DPP – 4 (Magnetic Field & Force)

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Q 1. Lorentz force can be calculated by using the formula (where the symbols have their usual meaning)

(a) $\vec{F} = q\left(\vec{E} + (\vec{V} \cdot \vec{B})\right)$ (b) $\vec{F} = q\left(\vec{E} - (\vec{V} \times \vec{B})\right)$

(c) $\vec{F} = q\left(\vec{E} + (\vec{V} \times \vec{B})\right)$ (d) $\vec{F} = q(\vec{E} \times \vec{B} + \vec{V})$

Q 2. A proton moving with a constant velocity passes through a region of space without any change in its velocity. If $\vec{E}$ and $\vec{B}$ represent the electric and magnetic fields respectively, then this region of space may not have:

(a) $\vec{E} = 0,\ \vec{B} = 0$ (b) $\vec{E} = 0,\ \vec{B} \neq 0$

(c) $\vec{E} \neq 0,\ \vec{B} = 0$ (d) $\vec{E} \neq 0,\ \vec{B} \neq 0$

Q 3. A proton beam (mass of proton = m) passes without deviation through a region of space where there are uniform transverse mutually perpendicular electric and magnetic field with magnitude E and B. Then the beam strikes a grounded target. Find the force imparted by the beam on the target if the beam current is equal to I ?

(a) $\frac{mEI}{Be}$ (b) $\frac{meI}{BE}$ (c) $\frac{2mEI}{Be}$ (d) $\frac{2meI}{BE}$

Q 4. A non-relativistic proton beam passes without deviation through a region of space where there are uniform transverse mutually perpendicular electric and magnetic fields with E = 120 kV/m and B = 50 mT. Then the beam strikes a grounded target. Find the force which the beam acts on the target if the beam current is equal to I = 0.8 mA. (mass of proton = 1.67×10^{-27}Kg)

(a) 20 μN (b) 2 μN

(c) 15 μN (d) 32 μN

Q 5. In a region of space, both electric and magnetic field are present simultaneously in opposite direction. A positively charged particle is projected with certain speed an angle θ(<90^0) with magnetic field. It will move in a

(a) Helical path of uniform pitch

(b) Helical path of increasing pitch

(c) Helical path of decreasing pitch

(d) Helical path, whose pitch first decreases and then increases

Q 6. In a certain region uniform electric field E and magnetic field B are present in the opposite direction. At the instant t = 0, a particle of mass m carrying a charge q is given

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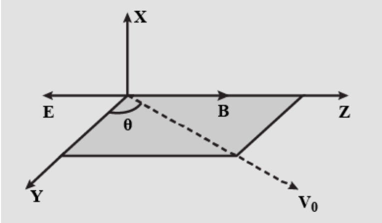
velocity V_o at an angle θ, with the y axis, in the yz plane. The time after which the speed of the particle would be minimum is equal to:



(a) $\frac{mV_0}{qE}$

(b) $\frac{mV_0 \sin\theta}{qE}$

(c) $\frac{mV_0 \cos\theta}{qE}$

(d) $\frac{\pi mV_0 \sin\theta}{qE}$

Q 7. A charged particle is at rest in the region where magnetic field and electric field are parallel. The particle will move in a

(a) Straight line (b) Circle

(c) Ellipse (d) Helical path

Q 8. A particle of mass 1×10^{-26}kg and charge $+1.6 \times 10^{-19}$C travelling with a velocity of 1.28×10^6 m/s along positive direction of x-axis enters a region in which a uniform electric field $\vec{E}$ and a uniform magnetic field $\vec{B}$ are present such that $E_x = E_y = 0, E_z = -102.4\ kV/m$ and $B_x = B_z = 0,\ B_y = 8 \times 10^{-2}\ Wb/m^2$. The particle enters this region at origin at time t=0. Then

(a) Net force acts on particle along the +ve z-direction

(b) Net force acts on the particle along –ve z-direction

(c) Net force acts on the particle is zero

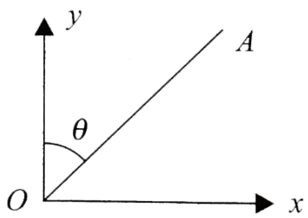
(d) Net force acts in x-z plane

Q 9. A charged particle moves undeflected in a region of crossed electric and magnetic fields. If the electric field is switched off, the particle has an initial acceleration `a`. If the magnetic field is switched off, instead of electric field, the particle will have an initial acceleration (magnitude)

(a) Equal to 0 (b) > a

(c) Equal to a (d) < a

Q 10. A uniform magnetic field B_0 and electric field E_0 exist along y and negative z axis respectively. Under the influence of these field a charge particle moves along OA undeflected. If electric field is switched off, find the pitch of helical trajectory in which the particle will move.



