PHYSICS

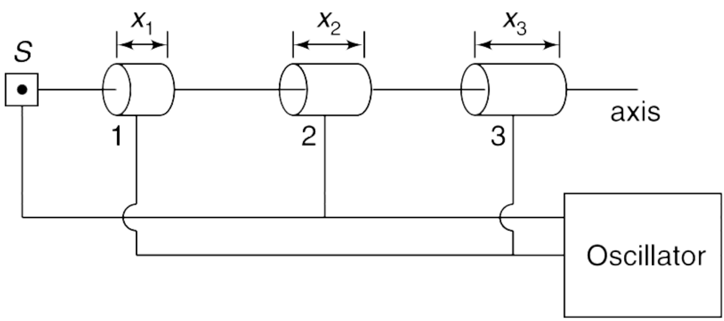
BOOKS - ARIHANT PHYSICS (HINGLISH)

MOTION OF CHARGE IN MAGNETIC FIELD

Level 1

1. A linear oscillator (Linac) is a device which accelerates charged particles in a straight line by means of oscillating electric field. S is a source of ion, emitting ions along a straight line (marked as axis) with negligible kinetic energy. The particles travel along a series of co-axial metallic cylindrical electrodes 1, 2, 3, etc. These electrodes are called drift tubes. These tubes are connected to a high frequency oscillator so that alternate tubes have opposite polarities. Thus in one half cycle if tubes 1, 3, 5... are negative then the source

(S), tube 2, 4, 6... are positive. After every half cycle the polarities reverse. Assume that there is no electric field inside the metallic tube and the charged particles maintain a straight line trajectory. Find the ratio of lengths of the tubes x1 : x2 : x3... for the device to work



Watch Video Solution

2. A particle of mass m and charge q is projected into a uniform magnetic field $\underset{B}{\longrightarrow} = -B_0\widehat{K}$ with velocity $\underset{V}{\longrightarrow} - V_0\hat{i}$ from origin. The position vector of the particle at time t is $\underset{r}{\longrightarrow}$. Find the impulse of magnetic force on the particle by the time $\underset{r}{\longrightarrow} \cdot \underset{V}{\longrightarrow}$ becomes zero for the first time.

Watch Video Solution

3. In a cyclotron the radius of dees is R and the applied magnetic field has a magnitude of B. Particles having charge q and mass m are accelerated using this cyclotron and the maximum kinetic energy that can be imparted to a particle is k.

(a) Find k in terms of R, B, q and m.

(b) If protons and alpha particles are accelerated using this cyclotron which particle (proton or alpha) will gain more kinetic energy?

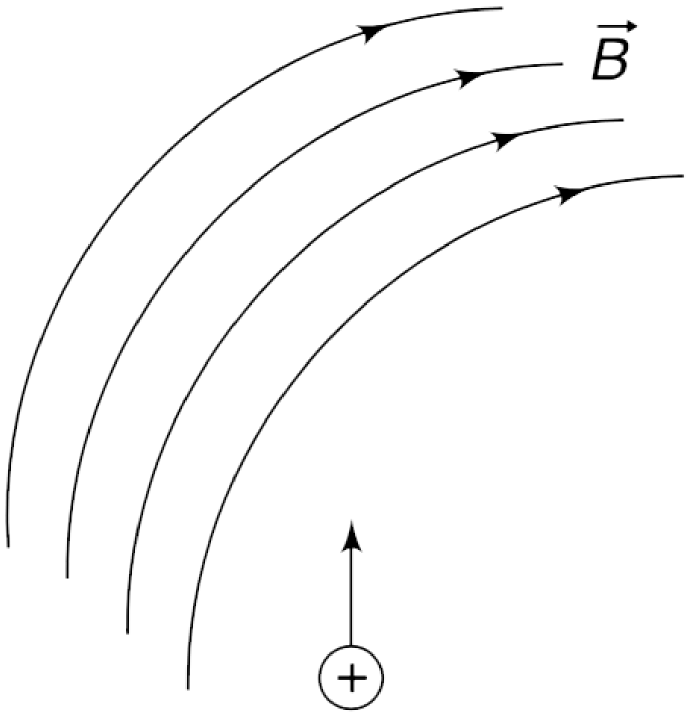
(c) Can we use a cyclotron to impart very high kinetic energy to an electron?

Watch Video Solution

4. A particle having mass m and charge q is projected at an angle of 75° to the horizontal with a speed u. A uniform electric field $E = \frac{mg}{q}$ exists in horizontal direction. Find the time after projection when the velocity of particle makes an angle of 45° with horizontal.

