PHYSICS

BOOKS - ARIHANT PHYSICS (HINGLISH)

MAGNETIC EFFECT OF CURRENT

Magnetic Effect Of Current

1. Sketch the magnetic field lines in xy plane for a pair of long parallel wires laid along z direction if-

(a) Both wires carry current in same direction.

(b) Both wire carry current in opposite directions.

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2. A long wire is along $x = 0, z = d$ and carries current in positive y direction. Another wire is along $x = y, z = 0$ and carries current in direction making acute angle with positive x direction. Both the wires have current I. Find the magnitude of magnetic induction at $(0, 0, 2d)$.

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3. Six long parallel current carrying wires are perpendicular to the plane of the fig. They pass through the vertices of a regular hexagon of side length a. All wires have same current I. Direction of current is out of the plane of the figure in all the wires except the one passing through vertex F, which has current directed into the plane of the figure. Calculate the magnetic induction field at the centre of the hexagon. Also tell the direction of the field.

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4. Two infinitely long parallel wires carry current $I_1 = 8A$ and $I_2 = 10$ A in opposite directions. The separation between the wires is $d = 0.12$ m. Find the magnitude of

magnetic field at a point P that is at a perpendicular distance $r_1 = 0.16$ m and $r_2 = 0.20$ m respectively from the wires.

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5. A wire frame is in the shape of a regular polygon of 2016 sides. Each side is of length $L = 1$ cm. If a current $I = 5.0$ A is given to the wire frame estimate the magnetic induction field (B) at the centre of the polygon. $\left[Take \pi^2 = 10.08\right]$

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6. Two coplanar concentric circular wires made of same material have radius R_1 and $R_2(=2R_1)$. The wires carry current due to identical source of emf having no internal resistance. Find the ratio of radii of cross section of the two wires if the magnetic induction field at the centre of the circle is zero.

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7. An infinitely long wire carrying current I is bent to from a L shaped wire. Let the bend be the origin and the two arms be along x and y direction (see figure). Calculate the magnitude of magnetic field at point P (in first quadrant) whose co-ordinates are (x, y).

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8. In the figure shown ABC is a circle of radius a. Arc AB and AC each have resistance R. Arc BC has resistance 2R. A current I enters at point A and leaves the circle at B and C. All straight wires are radial. Calculate the magnetic field at the centre of the circle. Each arc AB, BC and AC subtends 120° at the centre of the circle.

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9. A square loop of side length L carries a current which produces a magnetic field B_0 at the centre (O) of the loop. Now the square loop is folded into two parts with one half being perpendicular to the other (see fig). Calculate the magnitude of magnetic field at the centre O.

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10. A current I flows in a long straight wire whose cross section is in the shape of a thin quarter ring of radius R. Find the induction of

the magnetic field (B) at point O on the axis.

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11. The figure shows a long cylinder and its cross section. There are N (N is a large number) wire on the curved surface of the cylinder at uniform spacing and paral- lel to its axis. Each wire has current I and cross sectional radius of wires are small compared to radius R of the cyl- inder. Find magnetic field at a distance x from the axis of the cylinder for $(a) x < R$ (b) $x > R$

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12. A straight current carrying wire has current I directed into the plane of the fig. There is a line AB of length $2a$ at a distance a from the wire (see fig.). Find the value of line integral $\int_A^B \overrightarrow{B}.\overrightarrow{dl}$ where $\overrightarrow{B}$ represents magnetic field at a point due to current I. Will the value of integral change if a is changed? Length of line AB is always double that of a.

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13. There are two separate long cylindrical wires having uniform current density. The radius of one of the wires is twice that of the other. The fig. shows the plot of magni- tude of magnetic field intensity versus radial distance (r) from their axis. The curved parts of the two

graphs are overlapping. Find the ratio $B_1 : B_2$.

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14. A long cylindrical conductor of radius R has two cylindrical cavities of diameter R through its entire length, as shown in the figure. There is a current I through the conductor distributed uniformly in its entire cross section (apart from the cavity region). Find magnetic field at point P at a distance $r = 2R$

from the axis of the conductor (see figure).