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(a) $\frac{2\pi m E_0}{qB_0^2 \tan\theta}$ (b) $\frac{2\pi m E_0}{qB_0^2 \cot\theta}$

(c) $\frac{4\pi m E_0}{qB_0^2 \tan\theta}$ (d) $\frac{4\pi m E_0}{qB_0^2 \cot\theta}$

Q 11. A moving charge will gain energy due to the application of

(a) Electric field (b) Magnetic field

(c) Both of these (d) None of these

Q 12. An electron (mass = 9.1×10^{-31}kg ; charge = 1.6×10^{-19}C experiences no deflection if subjected to an electric field of 3.2×10^5 V/m, and a magnetic fields of $2.0 \times 10^{-3}\ Wb/m^2$. Both the fields are normal to the path of electron and to each other. If the electric field is removed, then the electron will revolve in an orbit of radius:

(a) 45 m (b) 4.5 m

(c) 0.45 m (d) 0.045 m

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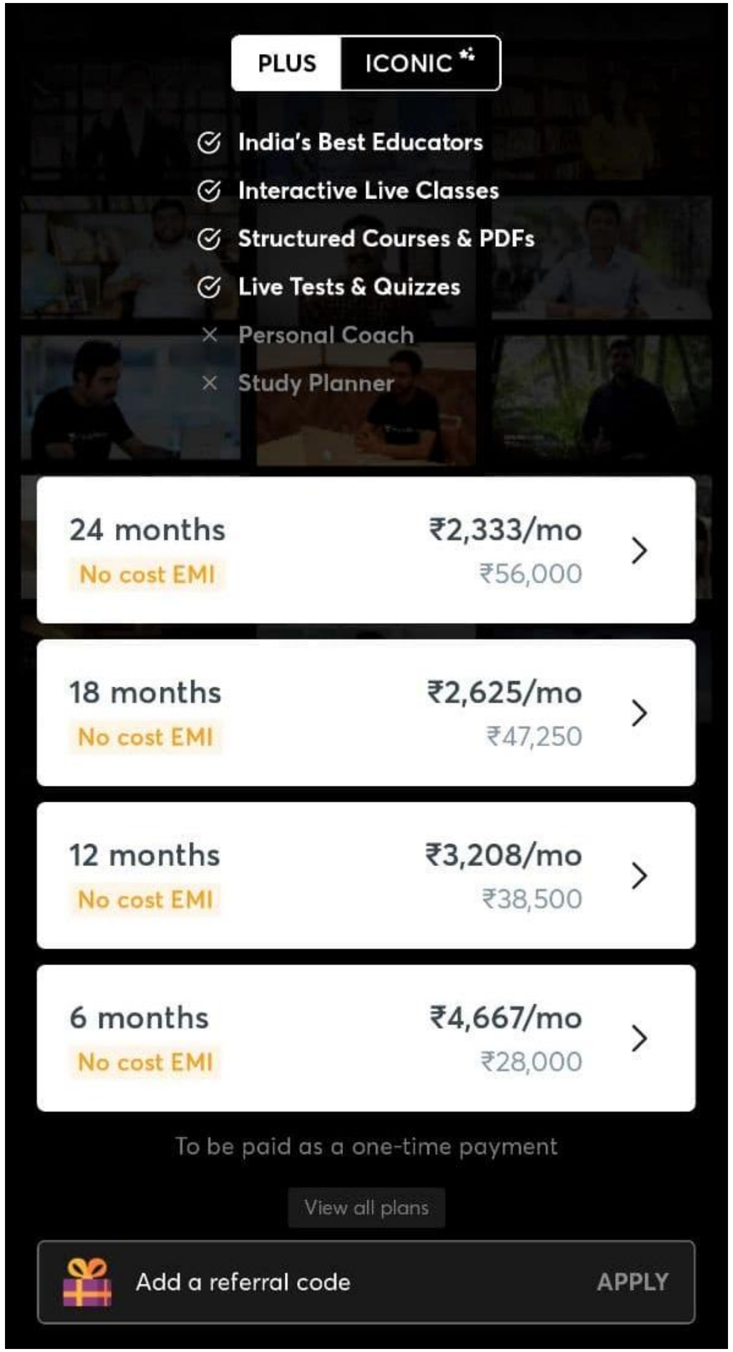
Answer Key