Watch Video Solution

5. A wide region of space has curved magnetic field lines as shown in the figure. A proton enters into the region as shown. Draw the path of the proton.

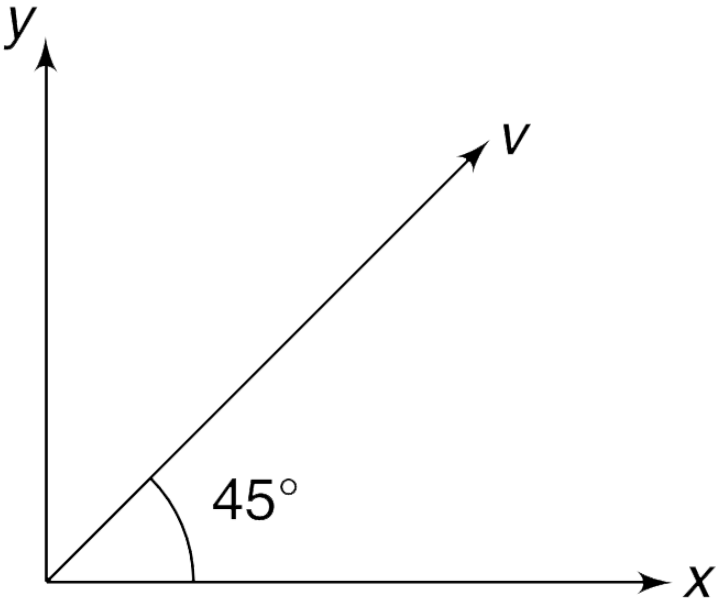


Watch Video Solution

6. A uniform electric field E exists in a region of space. A charged particle is projected in the plane of electric field making an angle 0 with the direction of field. Is it possible to make the particle move in a straight line by applying a uniform magnetic field?

Watch Video Solution

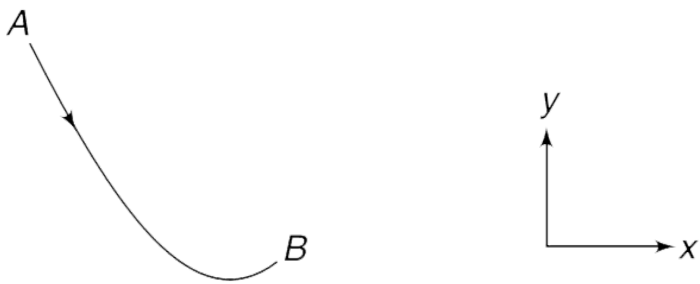
7. A particle having charge $q = 10\mu C$ is moving with a velocity of $V = 10^6 m/s$in a direction making an angle of 45º with positive x axis in the xy plane (see figure). It experiences a magnetic force along negative z direction. When the same particle is projected with a velocity $v' = 10^6 m/s$in positive z direction, it experiences a magnetic force of 10 mN along X direction. Find the direction and magnitude of the magnetic field in the region.



Watch Video Solution

8. A uniform magnetic field exists perpendicular to the plane of the figure and a

uniform electric field exists in the plane of the figure in positive y direction. A charged particle, when projected along xy plane moves along the path shown in the figure. Is the particle positively charged or negatively charged?

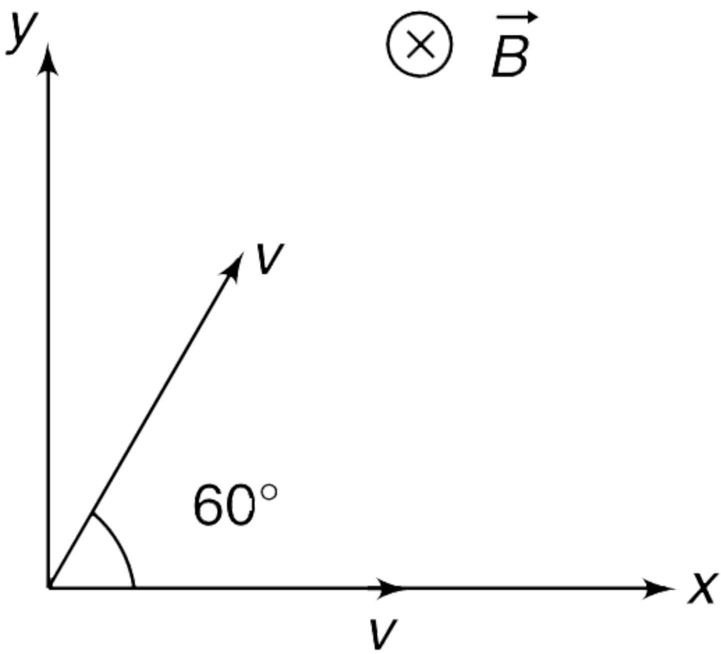


Watch Video Solution

9. Two identical charged particles are projected simul- taneously from origin in xy plane. Each particle has charge q and mass m and has been projected with velocity v as shown in the figure. There exists a uniform magnetic field B in negative z direction.