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15. A uniform magnetic field exists in vertical direction in a region of space. A long current carrying wire (having current I) is placed horizontally in the region perpendicular to the figure. The resultant field due to superposition of the uniform field and that due to the current is represented by the field lines shown in the figure. In which direction does the current carrying wire experience the magnetic force?

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16. A conducting wire of length and mass m is placed on a horizontal surface with its length along y direction. There exists a uniform magnetic field B along positive x direction. With wire carrying a current I in positive y direc- tion, the least value of force required to move it in x and y directions are F_1 and F_2. Now the direction of current in the wire is reversed and the value of two forces becomes F'_1 and F'_2. Find the ratio of forces $F_1 : F_2 : F'_1 : F'_2$

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17. How will the conductor, carrying current I_0 rotate immediately after it is released in following three cases [consider magnetic force only]

(a) Conductor carrying current I_0 is placed symmetrically above poles of a fixed U shaped magnet (figure a).

(b) Conductor carrying current I0 is placed symmetrically at a distance from a fixed current (I_1) carrying wire (fig. (b))

(c) An insulated circular current carrying wire is held fixed in vertical plane. Conductor carrying current I_0 is in the shape of a circle of diameter nearly equal to that of the fixed insulated circle. The planes of the two circles are perpendicular to each other (fig. (c)) with xy as common diameter

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18. A straight wire AB of length a is placed at a distance a from an infinitely long straight wire as shown in the figure. Angle θ is 30°. Find the magnetic force on wire AB if it is also given a current I. Both the wires are in xy plane.

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19. A dielectric spheri- cal shell of radius R, having charge Q is rotating with angular speed w about its diameter. Calculate the magnetic dipole moment (M) of the shell. Write the ratio of M and angular momentum (L) of the rotating shell. This ratio is called gyro-magnetic ratio. Mass of shell is m.

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20. A wooden cubical block of mass m and side a is resting on a horizontal surface. A wire carrying current I, is wrapped around it in from of a square of side a. A uniform magnetic field $\overrightarrow{B} = B_0 \overrightarrow{j}$ is switched on in the region. Neglect the mass of the wire.

(a) At what distance from the x axis does normal force applied by the horizontal surface on the wooden cube act?

(b) What is the maximum value of current for which the block will not topple?

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21. A square loop of mass m and side length a lies in xy plane with its centre at origin. It carries a current I. The loop is free to rotate about x axis. A magnetic field $\overrightarrow{B} = B_0 = B_0 \overrightarrow{j}$ is switched on in the region. Calculate the angular speed acquired by the loop when it has rotated through 90°. Assume no other force on the loop apart from the magnetic force.

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22. Two long parallel wires are along z direction at $x = 0$ and $x = d$. The magnetic field along x axis has been plotted in the given figure with field (B) positive when it is in positive y direction. The co-ordinate of point R is $x = -d$. Find co-ordinate of points P and Q

shown in figure.

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23. A straight wire of length L and radius a has a cur- rent I. A particle of mass m and charge q approaches the wire moving at a velocity v in a direction anti parallel to the current. The line of motion of the particle is at a distance r from the axis of the wire. Assume that r is slightly larger than a so that the magnetic field seen by the particle is simi- lar to that caused by a long wire. Neglect end effects and assume that speed of the particle is high so that it crosses the wire quickly and suffers a small deflection θ in its path. Calculate θ.

24. A long narrow solenoid is half filled with material of relative permeability μ_1 and half filled with another material of relative permeability μ_2. The number of turns per meter length of the solenoid is n. Calculate the magnetic field (B) on the axis of the solenoid at boundary of the two material (i.e. at point P). The current in solenoid coil is I.

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25. Two identical coils having radius R and number of turns N are placed co-axially with their centres separated by a distance equal to their radius R. The two coils are given same current I in same direction. The configuration is often known as a pair of Helmholtz coil.

(i) Calculate the magnetic field (B) at a point (P) on the axis between the coils at a distance x from the centres of one of the coils.

(ii) Prove that $\frac{dB}{dx} = 0$ and $\frac{d^2B}{dx^2 = 0}$ [In fact $\frac{d^3B}{dx^3}$ is also equal to zero] at the point lying midway between the two coils. What conclusion can you draw from these results?

