PHYSICS

BOOKS - MODERN PUBLICATION

FORCE ON A CHARGE

Example

1. A Charge of 3 C is moving with velocity $\vec{v} = \left(4\hat{i} + 3\hat{j}\right) ms^{-1}$ in a magnetic field $\vec{B} = \left(4\hat{i} + 3\hat{j}\right) Wbm^{-2}$. Find the force acting on the test charge

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2. An electron is projected with a velocity of $10^5 ms^{-1}$ at right angles to the magnetic field of 0.019 G. Caclculate the radius of the circle described by the electron.

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3. A proton is travelling with horizontal velocity $v_x = 2.5 \times 10^8 cms^{-1}$. Calculate the transverse deflection in travelling horizontal distance, x=5cm in electric field of $E_y = 400V/cm$. Mass of proton,$m = 1.6 \times 10^{-24} g$, charge on proton, $e = 1.6 \times 10^{-19} C$.

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4. A copper has 80×10^{28} per cubic metre. A copper wire of length 1m and cross-sectional area $8.0 \times 10^{-6} m^2$ carrying a current and lying at right angle to a magnetic field of strength 5xx10^-3T experiences a force of $8.0 \times 10^{-2} N$. Calculate the drift velocity of free electrons in wire.

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5. An electron is moving northwards with a velocity of $10^7 ms^{-1}$ in a magnetic field of 3 T,directed downwards.Calculate the instantaneous force on the electron. Given that charge on electron $= 1.6 \times 10^{-19} C$

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6. A long straight wire carries a current of 2A. An electron travels with a velocity of $4 \times 10^4 ms^{-1}$parallel to the wire 0.1mm from it, and in a direction opposite to the current. What force does the magnetic field of current exert on the moving electron. Charge on electron $= 1.6 \times 10^{-19} C$.

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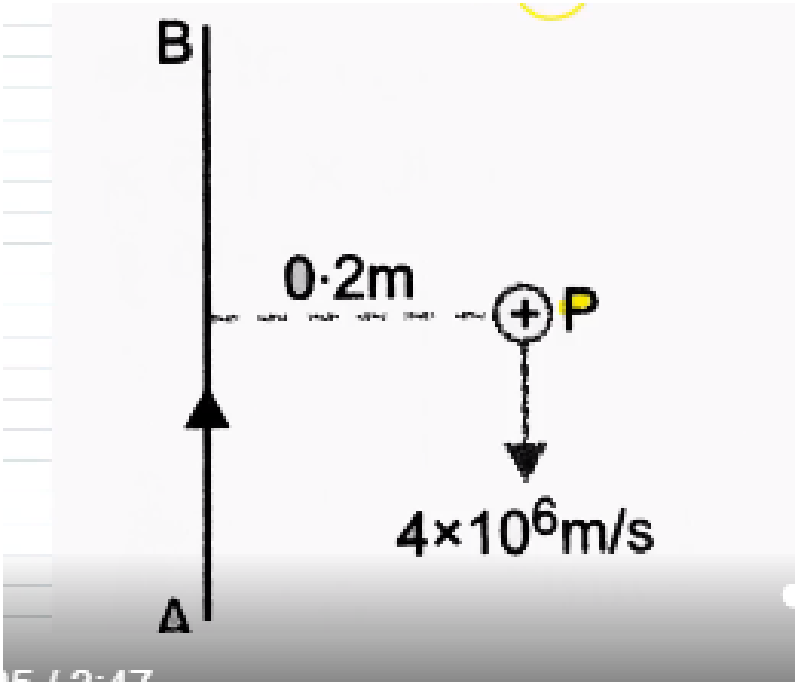
7. A long straight wire AB carries a current of 4A. A proton P travels at 4x10^6ms^-1 parallel to the wire, 0.2m from it and in a direction opposite to the current as shown in figure. Calculate the force which the magnetic field of current exerts

on the proton. Also specify the direction of the force.



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8. An electron having charge $1.6 \times 10^{-19} C$ and mass 9×10^{-31} kg is moving with $4 \times 10^{6} ms^{-1}$ speed in a magnetic field 2×10^{-1} tesla in circular orbit. The force acting on an electron and the radius of circular orbit will be:

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9. A proton and an alpha particle having the same kinetic energy are allowed to pass through a uniform magnetic field perpendicular to the direction of their motion. Compare the radii of the paths of the proton and alpha particle.