(i) Find $\overrightarrow{V_1} \cdot \overrightarrow{V_2}$ at time t where $\overrightarrow{V_1}$ and $\overrightarrow{V_2}$ are velocities of the particles at time t.

Find $\overrightarrow{V_1} \cdot \overrightarrow{V_2}$ at time $t = \frac{\pi m}{qB}$ where $\overrightarrow{r_1} \cdot \overrightarrow{V_2}$ are the position vectors of the two particles.



Watch Video Solution

10. A particle having specific charge s is projected in xy plane with a speed V. There exists a uniform magnetic field in z direction having a fixed magnitude B0. The field is made to reverse its direction after every interval of $\frac{2\pi}{\sigma B}$. Calculate the maximum separation between two positions of the particle during its course of motion.

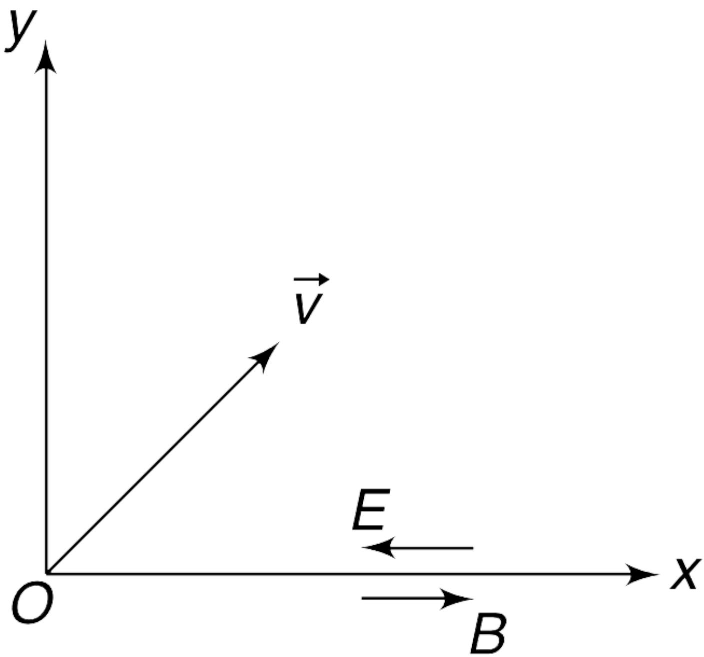
Watch Video Solution

11. A particle having mass m and charge q is projected with a velocity v making an angle q with the direction of a uniform magnetic field

B. Calculate the magnitude of change in velocity of the particle after time $t = \frac{\pi m}{2qB}$.

Watch Video Solution

12. A region has a uniform magnetic field B along positive x direction and a uniform electric field E in negative x direction. A positively charged particle is projected from origin with a velocity $\underset{V}{\longrightarrow} = V_0\hat{i} + V_0\hat{j}$. After some time the velocity of the particle was observed to be$V_0\widehat{J}$ while its x co-ordinate was positive. Write all possible values of $\frac{E}{B}$

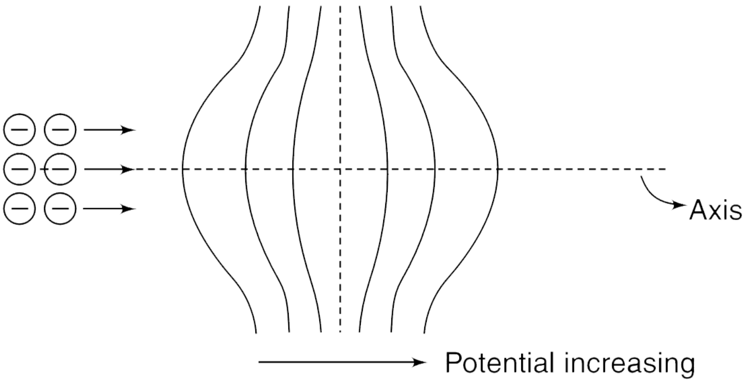


Watch Video Solution

13. A positively charged particle with specific charge σ leaves the origin with a velocity u directed along positive x direction. The entire space has a uniform electric field (E) and magnetic field (B) directed along the positive y direction. Find the angle that the velocity of the particle makes with y direction at the instant it crosses the y axis for n^{th} time.