26. A current carrying wire is in the shape of a semicircle of radius R and has current I. M is midpoint of the arc and point P lies on extension of MC at a distance $2R$ from M. Find the magnetic field due to circular arc at point P.

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27. The figure shows three straight current carrying conductors having current I_1, I_2 and I_3 respectively. Calculate line integral of magnetic induction field $\vec{B}$ along the closed path ABCDEFA

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28. A circular coil of N turns carries a current I. Field at a distance x from centre of the loop on its axis is B. Write the value of integral $\int_{-\infty}^{\infty} B.\,dx.$

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29. In the figure shown $W1$ represent the cross section of an infinitely long wire carrying current I1 into the plane of the fig. AB is a line of length L and the wire $W1$ is symmetrically located with respect to the line. The line integral $\int_A^B \vec{B}.\vec{d}\,l.$ d l along the line from A to B is equal to – a_0 where a_0 is a positive number. Another long wire $W2$ is placed symmetrically with respect to AB (see fig) and the value of $\int_A^B \vec{B}\,.\,\vec{d}\ l$ becomes zero. Consider a line DC to the right of $W2$. The line is parallel to AB and has same length. The two wires fall on perpendicular bisector of both lines. If $\int_C^D \vec{B}\,.\,\vec{d} = 2a_0$ with both wires $W1$ and $W2$ present, calculate the ratio of current $\frac{I_2}{I_1}$ in the two wires.

30. (a) A long straight wire carries a current I into the plane of the figure. AB is a straight line in the plane of the figure subtending an angle θe point of intersection of the wire with the plane. Find (by integration) the line integral of magnetic field along the line AB.

(b) In the last problem the straight line AB is replaced with a curved line AB as shown in figure. Can you calculate the line integral of magnetic field B along this curved line? If yes, what is its value?

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31. A long straight cylindrical region of radius a curries a current along its length. The current density (J) varies from the axis to the edge of the cylindrical region according to $J = J_0\left(1 - \frac{r}{a}\right)$ Where r is distance from the axis $(0 < r < a)$

(a) Find the mean current density.

(b) Plot the variation of magnetic field (B) with distance r from the axis of the cylinder for $0 < r < a$.

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32. A student has studied the use of Ampere's law in calculation of magnetic field (B) due to a straight current carrying conductor of infinite length. Now she used similar arguments for calculation of B due to a current carrying conductor (AB) of finite length. She assumes a closed circular path (C) of radius r with the conductor along the axis (see fig.). She argues that because of symmetry the field (B) shall be tangential to C and must have same magnitude at all points on C. Therefore she writes $B = \frac{\mu_0 I}{2\pi r}$ Do you support the answer? Give reasons.

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33. There are two co-axial non conducting cylinders of radii a and $b(> a)$. Length of each cylinder is $L(> > b)$ and their curved surfaces have uniform surface charge densities $of - \sigma$ (on cylinder of radius a) and $+\sigma$ (on cylinder of radius b). The two cylinders are made to rotate with same angular velocity ω as shown in the figure. The charge distribution does not change due to rotation. Find the electric field (E) and magnetic field (B) at a point (P) which is at a distance r from the axis such that (a) $0 < r < a$ (b) $a < r < b$

(c) $r > b$. Assume that point P is close to perpendicular bisector of the length of the cylinders

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34. An infinite sheet in xy plane has a uniform surface charge density σ. The thickness of the sheet is infinitesimally small. The sheet begins to move with a velocity $\overrightarrow{v} = v\hat{i}$

(i) Find the electric field $\left(\overrightarrow{E}\right)$ and magnetic field $\left(\overrightarrow{B}\right)$ above and below the sheet.

(ii) If the velocity of the sheet is changed to $\overrightarrow{v} = v\hat{k}$, find the electric and magnetic field above and below the sheet.

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35. Consider two slabs of current shown in the figure. Both slabs have thickness b in y direction and extend up to infinity in x and z directions. The common face of the two slabs is $y = 0$ plane. The slab in the region

$0 < y < d$ has a constant current density $= J_0 \hat{k}$ and the other slab in the region $-d < y < 0$ has a constant current density $= J_0 \left(-\hat{k}\right)$.