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10. A magnetic field set up using Helmholtz coils is uniform in a small region and has a magnitude of 0.75 T. In the same region, a uniform electrostatic field is maintained in a direction normal to the common axis of the coils. A narrow beam of (single species) charged particles all accelerated through 15 kV enters this region in a direction perpendicular

to both the axis of the coils and the electrostatic field. If the beam remains undeflected when the electrostatic field is $9.0 \times 10^5 Vm^{-1}$ make a simple guess as to what the beam contains. Why is the answer not unique?

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11. A cyclotron's oscillator frequency is 10MHz. What should be the operating magnetic field fro accelerating protons? If the radius of its dees is 60cm, what is the kinetic energy (in MeV) of the proton beam produced by the acceleration?

(e-

$1.60 \times 10^{-19} C, m_p = 1.67 \times 10^{-27} kg, 1MeV = 1.6 \times 10^{-13} J)$

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12. The region between x=0 and x=L is filled with uniform steady magnetic field $B_0\hat{k}$. A particle of mass m, positive charge q and velocity $v_0\hat{i}$ travels along x-axis and enters the region of the magnetic field. Neglect the gravity throughout the question.

Find the value of L if the particle emerges from the region of magnetic field with its final velocilty at an angel 30° to its initial velocity.

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13. The region between x=0 and x=L is filled with uniform steady magnetic field $B_0\hat{k}$. A particle of mass m, positive charge q and velocity $v_0\hat{i}$ travels along x-axis and enters the region of the magnetic field. Neglect the gravity throughout

the question.

Find the value of L if the particle emerges from the region of magnetic field with its final velocilty at an angel 30° to its initial velocity.

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14. A beam of protons with a velocity of $4 \times 10^5 ms^{-1}$ enters a uniform magnetic field of 0.3 T. The velocity makes an angle of 60° with the magnetic field. Find the radius of the helicla path taken by the proton beam and the pitch of the helix. Given that mass of proton $= 1.67 \times 10^{-27} kg$

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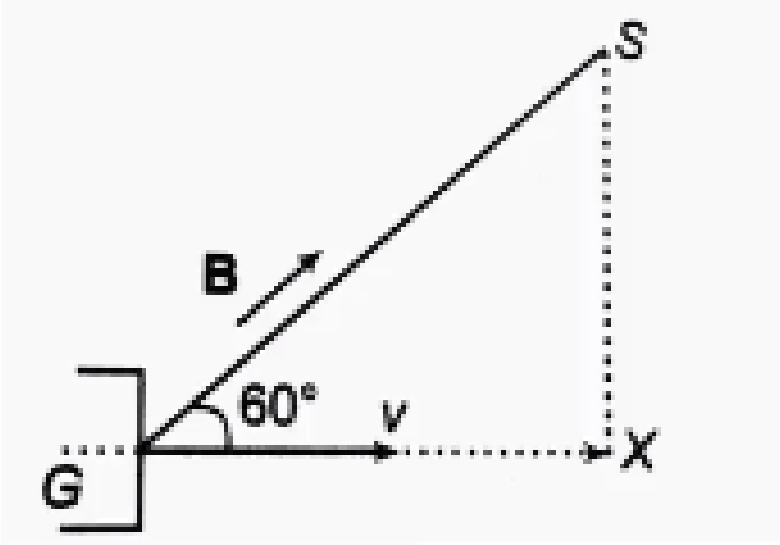
15. An electron gun G emits electons of energy 2 keV travelling in the positive x-direction. The electons are required to hit the spot S where GS=0.1 m, and the line GS makes an angle of 60° with the x-axis as shown in figure. A uniform magnetic field B parallel to GS exists in the region outside the electron gun.



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16. An electric charge enters in electric field at right angles to the direction of electric field. What is the nature of the path followed?

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17. What is the magntiude of transverse acceleration produced in the motion of the electric charge, when it passes through the electric field?