Q.1 c	**Q.2 c**	**Q.3 a**	**Q.4 a**	**Q.5 d**
Q.6 b	**Q.7 a**	**Q.8 c**	**Q.9 c**	**Q.10 a**
Q.11 a	**Q.12 c**			



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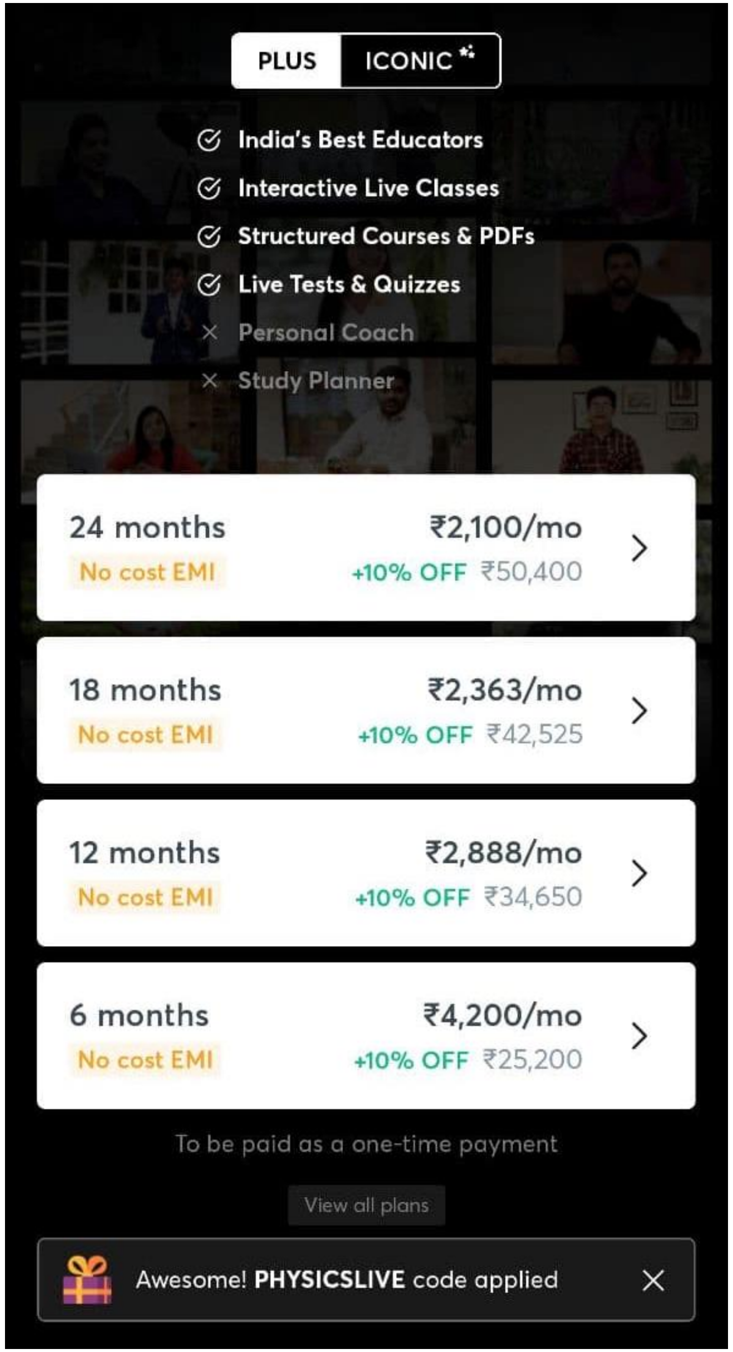