(a) Find magnetic field at $y = 0$

(b) Plot the variation of magnetic field (B) along the y axis.

36. A current carrying conductor is in the shape of an arc of a circle of radius R subtending an angle q at the centre (C). A long current carrying wire is perpendicular to the plane of the arc and is at a distance $2R$ from the midpoint (M) of the arc on the line joining the points M and C. Current in the arc as well as straight wire is I. Find the magnetic force on the arc.

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37. Two long straight conducting wires with linear mass density λ are kept parallel to each other on a smooth horizon- tal surface. Distance between them is d and one end of each wire is connected to each other using a loose wire as shown in the figure. A capacitor is charged so as to have energy U_0 stored in it. The capacitor is connected to the ends of two wires as shown. The resistance (R) of the entire arrangement is negligible and the capacitor discharges quickly. Assume that the distance between the wires do not change during the discharging process. Calculate the speed acquired by two wires as the capacitor discharges

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38. A current carrying loop is in the shape of an equilateral triangle of side length a. Its mass is M and it is in vertical plane. There exists a uniform horizontal magnetic field B in the region shown.

(a) The loop is in equilibrium for $y_0 = \frac{\sqrt{3}}{4}$ a. Find the current in the loop.

(b) The loop is displaced slightly in its plane perpendicular to its side AB and released. Find time period of its oscillations. Neglect emf induced in the loop. Express your answer in terms of a and g.

39. A current loop consist of two straight segments (OA and OB), each of length , having an angle θ between them and a semicircle (ACB). The loop is placed on an incline plane making an angle θ with horizontal (see figure). The loop carries a current I. A uniform vertical magnetic field B is switched on. (a) Write the value of magnetic torque on the loop. (b) Tell whether the normal contact force between the incline and the loop increases or decreases when magnetic field is switched on. Assume that the loop remains stationary on the incline.

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40. A wooden disc of mass M and radius R has a single loop of wire wound on its circumference. It is mounted on a massless rod of length d. The ends of the rod are supported at its ends so that the rod is horizontal and disc is vertical. A uniform magnetic field B_0 exists in vertically upward direction. When a current I is given to the wire one end of the rod leaves the support. Find least value of I.

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41. A uniform ring of mass M and radius R carries a current I (see figure). The ring is suspended using two identical strings OA and OB. There exists a uniform horizontal magnetic field B_0 parallel to the diameter AB of the ring. Calculate tension in the two strings. [Given $\theta = 60^\circ$]

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42. In a two dimensional $x - y$ plane, the magnetic field lines are circular, centred at the origin. The magnitude of the field is inversely proportional to distance from the origin and field at any point P has magnitude given by $B = \dfrac{k}{r}$, where k is a positive constant. A wire carrying current I is laid in xy plane with its ends at point A $(x_1, y_1$ and point B $(x_2), y_2)$. Find force on the wire.

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43. A straight current carrying wire has its one end attached to an infinity conducting sheet (shown as a circle in the figure). The other end of the wire goes to infinity and the wire is perpendicular to the sheet. The current spreads uniformly on the surface of the sheet. Calculate the magnitude of magnetic induction field at a point P at a distance d from the straight wire. Current in the wire is I.

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44. A wire carrying current I is laid in shape of a curve which is represented in plane polar co-ordinate system as $r = b + \frac{c}{\pi}\theta$ for $0 < \theta < \frac{\pi}{2}$ Here b and c are positive constants. θ is the angle measured with respect to positive x direction in anticlockwise sense and r is distance from origin (see figure). Calculate the magnetic field at the origin due to the wire.

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45. A light freely deformable conducting wire with insulation has its two ends (A and C) fixed to the ceiling. The two vertical parts of the wire are close to each other. A load of mass m is attached to the middle of the wire. The entire region has a uniform horizontal magnetic field B directed out of the plane of the figure. Prove that the two parts of the wire take the shape of circular arcs when a current I is passed through the wire. Neglect the magnetic interaction between the two parts of the wire.

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