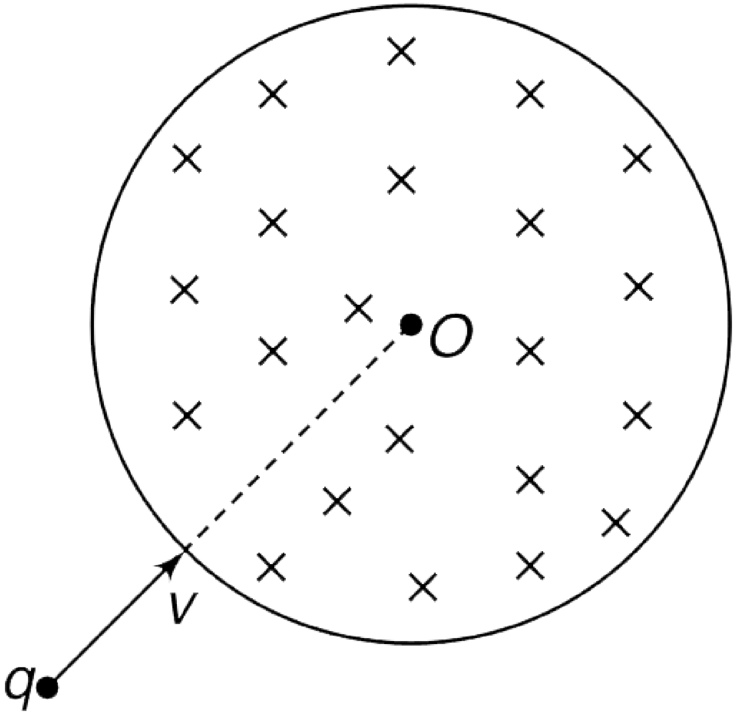
Watch Video Solution

14. Euipotential surfaces in a region of electric field are shaped as shown in the figure. The potential of field lines is increasing as one moves to right. A thin beam of electrons enters the region from left along the axis. Give qualitative arguments to show that the region will act as an electrostatic lens trying to focus the beam of electrons.



Watch Video Solution

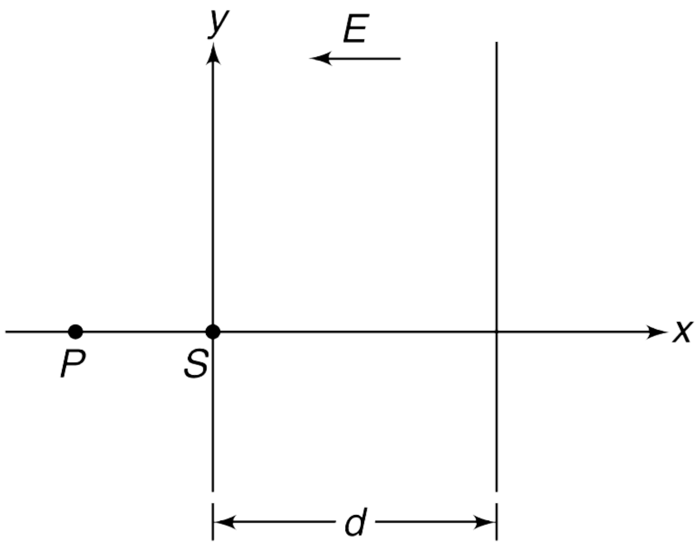
15. Figure shows a circular region of radius $R - \sqrt{3}m$ which has a uniform magnetic field $B = 0.2T$directed into the plane of the figure. A particle having mass $m = 2g,$ speed $v = 0.3m / s$ and charge $q = 1mC$ is projected along the radius of the circular region as shown in figure. Calculate the angular deviation produced in the path of the particle as it comes out of the magnetic field. Neglect any other force apart from the magnetic force.



Watch Video Solution

Level 2

1. A source(s) of electrons is kept at origin of the co- ordinate system and it shoots out electrons in xy plane with very small range of velocities. In the region x = 0 to x = d there is a uniform electric field $\overrightarrow{E} = -E\hat{i}$ which accelerates the electrons to speeds much larger than their original speed when they are ejected by the source. The electrons emerge from the field region, beyond x = d, travelling in straight lines. Prove that paths of the electrons, after they emerge out of the field, appear to be diverging from a point P having co-ordinates $(-d, 0)$.



