Motion of Charged Particles in Magnetic Fields Assignment ANSWERS

1.

a) $F = qvB\sin\theta$

$$\therefore B = \frac{F}{qv\sin\theta} = \frac{250}{2.31\times10^{-3}\times12.2\times\sin(90°)} = 8.87\times10^{3}\text{T} \ \ (3 \text{ s.f.})$$

/2

b) Into the page

/1

2.

a) Out of page

b) No force

c) Towards bottom of page

d) No force

/4

3.

a) $a = \frac{v^2}{r}$ {centripetal acceleration}

$\therefore F = \frac{mv^2}{r}$ {a inserted into $F = ma$}

$F = qvB\sin\theta$

$= qvB$ {since $\theta = 90°$ so $\sin\theta = 1$}

$\therefore qvB = \frac{mv^2}{r}$ {equating the two equations for F}

$\therefore qB = \frac{mv}{r}$

$\therefore rqB = mv$

$\therefore r = \frac{mv}{qB}$

/3

b) $r = \frac{mv}{qB}$ and $v = \frac{2\pi r}{T}$

$\therefore r = \frac{m\frac{2\pi r}{T}}{qB}$ {inserting the equation for v}

$\therefore r = \frac{2\pi rm}{TqB}$

$\therefore T = \frac{2\pi m}{qB}$

/2

c) The period of motion is *independent* of the speed of the ion. As the particle moves further out in its orbit of the cyclotron, it spends the same amount of time in each dee.

This means that the electric field between the dees can alternate at a constant rate, and the particle will always be crossing the field at the right time to accelerate.

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d) The magnetic field in a cyclotron must be uniform and directed down through the cyclotron or up through it, such that a charged particle's motion is always at right angles to the magnetic field (so the accleration is directed towards the centre of the cyclotron).

/2

4.

a) Kinetic energy depends on mass and speed (magnitude of velocity) since K = ½ mv^2. Both of these remain constant, only the direction of motion is changed by the force on the proton due to the motion in the magnetic field.

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b) Since it has no charge it will continue through the field unaffected (velocity will remain constant).

/2

5.

a) Out of the page /1

b) The force is always directed towards the centre of the circle of motion because the particle's force is always at right angles to its motion – as its motion changes, the direction of force changes too. Since the magnetic field's force is providing a centripetal acceleration, circular motion is experienced.

/2

c) $r = \frac{mv}{qB}$

$$\therefore R = \frac{M \times 1.00\times10^{7}}{1.60\times10^{-19}\times0.330} \qquad \frac{R}{M}$$

$$\therefore \frac{R}{M} = \frac{1.00\times10^{7}}{1.60\times10^{-19}\times0.330} = 1.89\times10^{26} \text{ mkg}^{-1} \text{ (3 s.f.)}$$

/3

6.

a) $K = \frac{1}{2}mv^2$

$$r = \frac{mv}{qB} \quad \therefore v = \frac{qBr}{m}$$

$$\therefore K = \tfrac{1}{2}m\left(\frac{qBr}{m}\right)^2 \quad \{\text{inserting } v\}$$

$$\therefore K = \frac{q^2B^2r^2}{2m}$$

/2

b)

$$K = \frac{q^2B^2r^2}{2m} = \frac{\left(1.60\times10^{-19}\right)^2\times(0.80)^2\times(0.12)^2}{2\times1.67\times10^{-27}} = 7.1\times10^{-14}\text{ J (2 s.f.)}$$

/2

c) $$\therefore T = \frac{2\pi m}{qB} = \frac{2\pi\times1.67\times10^{-27}}{1.60\times10^{-19}\times0.80} = 8.2\times10^{-8}\text{ s (2 s.f.)}$$

/2

TOTAL /32