***Code: Phy/ EM-4/MEC/001***

# Electromagnetism: Magnetic Effect of Electric Current

## Typical Questions (Set-1)

**No of Questions: 55** **Time Allotted: 10- Hours (in 3 parts)**

**All questions are compulsory**

**[Note: a.** Figures are conceptual only and not to the scale**]**

**[b.** Solutions may be taken up in Three parts as, Part I: 1 to 30 of Three Hours;**]**

**[** Part II: 31 to 55 of Three Hours**]**

**Important Note: 1.** Capacitors are implementation aspect of concepts of electrostatics. The capacitors are integral part of any electrical system or circuit and any kind of application of electricity.

**2.** A student at a stage to refer to these questions and illustrations is expected to have attained a reasonable understanding of concepts and visualization. Moreover, forward journey involves integration of concepts on a wider canvas. Therefore, illustrations have been made a bit crisp. This would help students to harness their understanding at a faster rate.

**3.** Avoid fatigue due to long and continuous sitting in solving such problems. Take a reasonable break to refresh before taking next part. Gradually, capability to withstand fatigue will grow to enable you to take up bigger challenges.

**4.** Electromagnetism is a subject so closely intertwined that discretization of problems on Magnetism and Magnetic Effect of Electric Current fails as one goes ahead. This is brought out in footnote of illustration of such problems.

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| Q-1 | An electric current flows in a wire from north to south. What will be the direction of magnetic field due to this wire at a point –<br>(a) East of the wire<br>(b) West of wire<br>(c) Vertically above the wire<br>(d) Vertically below the wire |
| Q-2 | The magnetic field due to a long straight wire has been derived in terms of $\mu_0$, $i$ and $d$. Express this in terms of $\varepsilon_0$, $c$, $i$ and $d$. |
| Q-3 | You are facing a circular wire carrying an electric current. The current is clockwise as seen by you. Is the field at the center coming towards you or going away from you? |
| Q-4 | In Ampere's Law $\oint \vec{B}.d\vec{l} = \mu_0 i$, the current outside the curve is not included on the right hand side. Does it mean that the magnetic field $B$ calculated by using Ampere's Law, gives the contribution of only the currents crossing the area bound by the curve? |
| Q-5 | The magnetic field inside a tightly wound long solenoid is $B = \mu_0 n i$. It suggests that the field does not depend on the total length of the solenoid, and hence if we add more loops at the end of a solenoid the field should not increase. Explain quantitatively why the extra-added loops do not have a considerable effect on the field inside the solenoid. |
| Q-6 | A long straight wire carries current. Is Ampere's law valid for a loop that does not enclose the wire, or that encloses the wire but is not regular? |

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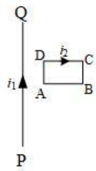
| Q-7 | A straight wire carrying an electric current is placed along the axis of a uniformly charged ring. Will there be a magnetic force on the wire if the ring starts rotating about the wire? If yes, in which direction? |
| Q-8 | Two wires carrying equal currents $i$ each, are placed perpendicular to each other, just avoiding a contact. If one wire is held fixed and the other is free to move under magnetic forces, what kind of motion will result? |
| Q-9 | Two proton beams going in the same direction repel each other whereas two wires carrying currents in the same direction attract each other. Explain. |
| Q-10 | In order to have a current in a long wire, it should be connected to a battery or some such device. Can we obtain magnetic field due to a straight long wire by using Ampere's Law without mentioning this other part of the circuit? |
| Q-11 | Quite often, connecting wires carrying currents in opposite directions are twisted together in using electrical appliances. Explain how it avoids unwanted magnetic field. |
| Q-12 | Two current carrying wires may attract each other. In absence of other forces, the wires will move towards each other increasing the kinetic energy. Does it contradicts the fact that magnetic force cannot do any work and hence cannot increase kinetic energy? |
| Q-13 | A vertical wire carries a current in upward direction. An electrons beam sent horizontally towards the wire will be deflected.<br>(a) Towards right (b) Towards left (c) Upwards (d) Downwards |
| Q-14 | A current carrying, straight wire is kept along the axis of a circular loop carrying a current. The straight wire –<br>(a) Will exert an inward force on the circular loop<br>(b) Will exert an upward force on the circular loop<br>(c) Will not exert any force on a circular loop<br>(d) Will exert a force on a circular loop parallel to itself |
| Q-15 | A proton beam is going from north to south and an electron is going from south to north. Neglecting the earth's magnetic field, the electron beam will be deflected –<br>(a) Towards the proton beam (b) Away from the proton beam (c) Upwards (d) Downwards |
| Q-16 | A circular loop is kept in that vertical plane which contains the north-south direction. It carries a current that is towards north at the topmost point. Let A be a point on the axis of the circle to the east of it and B a point on this axis to the west of it. The magnetic field due to the loop –<br>(a) is towards east at A and towards west at B<br>(b) is towards west at A and towards east at B<br>(c) is towards east at both A and B<br>(d) is towards west at both A and B |
| Q-17 | Consider the situation shown in the figure. The straight wire is fixed but the loop can move under magnetic force. The loop will –<br>(a) Remain stationary (b) Move towards the wire (c) Move away from the wire (d) Rotate about the wire<br> |
| Q-18 | A charged particle is moved along a magnetic field line. The magnetic force on the particle is –<br>(a) Along its velocity (b) Opposite to its velocity (c) Perpendicular to its velocity (d) Zero |
| Q-19 | A moving charge produces –<br>(a) Electric field only (b) Magnetic field only (c) Both of them (d) None of them |
| Q-20 | A particle is projected in a plane perpendicular to a uniform magnetic field. The area bound by the path described by the particle is proportional to – |