Watch Video Solution

2. A uniform electric field, $\underset{E}{\longrightarrow} = E_0\hat{i}$ and a uniform magnetic field, $\underset{B}{\longrightarrow} = B_0\hat{i}$ exist in region $y > 0. A$ particle hav- ing positive charge q and mass m is projected from the origin with a velocity $\underset{V}{\longrightarrow} = V_0\hat{i} + V_0\widehat{J}$.

The velocity of the particle when it leaves the region of fields was found to be $-\underset{V}{\longrightarrow}$.

(i) Find the ratio $\frac{E_0}{B_0}$ in terms of v0.

(ii) Find the co-ordinates of the point where the particle leaves the fields.

(iii) Find the minimum speed of the particle during the course of the motion.

Watch Video Solution

3. A positively charged ion is released at the origin of a co-ordinate system. The entire space is filled with a uniform electric field directed along positive x axis and a uniform magnetic field directed along positive z direction.

(i) Which$(x, y \text{ or } z)$ co-ordinate of the particle will always remain zero during its course of motion?

(ii) Which $(x, y \text{ or } z)$ co-ordinate of the particle will always be negative?

(iii) It is true to say that radius of curvature of the path of the particle is decreasing while its x co-ordinate decreases?

(iv) If the ion is negatively charged will its y co-ordinate ever become negative?

Watch Video Solution

4. A particle of mass m and charge q is moving in a region where uniform electric field $\overrightarrow{E}$ and and uniform mag-netic field $\overrightarrow{B}$ are present. It is given that $\frac{\overrightarrow{E}}{\left|\overrightarrow{E}\right|} = \frac{\overrightarrow{B}}{\left|\overrightarrow{B}\right|}$. At time t = 0, velocity of the particle is $\overrightarrow{V}_0$ and

$\overrightarrow{V_0} \cdot \overrightarrow{E} = 0$. Write the velocity of the particle at time t.

Watch Video Solution

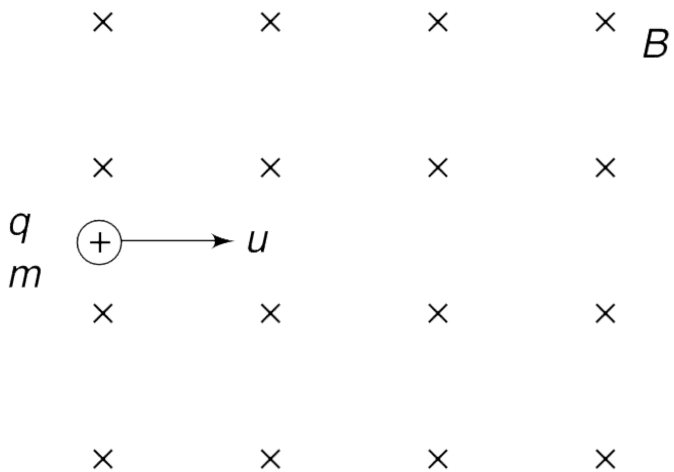
5. A particle of mass m and charge q is projected into a region having a uniform magnetic field B0. Initial velocity (v0) of the particle is perpendicular to the magnetic field. Apart from the magnetic force the particle faces a frictional force which has a magnitude of f = kv where v is instanta- neous speed and k is a positive constant.

(a) Find the radius of curvature of the path of the particle after it has travelled through a distance of $x_0 = \frac{mv_0}{2K}$.

(b) Plot the variation of radius of curvature of the path of the particle with time (t).

Watch Video Solution

6. A uniform magnetic field B0 exists perpendicular to the plane of the fig. A positively charged particle having charge q and mass m is projected with velocity u into the field. The particle moves in the plane of the fig. During its course of motion the particle is subjected to a friction force which varies with velocity as $\underset{F}{\longrightarrow} = -K\vec{V}$ where k is a positive constant and $\vec{V}$ is instantaneous velocity.



(a) What kind of path the particle will trace?

Give quali- tative argument to support your answer.

(b) Write the speed of the particle as function of time. Plot the speed–time graph.

(c) Calculate the distance travelled by the particle before it stops.

Assume no other force apart from magnetic force and the friction force.