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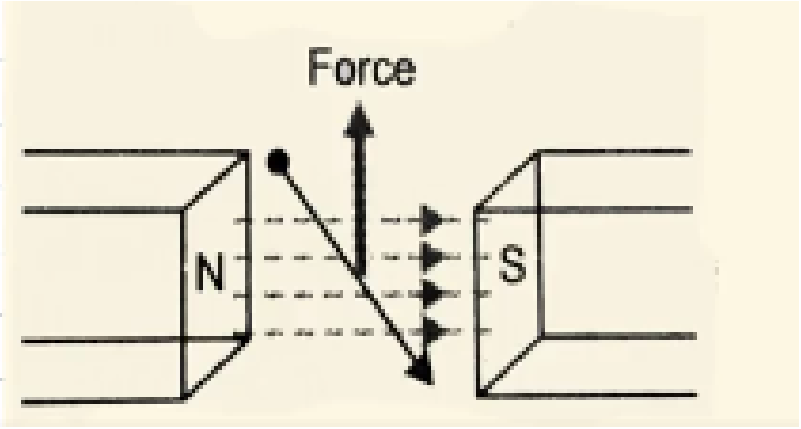
18. Charged particle enters into a uniform magnetic field and experiences an upward force as indicated in the figure what is

the charge sign on the particle?



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19. A beam of α -particles projected along +x-axis experience a force due to a magnetic field along + y-axis. What is the direction of the magnetic field?

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20. An electron beam is projected along +ve x-axis, experiences a force due to magnetic field along y-axis. What is the direction of magnetic field?

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21. What is magnetic Lorentz force?

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22. Write an expression for the force expereinced by a charged particle moving in a uniform magnetic field B.

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23. Define one Tesla.

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24. Write down the expression for Lorentz force.

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25. The force $\vec{F}$ experienced by a particle of charge q moving with velocity $\vec{v}$ in a magnetic field $\vec{B}$ is given by $\vec{F} = q\left(\vec{v} \times \vec{B}\right)$, which pair of vectors are always at right angle to each other?

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26. What is the force on a charge moving in magnetic field?

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27. An electric charge e moves with a constant velocity v parallel to the lines of force of a uniform magnetic field B, the force experienced by the charge is:

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28. Under what condition, an electron moving through a magnetic field experience maximum force ?

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29. Under what condition is the force acting on a charge moving through a uniform magnetic field is maximum?

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30. Under what condition, an electron moving through a magnetic field experience maximum force ?

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31. What is the direction of force acting on a charged particle q, moving with a velocity in a uniform magnetic field?

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32. Does an electric charge moving along the direction of magnetic field experiecne a force?

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33. Under what condition is the force acting on a charge moving through a uniform magnetic field minimum?

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34. How much force will be experienced by a cahrge in a uniform magnetic field?

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35. A stationery charge experiences no magnetic Lorentz force. Why?

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36. In a certain arrangement a proton does not get deflected while passing through a magnetic field region. Under what conditions in this possible?

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37. An electron is not defiected in passing through a certain region of space. Can we be sure that there is no magnetic field in the region ?

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38. An electron is projected in the direction of magnetic field. How will its motion be affected by the action of magnetic field?

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39. What will be the path of a charged particle moving along the direction of a uniform magnetic field?

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40. Show that the path followed by a charged particles moving in a direction perpendicular to the electric field is parabolic?

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41. A particle carrying a charge $5\mu C$ is moving with a velocity $\overrightarrow{v} = \left(4\hat{i} + 3\hat{k}\right) ms^{-1}$ in a magnetic field $\overrightarrow{B} = \left(3\hat{k} + 4\hat{i}\right) Wbm^{-2}$. Calculate the force acting on the particle.

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42. A test charge of 1.6×10^{-19} C is moving with velocity $v = \left(2\hat{i} + 3\hat{j}\right) \frac{m}{\sec}$ in magnetic field $\overrightarrow{B} = \left(2\hat{i} + 3\hat{j}\right) Wbm^{-2}$. Find the force acting on the test charge.

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43. What is the work done by a magnetic field on a moving charge?

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44. A charged particle in a plasma trapped in a magnetic bottle leaks out after a millisecond. What is the total work done by the magnetic field during the time, the particle is trapped?

