. An electron is orbiting in a circular orbit of radius r under the influence of a constant magnetic field of strength B. Assuming that Bohr's postulate regarding the quantization of angular momentum holds good for this electron, find

a. the allowed values of the radius r of the orbit.

b. the kinetic energy of the electron in orbit.

c. the potential energy of the interaction between the magnetic moment of the orbital current due to the electron moving in its orbit and the magnetic field B.

d. the total energy of the allowed energy levels.

e. the total magnetic flux due to the magnetic field B passing through the nth orbit (assume that the charge on the electron is e and the mass of the electron is m).

3. $\dfrac{mv^2}{r} = eVB$

or $\dfrac{v}{r} = \dfrac{eB}{m}$ (i)

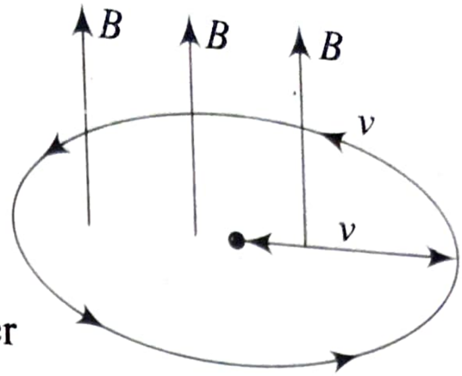

Fig. S4.2

Using Bohr quantization condition,

$$mvr = \frac{nh}{2\pi} = nh, \; n \rightarrow \text{integer}$$

or $vr = \dfrac{nh}{m}$ (ii)

a. $r^2 = \dfrac{nh}{Be}$

or $r = \sqrt{n}\sqrt{\dfrac{h}{Be}} = \sqrt{n}\, a_0$ (iii)

b. T (kinetic energy) $= \dfrac{1}{2}mv^2$

$$= \frac{m^2v^2}{2m} = \frac{1}{2m} \times \frac{n^2h^2}{r^2}$$

$$= \frac{1}{2m} \times 2hBe = \frac{1}{2}nh\left(\frac{Be}{m}\right) \quad \text{(iv)}$$

c. The time period of revolution of the electron,

$$\tau = \frac{2\pi r}{v} = \frac{2\pi m}{Be}$$

The current, $i = \dfrac{e}{\tau} = \dfrac{e^2B}{2\pi m}$ the magnetic moment, $\mu = 1$.

$$\text{Area} = \pi r^2 \times \frac{e^2B}{2\pi m} = \frac{e}{2m}\; nh$$

The potential energy of interaction

$$U = -\vec{\mu}\vec{B} = \frac{1}{2}nh\left(\frac{eB}{m}\right) \quad \text{(v)}$$

d. The total energy,

$$E = T + U = nh\left(\frac{eB}{m}\right)$$ which is quantized.

e. The total magnetic flux through the n^{th} orbit,

$$\phi = \pi r^2 B = \pi\left(\frac{nh}{Be}\right)B = \frac{nh}{2e} \quad \text{(vi)}$$