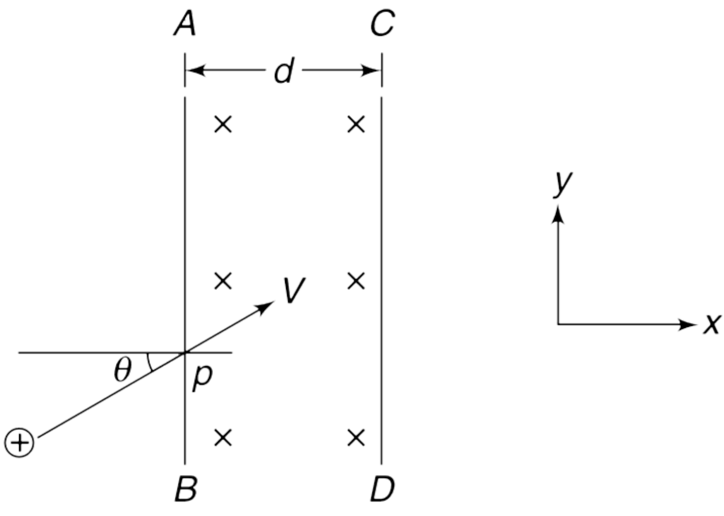
Watch Video Solution

7. AB and CD are two parallel planes perpendicular to the X axis. There is a uniform magnetic field (B) in the space between them directed in negative Z direction. Width of the region having field is d and rest of the space is hav- ing no field. A particle having mass m and charge + q enters the region with a velocity V making an angle q with the X direction as shown.

(a) Find the values of d for which the particle will come out of the magnetic field crossing CD.

(b) For $d = \left(\frac{\sqrt{2}-1}{2}\right)\frac{mv}{qB}$ and $0 = \frac{\pi}{6}$ find the angular deviation in the path of the particle.

(c) Find the deviation in path of the particle if $d = \frac{5mv}{4qB}(1 - \sin 0)$



Watch Video Solution

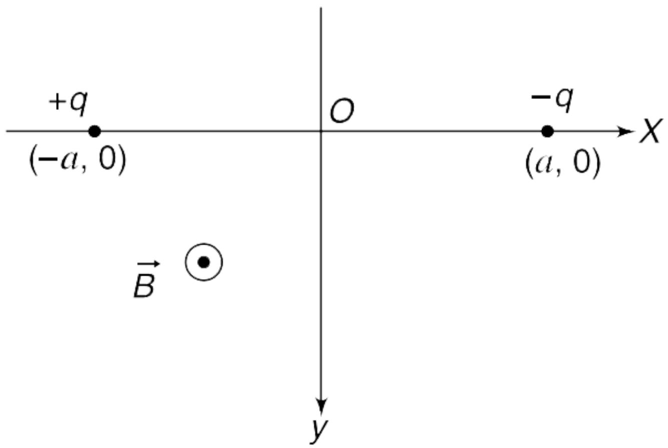
8. In the last problem, region to the right of CD is filled with a magnetic field of strength twice that in the region between AB and CD. This field exists up to a large distance and both fields are parallel in direction. For $d = \left(\frac{\sqrt{2}-1}{2}\right)\frac{mv}{qB}$ and $0 = \frac{\pi}{6}$, find the displacement of the particle (measured from its entry point P) by the time it comes out of the magnetic fields. Find the total time spend by the particle in the two fields.

Watch Video Solution

9. A particle of mass m is thrown along a horizontal surface with speed u and comes to rest after travelling a distance x_0. A uniform magnetic field B_0 is switched on in vertically downward direction and the particle is projected as before after putting a charge q on it. This time it travelled through a distance X_1 before stopping. Now the experiment is repeated with a uniform electric field E0 in addition to the magnetic field, electric field being parallel to the magnetic field. Particle having mass m and charge q is projected as earlier and found to travel a distance X_2 before stopping. Find X_1 and x_2

Watch Video Solution

10. Two particles have equal mass m and electric charge of equal magnitude (q) and opposite sign. The particles are held at rest at co-ordinates (– a, 0) and (a, 0) as shown in the figure. The particles are released simultaneously. Consider only the electrostatic force between the particles and the force applied by the external magnetic field on them.

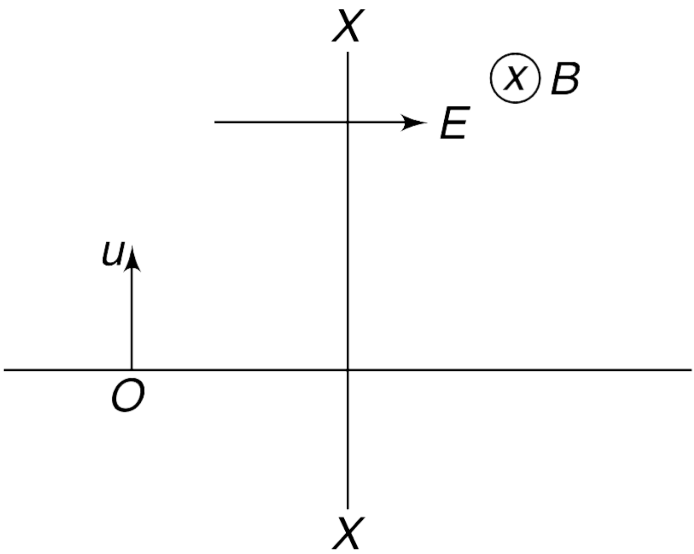


(a) Find the speed of negatively charged particle as function of its x co-ordinate.