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45. Two protons P and Q moving with the same speed enter magnetic field B_1 and B_2 respectively at right angles to the field directions. If$B_2$is greater than B_1 for which of the

protons P and Q the circular path in the magnetic field will have a smaller radius?

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46. An electron and a proton moving with same speed enter the same magnetic field region at right angles to the direction of the field. For which of the two particles will the radius of the circular path be smaller?

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47. Write down the expression for the Lorentz force on a charged particle.

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48. In an electric field a stationary charge (i)experience a force (ii) does not experience any force.

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49. In a field, the force experienced by a charge depends only upon the magnitude of the field and does not depend upon the velocity. Is field electric or magnetic in nature?

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50. In a field, the force experienced by a charge depends upon tis velocity and becomes zero, when it is at rest. What is the nature of the field?

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51. What is the principle of cyclotron?

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52. Does time spent by a proton inside the dee of the cyclotron depend upon the radius of the circular path

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53. Does time spent by a proton inside the dee of the cyclotron depend upon the velocity of the proton?

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54. What are the primary functions of electric field and magnetic field in a cyclotron?

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55. The frequency of a charge circulating iside the dees of a cyclotron does not depend upon the speed of the charge. Why?

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56. Can neutron be accelerated in a cyclotron? Why?

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57. What is meant by cyclotron frequency?

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58. Describe qualitatively the path of a charged particle moving in a region with uniform electrosatic and magnetic fields parallel to each other, with initial velocity parallel

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59. Describe qualitatively the path of a charged particle moving in a region with uniform electrosatic and magnetic fields parallel to each other, with initial velocity perpendicular.

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60. Describe qualitatively the path of a charged particle moving in a region with uniform electrosatic and magnetic fields parallel to each other, with initial velocity at an arbitrary angle with common direction of the fields.

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61. An electric charge enters in electric field at right angles to the direction of electric field. What is the nature of the path followed?

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62. An electron and a proton are freely situated in an electric field. Will the electric force on them be equal? Will their

acceleration be equal ? Justify your answer.

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63. An electron travelling west to east enters a chamber having u uniform electrostatic field in the north to south direction. Specify the direction in which a uniform magnetic field should be set up to prevent the electron from deflection from is straight line path.

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64. What do you understand by magnetic field ? What is the force acting on a moving charge in a uniform magnetic field ? Discuss the cases when the force is maximum and minimum.

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65. Write a relation for the force $\vec{F}$ acting on a charge carrier q moving with velocity $\vec{v}$ through the magnetic field $\vec{B}$ in vector notation. Using this relation, deduce the conditions under which this force will be

maximum?

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66. Write a relation for the force $\vec{F}$ acting on a charge carrier q moving with velocity $\vec{v}$ through the magnetic field $\vec{B}$ in vector notation. Using this relation, deduce the conditions under which this force will be

minimum?

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67. A charged particle moving with a uniform velocity $\vec{v}$ enters a region where uniform electric and magnetic fields $\vec{E}$ and $\vec{B}$ are present. It passes through the region without any change in its velocity. What can we conclude about the relative direction of $\vec{E}$, $\vec{v}$ and $\vec{B}$?

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68. A charged particle moving with a uniform velocity $\vec{v}$ enters a region where uniform electric and magnetic fields $\vec{E}$ and $\vec{B}$ are present. It passes through the region without any change in its velocity. What can we conclude about the magnitude of $\vec{E}$ and $\vec{B}$?

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69. Write the S.I. unit of magnetic field $\vec{B}$.

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70. Under what condition an electron moving through a magnetic field experiences the maximum force?

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71. What is the work done by a magnetic field on a moving charge?

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72. Describe qualitatively the path of a charged particle moving in a region with uniform electrosatic and magnetic fields parallel to each other, with initial velocity parallel

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73. What is the effect of charged particle in magnetic field and electric field acting perpendicular to each other?

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74. Discuss the motion of a charged particle when subjected to a uniform magnetic field when The direction of motion of the charged particle makes an angle with the direction of magnetic field?

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75. What will be the path of a charged particle moving along the direction of a uniform magnetic field?

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76. Answer the following questions: A magnetic field that varies in magnitude from point to point but has a constant direction (east to west) is set up in a chamber. A charged particle enters the chamber and travels undeflected along a straight path with constant speed. What can you say about the initial velocity of the particle?