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Written Solution

DPP- 4 Lorentz Force, Motion of charge in Electric and Magnetic field

By Physicsaholics Team

Solution: 1

$$\vec{F} = \vec{F}_E + \vec{F}_B$$

$$\vec{F} = q\vec{E} + q(\vec{v} \times \vec{B})$$

$$\boxed{\vec{F} = q\left[\vec{E} + (\vec{v} \times \vec{B})\right]}$$

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Ans. c

Solution: 2

if charge moves without any change in its velocity ; Net force on charge particle

~~then~~ $\vec{F}_{net} = 0$

$$\vec{F}_{net} = q(\vec{E} + (\vec{v} \times \vec{B}))$$

to be $\vec{F}_{net} = 0$

(a) $\vec{E} = 0$; $\vec{B} = 0$

$\vec{F}_{net} = 0$ ✓

(b) $\vec{E} = 0$; $\vec{B} \neq 0$

then ; $\vec{F}_{net} = q(\vec{v} \times \vec{B}) \neq 0$ or $= 0$

when $\vec{v} \parallel \vec{B} \Rightarrow F_{net} = 0$ ✓

(c) $\vec{E} \neq 0$; $\vec{B} = 0$

then ; $\vec{F}_{net} = q\vec{E} \neq 0$

✗

(d) $\vec{E} \neq 0$ & $\vec{B} \neq 0$

then ; $\vec{F}_{net} = q(\vec{E} + (\vec{v} \times \vec{B}))$

when ; $\vec{E} = -(\vec{v} \times \vec{B})$

$\vec{F}_{net} = 0$ ✓

∴ in the case when (c) $\vec{E} \neq 0$ & $\vec{B} = 0$; $\vec{F}_{net}$ on charge cannot be zero.

Ans. c

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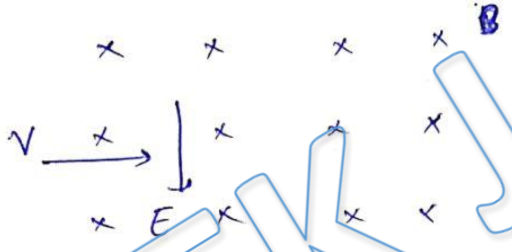
Solution: 3

Proton ; mass = m
charge = e

if proton beam passing without deviated then; $\vec{E} = -(\vec{V} \times \vec{B})$



$F_e = F_B$

$qE = qVB$

$E = VB \Rightarrow V = \frac{E}{B}$

$F = \frac{dP}{dt} = \frac{d}{dt}(mV) = V\frac{dm}{dt}$

no. of electrons striking per sec $= \frac{I}{e}$

mass of electrons striking per sec $= \frac{dm}{dt} = \left(\frac{I}{e}\right) \times m$

$\therefore F = V\left(\frac{I}{e} \times m\right)$

$F = \frac{E}{B}\frac{Im}{e}$

$$\boxed{F = \frac{mEI}{Be}}$$

Ans. a

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Solution: 4

$$F = \frac{mEI}{Be}$$

$$F = \frac{(1.67\times10^{-27})\times(120\times10^{3})\times(0.8\times10^{-3})}{50\times10^{-3}\times1.6\times10^{-19}}$$

$$F = \frac{1.67\times120\times0.8\times10^{-27-5}}{50\times1.6\times10^{-22}}$$

$$F = 2.004\times10^{-5}\,N$$

$$F \simeq 2\times10^{-5}\,N$$

$$F = 20\times10^{-6}\,N$$

$$\boxed{F = 20\ \mu N}$$

Ans. a

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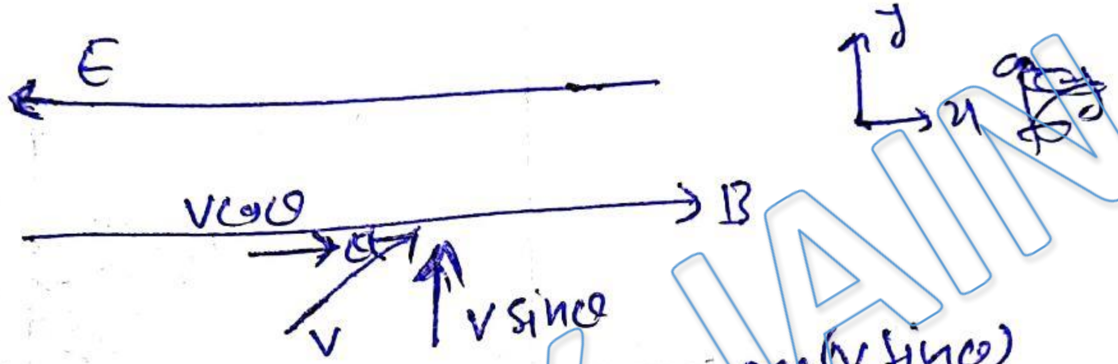
Solution: 5