(b) Find the y component of velocity of the negative particle as a function of its x co-ordinate.

Watch Video Solution

11. In the fig shown XX represents a vertical plane perpendicular to the plane of the fig. To the right of this plane there is a uniform horizontal magnetic field B directed into the plane of the fig. A uniform electric field E exists horizontally perpendicular to the magnetic field in entire space. A charge particle having charge q and mass m is projected vertically upward from point O. It crosses the plane XX after time T. Find the speed of projection of the particle if it was observed to move uniformly after time T. It is given that qE = mg.



Watch Video Solution

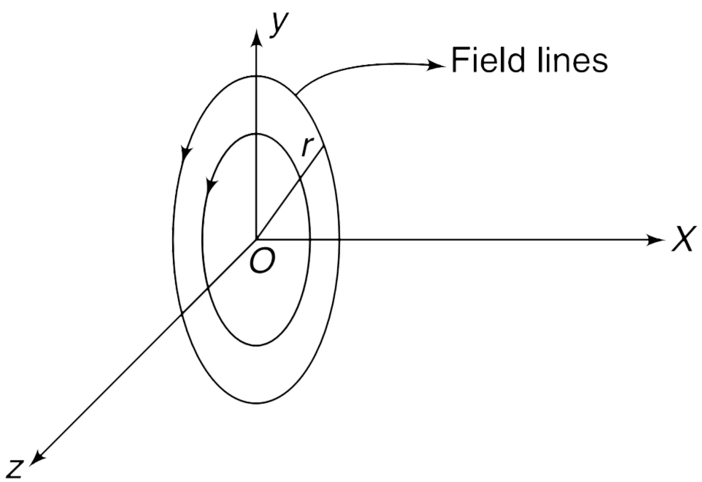
12. A particle of mass m and charge + q is projected from origin with velocity $\overrightarrow{V} = V_0 \hat{i}$ in a magnetic field $\overrightarrow{B} = -(B_0 x)\hat{k}$. Here V_0

and B_0 are positive constants of proper dimensions. Find the radius of curvature of the path of the particle when it reaches maximum positive x co-ordinate.

Watch Video Solution

13. A long uniform cylindrical beam of radius R consists of positively charged particles each of charge q, mass m and velocity V along positive x direction. The axis of the beam is the x-axis. The beam is incident on a region having magnetic field in y-z plane. The magnetic field in the region is confined to $0 \le x \le \Delta x (\Delta x \text{is small})$. The field lines are circular in yz plane as shown. The magnitude of the field is given by

$B = B_0 r$ where B_0 is a constant and r is distance from the origin.



Show that this magnetic field acts as a

converging lens for the ion beam and obtain the expression for focal length. Neglect the divergence in the beam caused due to electromagnetic interaction of the charge particles.

Watch Video Solution

Level 3

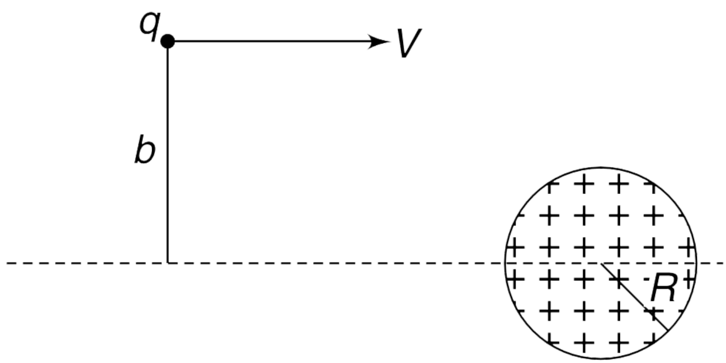
1. There is a fixed sphere of radius R having positive charge Q uniformly spread in its volume. A small particle having mass m and negative charge $(-q)$ moves with speed V when it is far away from the sphere. The impact parameter (i.e., distance between the centre of the sphere and line of initial velocity of the particle) is b. As the particle passes by the sphere, its path gets deflected due to electrostatics interaction with the sphere.