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77. Why does not a charged particle moving at right angle to the direction of a magnetic field undergo any change in kinetic energy?

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78. The energy of a charged particle moving in a uniform magnetic field does not change. Why? Explain.

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79. Two identical charged particles moving with same speed enter a region of uniform magnetic field. If one of these enters normal to the field direction and the outer enters

along a direction of 30° with the field, what would be the ratio of their angular frequencies?

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80. The magnitude of velocites of two α-particle A and b, entering a uniform magnetic field perpendicularly, are in the ratio 6:1. On entering the field, they move along circular paths. Find the ratio of the radii of their paths.

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81. A beam of α- particles and of protons, of the same velocity v, enters a uniform magnetic field at right angles to the field lines. The aprticles describe

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82. An alpha-particle and a proton are moving in the plane of the paper in a region where there is a uniform magnetic field vecB directed normal to the plane of the paper. If the two particles have equal linear momenta, what will be the ratio of their trajectories in the field?

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83. Both the electric and magnetic fields can deflect a moving electron. What is the difference between these deflections?

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84. An electron beam with equivalent electric current I enters a region of crossed electric field and magnetic field B. Both the fields are uniform. It is found that the electron beam goes undeviated through the region of fields. After passing the field region, electrons hit a grounded target. How much force is exerted by the electron beam on urget? Assumem is the mass of electron and e its charge.

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85. State the principle of cyclotron.

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86. Cyclotron is not suitable for accelerating electrons.' Explain why.

Watch Video Solution

87. Cyclotron is not suitable for accelerating electrons.' Explain why.

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88. A charged particle is released from rest in a region of steady and uniform electric and magnetic fields which are parallel to each other . What will be the nature of the path followed by the charged particle?

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89. A charged particle may experience a force in an electric field and in a magnetic field . State two differnces between the forces experienced in the two types of field.

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90. An electric charge moving in a direction making an angle $\phi(\neq 90^{\circ})$ with the direction of magnetic field follows a helical path. Why?

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91. A charged particle enters an environment of a strong and non-unifrom magnetic field varying from point to point both in magnitude and direction, and comes out of it following a complicated trajectory. Would its final speed equal the initial speed if it suffered no collisions with the environment ?

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92. A cloud chamber photograph shows a pair of circular tracks emerging form a common point. The tracks have similar density of droplets, but curve in opposite directios in a plane normal to the magnetic field maintained in the chamber. If one of the ionizing particles is established to be an electron, guess the hgih energy event that took place at the common point of the track.

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Exercise

1. Show that the path followed by a charged particle inside the electric field is parabolic in nature.

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2. Show that the path followed by a charged particles moving in a direction perpendicular to the electric field is parabolic?

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3. An electron and a proton,moving parallel to each other in the same direction with equal momenta enter into a uniform magnetic field which is at right angles to their velocities.Trace their trajectories in the magnetic field.

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4. A stream of elelctrons travelling with speed vms^{-1} at right angles to a uniform magnetic field 'B' is deflected in a cirucular path of radius 'r'.

Prove that $\frac{e}{m} = \frac{v}{rB}$.

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5. A hydrogen ion of mass m and charge q travels with a speed v along a circle of radius r in a uniform magnetic field of flux density B. Obtain the expression for the magnetic force on the ion and determine its time period.

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6. A particle of mass m, with charge q moving with a uniform speed v, normal to a uniform magnetic field B, describes a circular path of radius r. Derive expression for the time period of revolution?

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7. A particle of mass m, with charge q moving with a uniform speed v, normal to a uniform magnetic field B, describes a circular path of radius r. Derive expression for the kinetic energy of the particle?

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8. Write down the expression for the Lorentz force on a charged particle.

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9. Write an expression for the force expereinced by a charged particle moving in a uniform magnetic field B.

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10. Write a relation for the force $\vec{F}$ acting on a charge carrier q moving with velocity $\vec{v}$ through the magnetic field $\vec{B}$ in vector notation. Using this relation, deduce the conditions under which this force will be

minimum?

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11. Discuss the circular motion of a charged particle under the action of a magnetic field. Hence, find expression for its time period.