radius of path $r = \frac{m(v\sin\theta)}{qB}$

Pitch $= V_x T \quad \left(T = \frac{2\pi m}{qB}\right)$

as $V_x = V\cos\theta - \left(\frac{qE}{m}\right)t$

first V_x is decreasing $\Rightarrow$ pitch will decrease

after it will start moving in backward direction, it's speed will increase in backward (−x) direction, so pitch increases

∴ pitch first decreases and then increases.

Ans. d

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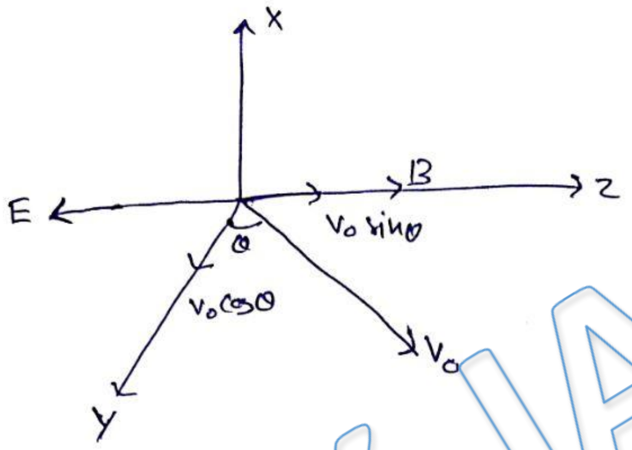
Solution: 6



it will move in a helical path of radius $r = \frac{m V_0 \cos\theta}{qB}$

and pitch $P = V_x \cdot T$ $\left(T = \frac{2\pi m}{qB}\right)$

where, $V_x = V_0 \sin\theta - \left(\frac{qE}{m}\right)t$

$\vec{u} = (V_0 \sin\theta)\hat{i} + (V_0 \cos\theta)\hat{j}$

$\vec{v} = \left[V_0 \sin\theta - \left(\frac{qE}{m}\right)t\right]\hat{i} + (V_0 \cos\theta)\hat{j}$

V will be minimum

when $V_0 \sin\theta - \left(\frac{qE}{m}\right)t = 0$

as $[V_0 \cos\theta = \text{Constant}]$

$\therefore V_0 \sin\theta - \left(\frac{qE}{m}\right)t = 0$

$\Rightarrow \boxed{t = \frac{m V_0 \sin\theta}{qE}}$

Ans. b

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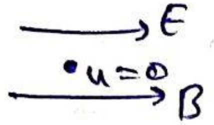
Solution: 7



$$\vec{F} = q\vec{E} + q(\vec{u} \times \vec{B})$$

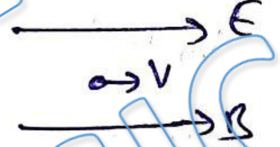
$$\vec{F} = q\vec{E}$$

initially only $\vec{F_e}$ (force due to electric field) is acting on charge as ($u=0$)

so; it will increases its speed in the direction of electric field

let, at any time 't' speed of particle $= V$ $\quad (\because V = u + at)$

$$(V = 0 + \frac{qE}{m}t)$$



here $V \parallel B$

$$\therefore \vec{F_B} = q(\vec{V} \times \vec{B}) = 0$$

$\therefore$ It will not deflect and will continue in straight line

Ans. a

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Solution: 8

$$\vec{E} = (-102.4\ \text{kV/m})(\hat{k})$$

$$\vec{v} = 1.28 \times 10^{6}\ \text{m/s}\ (\hat{i})$$

$$\vec{B} = (8 \times 10^{-2}\ \text{wb/m}^2)\ (\hat{j})$$

$$\vec{F}_{net} = q(\vec{E} + (\vec{v} \times \vec{B}))$$

$$\vec{v} \times \vec{B} = (1.28 \times 10^{6}\ \hat{i}) \times (8 \times 10^{-2}\ \hat{j})$$