(a) Assuming that the charge on the particle does not cause any effect on distribution of charge on the sphere, calculate the minimum impact parameter b0 that allows the particle to miss the sphere. Write the value of b_0 in term of R for the case

$$\frac{1}{2}mV^2 = 100.\left(\frac{kQq}{R}\right)$$

(b) Now assume that the positively charged sphere moves with speed V through a space which is filled with small particles of mass m and charge – q. The small particles are at rest and their number density is n [i.e., number of particles per unit volume of space is n].

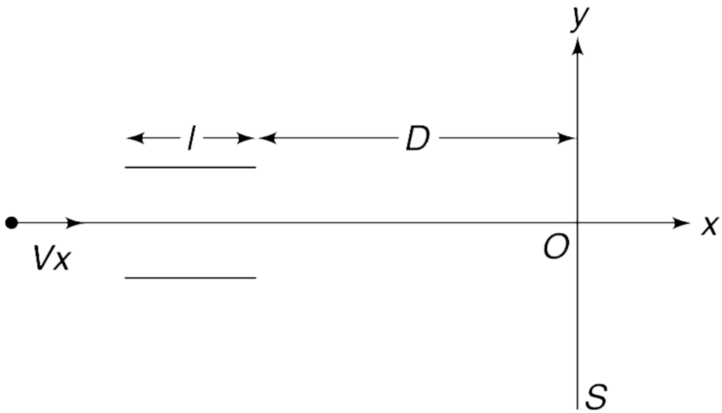
The particles hit the sphere and stick to it. Calculate the rate at which the sphere starts losing its positive charge $\frac{dQ}{dt}$. Express your answer in terms of b_0



Watch Video Solution

2. (a) A charge particle travelling along positive x direction with speed V_x enters a region of width having a uniform electric field E in positive y direction. A screen is kept, at a distance $D(> > l)$ from the region of the field, in yz plane. Find the y co-ordinate of the point where the particle strikes the screen. Charge and mass of the par- ticle is + q and m respectively.

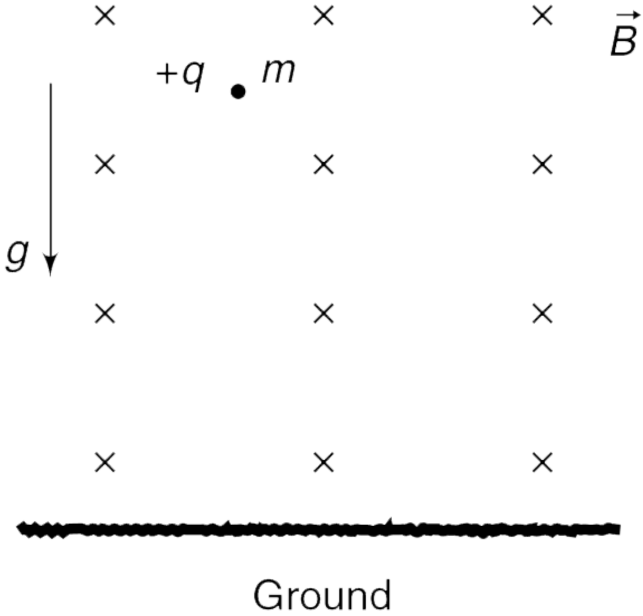
(b) The electric field in the region is replaced with a uniform magnetic field B in negative z direction. Now calculate the y co-ordinate of the point on the screen where the particle hits it. Assume deflection due to field to be small and $D > > l$.



(c) Now the field region is filled with a uniform electric (E) and magnetic field (B) both directed in positive y direction. A beam of protons and some other positive ion enters the region trav- elling along x direction. The particles hit the screen along two curved paths. Explain. Draw the two curves in yz plane and point out which one represents the protons.

Watch Video Solution

3. A particle having charge q and mass m is dropped from a large height from the ground. There exists a uniform horizontal magnetic field B in the entire space as shown in the fig. Assume that the acceleration due to gravity remains constant over the entire height involved.



(a) Argue qualitatively that the particle will touch a maximum depth and then start climbing up. It brgt (b) Find the speed of the particle at the moment it starts climbing up.

(c) At what depth from the starting point does the par- ticle starts climbing up?

4. In a region of space a uniform magnetic field exist in positive z direction and there also exists a uniform electric field along positive y direction. A particle having charge + q and mass m is released from rest at the origin. The particle moves on a curve known as cycloid. If a wheel of radius R were to roll on the X axis, a fixed point on the circumference of the wheel would generate this cycloid. Find the radius R. It is given that strength of magnetic and electric fields are B0 and E0 respectively.

Watch Video Solution