Name of the Student:_____
Max. Marks : 24 Marks **Time : 24 Minutes**

Mark Schemes

Q1.

(a)

(Using $m = \frac{m_o}{\sqrt{1-\frac{v^2}{c^2}}}$ gives)

$2 = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$ or $\sqrt{1-\frac{v^2}{c^2}} = 0.5$ ✓

(Rearranging gives)

$v\ (= \sqrt{1-0.5^2}\ c) = 0.866\ c$ or 2.6×10^8 m s^{-1} ✓

Accept either answer.

2

(b) curve starts at v=0, $m = m_o$ and rises smoothly ✓

2nd mark; ecf from a if plotted correctly

curve passes through $2m_o$ at v = 0.87 c (± 0.03*c* or in 2nd half of x-scale div containing 0.87c) ✓

3rd mark; There must be visible white space between the curve and the v = c line; also, the curve must reach $7m_o$ at least.

curve is asymptotic at *v* = *c* (and does not cross or touch *v* =*c* or curve back) ✓

3

(c) Energy = mc^2 so (as *v* -> *c*) energy of particle increases as mass increases ✓

Alternative scheme for 1 mark only; mass infinite at v = c which is (physically) impossible ✓

mass -> infinity as *v* -> *c* so energy -> infinity which is (physically) impossible ✓

[OR for one mark only

force = *ma* so force increases as mass increases

Mass -> infinity as v->c so force -> infinity which is (physically) impossible ✓]

2

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Q2.

(a) (Matter) particles have wave-like properties (owtte) ✓

Accept mv or mass x velocity in place of p

and an associated wavelength = *h / p where p* is the momentum of the particles ✓.

Accept 'inversely proportional to momentum (or mv)' after 'wavelength'

2

(b) E_K (= 0.021 eV) = 0.021 × 1.60 × 10^{-19} or 3.36 × 10^{-21} J ✓

(Using E_K = ½ m v^2 gives)

For 2nd mark, allow individual values of e and V in place of E_K value in data substitution

mv =(*2 m* E_K)$^{1/2}$ = (2 × 1.67(5)×10^{-27} × 3.36 × 10^{-21})$^{1/2}$

(= 3.35 × 10^{-24} kg m s^{-1}) ✓

For 3rd mark, allow individual values of m and v in denominator

[OR

v =(2 E_K/ m)$^{1/2}$ = (2 × 3.36 × 10^{-21}/ × 1.67(5)×10^{-27})$^{1/2}$

(= 2.0 × 10^3 m s^{-1})

mv = (1.67(5)×10^{-27} × 2.0 × 10^3 (= 3.35 × 10^{-24} kg m s^{-1})]

$$\lambda = \frac{h}{mv} \left(= \frac{6.63\times10^{-34}}{3.35\times10^{-24}}\right) = 1.88\times 10^{-10}\text{ m}$$ ✓

= 2.0 × 10^{-10} m to 2 sf ✓

Alternative;

Correct use of 0.021 eV in λ= h / (2meV)$^{1/2}$ ✓

$$= \frac{6.63\times10^{-34}}{(2\times1.67(5)\times10^{-27}\times0.021\times1.6\times10^{-19})^{0.5}}$$ ✓

= 1.88 × 10^{-10} m ✓ *= 2.0 × 10^{-10} m to 2 sf* ✓

Final sf mark - need to see some valid working

4

(c) electron's momentum (p) is the same (as that of the neutron) and its mass is (much) smaller than neutron mass ✓

kinetic energy = p^2 / *2m* so kinetic energy of electron is (much) greater ✓

Alternative for 2nd mark;- (so) electron's speed is (much) greater and as kinetic energy = ½ mv^2, the electron's kinetic energy is (much) greater as v^2 is more significant than m (here)(owtte)

2nd alternative for 2nd mark using λ = h / (2 mE_K)$^{1/2}$

λ = h / (2 mE_K)$^{1/2}$ so (same λ means) mE_K (in equation) is the same for electron as for the neutron). So E_K is (much) greater as electron mass is (much) smaller than neutron mass (owtte)

Note; allow use of eV in place of E_K if eV is identified as E_K.

2

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Q3.

(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

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