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12. Deduce an expression for the frequency of revolution of a charged particle in a magnetic field and show that it is independent of velocity or energy of the particle.

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13. A charge q moving in a straight line is accelerated by a potential difference V. It enters a uniform magnetic field B perpendicular to its path. Deduce in terms of V an expression for the radius of the circular path in which they travel?

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14. A charge q moving in a straight line is accelerated by a potential difference V. It enters a uniform magnetic field B

perpendicular to its path. Deduce in terms of V an expression for the radius of the circular path in which they travel?

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15. An electron beam of velocity v moving in the plane of paper enters a region of uniform magnetic field, which is perpendicular to the plane of the paper and traels in a circular path.Does the kinetic energy of electron change during this time? Give reason.

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16. A particle with charge q moving with a velocity v in the plane of the paper enters a uniform magnetc field B, acting perpendicular to the plane of the paper. Deduce an

expression for the tie period of the charge, as it moves in a circular path in the field. Why does the kinetic energy of the charge not change, while moving in the magnetic field?

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17. A particle of mass m, with charge q moving with a uniform speed v, normal to a uniform magnetic field B, describes a circular path of radius r. Derive expression for the kinetic energy of the particle?

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18. A particle of mass m, with charge q moving with a uniform speed v, normal to a uniform magnetic field B, describes a

circular path of radius r. Derive expression for the kinetic energy of the particle?

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19. Discuss the motion of charged particle in uniform magnetic field, when its moves at an angle θ with the direction of magnetic field. Prove that its path is helical. Calculate the pitch of helical path. What will be the nature of path if $\theta = 90^\circ$

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20. Show that the frequency revolution of a charged pawrticle in a uniform magnetic field $\vec{B}\left(\vec{B} = B\hat{k}\right)$, is independent of

the speed. Which particle machine makes use of this fact? What is the frequency of the alternating electric field, used in this machine?

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21. Find the freqency of electric field to be applied between the does of a cylotron to accelerate charged particles by it.

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22. The frequency of a charge circulating iside the dees of a cyclotron does not depend upon the speed of the charge. Why?

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23. A cyclotron is used to accelerate

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24. Draw a schmatic sketch of a cyclotron. Explain, giving the essential details of tis contruction, how it is used to accelerate the charged particles.

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25. Explain, by drawing a labelled diagram, how a positively charged particle is accelerated in a cyclotron.

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26. Explain principle and working of a cyclotorn with the help of a schematic diagram. Write the expression for cyclotron frequency.

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27. A charged particle is fired at an angle θ to a uniform magnetic field directed along the x-axis. During its motion along a helical path, if the pitch of the helical path is equal to the maximum distance of the particle from the x- axis.

A. $\cos\theta=\frac{1}{\pi}$

B. $\sin\theta=\frac{1}{\pi}$

C. $\tan\theta=\frac{1}{\pi}$

D. $\tan\theta=\pi$

Answer:

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28. With the help of labelled diagram, give the principle, construction and theory of cylotron.

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29. Explain the principle, construction and working of a cyclotron with the help of a labelled diagram. State its two limitations.

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30. Explain the principle, construction and working of a cyclotron with the help of a labelled diagram. State its two limitations.

Watch Video Solution

31. Explain the principle, construction and working of a cyclotron with the help of a labelled diagram. State its two limitations.

Watch Video Solution

32. Draw a schematic diagram of a cyclotron. Explain the underlying principle and working , stating clearly the function of the electric and magnetic fields applied to the charged

particle. Deduce an expression for the period of revolution and show that it does not depend upon the speed of the charged particle.

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33. With the help of labelled diagram, give the principle, construction and theory of cylotron.

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34. What is cycotron? With the help of a labelled diagram explain construction, working and theory of it. Write its one limitation.

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35. State the principle of cyclotron.

Watch Video Solution

36. What is meant by cyclotron frequency?

Watch Video Solution

37. Explain the principle, construction and working of a cyclotron with the help of a labelled diagram. State its two limitations.

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38. Draw a schematic diagram of a cyclotron. Explain the underlying principle and working , stating clearly the function of the electric and magnetic fields applied to the charged particle. Deduce an expression for the period of revolution and show that it does not depend upon the speed of the charged particle.