$$= 10.24 \times 10^{4}\ \hat{k}$$

$$\vec{v} \times \vec{B} = 102.4 \times 10^{3}\ \hat{k}$$

as $\vec{E} = -(\vec{v} \times \vec{B})$

so, $\boxed{\vec{F}_{net} = 0}$

Ans. c

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Solution: 9

initially charge is moving un-deflected

$$\therefore \vec{E} = -(\vec{v} \times \vec{B})$$

$$|\vec{E}| = |\vec{v} \times \vec{B}|$$

(i) when $E = 0$

$$a_1 = \frac{q|(\vec{v} \times \vec{B})|}{m}$$

(ii) when $B = 0$

$$a_2 = \frac{qE}{m}$$

as $E = |\vec{v} \times \vec{B}|$

$$a_2 = \frac{q(\vec{v} \times \vec{B})}{m}$$

$$\boxed{a_2 = a_1}$$

Ans. c

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Solution: 10

$\vec{E} = -E_0\hat{k}$; $\vec{B} = B_0\hat{j}$

$\vec{V} = V_0\sin\theta\,\hat{i} + V_0\cos\theta\,\hat{j}$

for $F_{net} = 0$ along OA

$\vec{E} = -(\vec{V}\times\vec{B})$

$-E_0\hat{k} = -\left[(V_0\sin\theta\,\hat{i} + V_0\cos\theta\,\hat{j})\times(B_0\hat{j})\right]$

$+E_0\hat{k} = +\left[B_0V_0\sin\theta\,\hat{k}\right]$

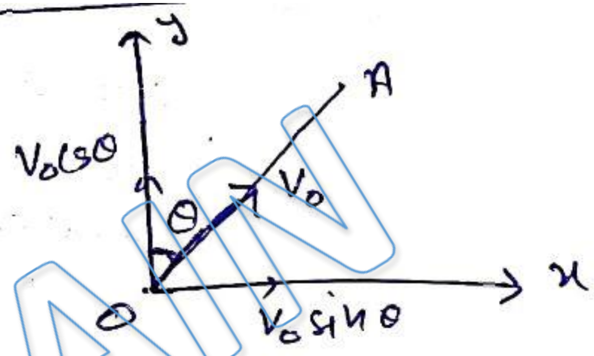
$\Rightarrow \boxed{V_0 = \dfrac{E_0}{B_0\sin\theta}}$

Now $E = 0$

then ; $\vec{B} = B_0\hat{j}$

and $\vec{V}_\perp = V_0\sin\theta\,\hat{i}$

$V_\perp = \dfrac{E_0}{B_0}\dfrac{\sin\theta}{\sin\theta} = \dfrac{E_0}{B_0}$



and $\vec{V}_{\parallel} = V_0\cos\theta\,\hat{j}$

$V_{\parallel} = \dfrac{E_0}{B_0}\dfrac{\cos\theta}{\sin\theta}$

$T = \dfrac{2\pi m}{qB_0}$

$\therefore$ pitch : P

$P = V_{\parallel}\times T = \dfrac{E_0}{B_0}\dfrac{\cos\theta}{\sin\theta}\times\dfrac{2\pi m}{qB_0}$

$P = \dfrac{2\pi m E_0\cos\theta}{qB_0^2\sin\theta}$

$\boxed{P = \dfrac{2\pi m E_0}{qB_0^2\tan\theta}}$

Ans. a

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Solution: 11

A moving charge will gain energy only by the application of electric field. In magnetic field, force acts perpendicular to velocity. The magnitude of the velocity (speed) of the charged particle does not change (only its direction changes).

Ans. a

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Solution: 12

$\vec{E}$, $\vec{B}$ & $\vec{V}$ all are per perpendicular to each other.

so; in condition of no deflection

$$E = BV$$

$$V = \frac{E}{B} = \frac{3.2 \times 10^5}{2 \times 10^{-3}} = 1.6 \times 10^8 \ m/s$$

Now when $E = 0$

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

$$= \frac{9.1 \times 10^{-31} \times 1.6 \times 10^{+8}}{1.6 \times 10^{-19} \times 2 \times 10^{-3}}$$

$$= 4.5 \times 10^{-1}$$

$$\boxed{r = 0.45 \ m}$$

Ans. c

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