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Problem 34.21 (RHK)

A proton, a deuteron, and an alpha particle with the same kinetic energy enter a region of uniform magnetic field, moving at right angles to $\vec{B}$. *The proton moves in a circle of radius* r_H. *In terms of* r_H, *we have to find the radii of* (a) *the deuteron path and* (b) *the alpha particle path.*

Solution:

Let the mass of proton be m_H and its charge be *e*,

The mass of a deuteron is, $m_{^2H} = 2m_H$, and its charge is also *e*, as deuteron is an isotope of hydrogen.

The mass of an alpha particle is, $m_{^4He} = 4m_H$ and its charge is 2*e*.

It is given that the proton, deuteron and the alpha particle have the same kinetic energy *K*. The speed, *v*, of a particle of mass, *m*, and kinetic energy *K* is determined by the relation

$$\frac{1}{2}mv^2 = K,$$

or

$$v = \sqrt{\frac{2K}{m}}.$$

Therefore,

$$v_H = \sqrt{\frac{2K}{m_H}},$$

$$v_{^2H} = \sqrt{\frac{2K}{m_{^2H}}} = \sqrt{\frac{2K}{2m_H}} = \frac{1}{\sqrt{2}}v_H,$$

and

$$v_{^4He} = \sqrt{\frac{2K}{m_{^4He}}} = \sqrt{\frac{2K}{4m_H}} = \frac{1}{2}v_H \; .$$

The radius of the circular orbit of a charged particle of mass, m, charge, q, velocity, $\vec{v}$, in magnetic field $\vec{B}$, perpendicular to $\vec{v}$ is determined by the relation

$$m\frac{v^2}{r} = qvB,$$

or

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

We, therefore, find that in terms of

$$r_H = \frac{m_H v_H}{eB},$$

the radius of the deuteron orbit will be

$$r_{^2H} = \frac{m_{^2H} v_{^2H}}{eB} = \frac{2m_H \times v_H / \sqrt{2}}{eB} = \sqrt{2} r_H ,$$

and the radius of the alpha particle will be

$$r_{^4He} = \frac{m_{^4He} v_{^4He}}{2eB} = \frac{4m_H \times v_H / 2}{2eB} = r_H .$$