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39. A cyclotron cannot be used to accelerate the:

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40. Write down the expression for the Lorentz force on a charged particle.

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41. With the help of labelled diagram, give the principle, construction and theory of cylotron.

Watch Video Solution

42. Draw a schematic diagram of a cyclotron. Explain the underlying principle and working , stating clearly the function of the electric and magnetic fields applied to the charged particle. Deduce an expression for the period of revolution and show that it does not depend upon the speed of the charged particle.

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43. Draw a schematic sketch of a cyclotron. Explain clearly the role of crossed electric and magnetic field in accelerating the charge. Hence derive the expression for the kinetic energy acquired by the particles.

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44. An a–particle and a proton are released from the centre of the cyclotron and made to accelerate. Can both be accelerated at the same cyclotron frequency? Give reason to justify your answer.

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45. An a–particle and a proton are released from the centre of the cyclotron and made to accelerate. When they are accelerated in turn, which of the two will have higher velocity at the exit slit of the dees?

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46. A cathode ray tube is operated at 2,500 V. What is the speed of electrons emitted?

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47. An electron beam is deflected by 1.76 mm in travelling a distance of 10 cm through an electric field of 1,800 Vm^{-1} acting perpendicular to its path. Find the electron chawrge to

mass ratio, if average velocity of the electrons is $3 \times 10^{7} ms^{-1}$

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48. A proton enters a magnetic field of 4 T intensity with a velocity of $2.5 \times 10^{6} ms^{-1}$ at an angle of 30° with the field. Find the magnitude of the force on the proton. Charge of the proton $= 1.602 \times 10^{-19}$ coulomb.

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49. An electron eneters a magnetic field of 5 T intensity with velocity of $5 \times 10^{6} ms^{-1}$ at an angle of 30° with the field. Find the magnitude of the force acting on the electron.

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50. A proton of velocity of $10^8 cms^{-1}$ is moving perpendicular to a uniform magnetic field of 10 kilogauss. What is the sideway force actig on the proton of charge $e = 4.8 \times 10^{10}$ e.s.u.?

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51. An electron is moving at $10^6 ms^{-1}$ in a direction parallel to a current of 5 A, flowing through an infinitely long straight wire, separated by a perpendicular distance of 10 cm in air. Calculate the magnitude of the force experiened by the electron.

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52. A 5 MeV proton moves vertically downward through a magnetic field of induction $1.5Wbm^{-2}$ pointing horizontally from south to north. Calculate the force acting on the potion, mass of proton = $1.6 \times 10^{-27}kg$.

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53. Electrons move at right angles to a magnetic field of 100 gauss and enter it with a velocity fo $2 \times 10^{10}cms^{-1}$. Find the radius of their circular path. Given $e/m = 1.7 \times 10^{7}e.m.ug^{-1}$

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54. Find the flux density of the magnetic field to cause $62.5eV$ electron to move in a circular path of radius 5 cm. Given $m = 9.1 \times 10^{-31}kg, e = 1.6 \times 10^{-19}C$

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55. An electron after bein accelerated through a potential difference of 1 00 V enters a uniform magnetic field of 0.004 T perpendiular to its direction of motion. Calculate the radius of the path describe by the electron. Given $m = 9.1 \times 10^{-31}kg$ and $e = 1.6 \times 10^{-19}C$

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56. A cyclotron is operated at an oscillator frequency of 12 MHz and has a dee radius R 50 cm. What is the magnitude of the magnetic field needed for a proton to be accelerated in the cyclotron?

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57. In a cyclotron to accelerate proton, the magnetic field is 15,000 gauss and radius of the dees is 15 cm. Calculate the energy of the proton beam and the frequency of the oscillator. Take e/m for proton to be 9,580.84 e.m.u g^{-1} and mass of proton $= 1.67 \times 10^{-24} g$

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58. In a cycltoron, magnetic induction of 1.55 Wbm^{-2} is used What must be the high voltage oscillating frequency of the cyclotron to accelerate duetrons ofo mass 3.34×10^{-27} kg and charge numerically equal to that of an electron ?

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59. In a cycltoron, magnetic induction of 1.55 Wbm^{-2} is used . If the radius of the dee is 0.50 m, what is the maximum attainable energy of the deutrons in eV?

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