**

$= 8.7 \times 10^{-12}$ m **(1)**

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

[or $\lambda = \frac{h}{(2meV)}$ with **(1)** for correct substitution and

(1) for correct answer]

4

(b) image would be brighter because more electrons reach the screen per sec **(1)**
image would be more detailed because de Broglie wavelength
would be reduced **(1)**
and because speed of the electrons is increased **(1)**

max 2

[6]