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| | (a) The velocity (b) The momentum (c) The kinetic energy (d) None of these |
| Q-21 | Two particles X and Y having equal charge, after being accelerated through the same potential difference enter a region of uniform magnetic field and describe circular path of radii $R_x$ and $R_y$ respectively. The ratio of the mass of X and that of Y is – <br> (a) $\left(\frac{R_x}{R_y}\right)^{\frac{1}{2}}$ (b) $\frac{R_y}{R_y}$ (c) $\left(\frac{R_x}{R_y}\right)^2$ (d) $R_x R_y$ |
| Q-22 | Two parallel wire carry currents of 20 A and 40 A in opposite directions. Another wire carrying a current antiparallel to 20 A is placed midway between the two wires. The magnetic force on it will be – <br> (a) Towards 20 A (b) Towards 40 A (c) Zero (d) Perpendicular to the plane of the currents |
| Q-23 | Two parallel long wires carry currents $i_1$ and $i_2$ with $i_1 > i_2$. When the currents are in the same direction, the magnetic field at a point midway between the wires is 10 μT. If the direction of $i_2$ is reversed, the field becomes 30 μT. The value of $\frac{i_1}{i_2}$ is – <br> (a) 4 (b) 3 (c) 2 (d) 1 |
| Q-24 | Consider a long straight wire of cross-sectional area A carrying a current $i$. Let there be $n$ free electrons per unit volume. An observer places himself on a trolley moving in the direction opposite to the current with a speed $v = \frac{i}{nAe}$ and separated from the wire by a distance $r$. The magnetic field seen by the observer is very nearly – <br> (a) $\frac{\mu_0 i}{2\pi r}$ (b) Zero (c) $\frac{\mu_0 i}{\pi r}$ (d) $\frac{2\mu_0 i}{\pi r}$ |
| Q-25 | The magnetic field at the origin due to a current element $id\vec{l}$ placed at a position $\vec{r}$ is – <br> (a) $\frac{\mu_0 i}{4\pi}\left(\frac{d\vec{l}\times\vec{r}}{r^3}\right)$ (b) $-\frac{\mu_0 i}{4\pi}\left(\frac{\vec{r}\times d\vec{l}}{r^3}\right)$ (c) $\frac{\mu_0 i}{4\pi}\left(\frac{\vec{r}\times d\vec{l}}{r^3}\right)$ (d) $-\frac{\mu_0 i}{4\pi}\left(\frac{d\vec{l}\times\vec{r}}{r^3}\right)$ |
| Q-26 | Consider three quantities $x = \frac{E}{B}$, $y = \sqrt{\frac{1}{\mu_0\varepsilon_0}}$ and $z = \frac{l}{CR}$. Here, $l$ is the length of wire, $C$ is a capacitance and $R$ is a resistance. All other symbols have standard meaning. <br> (a) $x, y$ have same dimensions <br> (b) $y, z$ have same dimensions <br> (c) $z, x$ have same dimensions <br> (d) None of the three have same dimensions |
| Q-27 | A long straight wire carries a current along Z-axis. One can find two points in the X-Y plane such that – <br> (a) The magnetic fields are equal <br> (b) The direction of the magnetic fields are same <br> (c) The magnitudes of the magnetic fields are equal <br> (d) The field at one point is opposite to that at the other point |
| Q-28 | A long straight wire of radius $R$ carries a current distributed uniformly over its cross-section. The magnitude of the magnetic field is – <br> (a) Maximum at the axis of the wire <br> (b) Minimum at the axis of the wire <br> (c) Maximum at the surface of the wire <br> (d) Minimum at the surface of the wire |
| Q-29 | A hollow tube is carrying an electric current along its length distributed uniformly over its surface. The magnetic field – |

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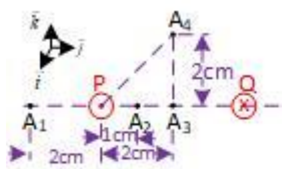
| | (a) Increases linearly from its axis to the surface.<br>(b) Is constant inside the tube<br>(c) Is zero at the axis of the tube<br>(d) Is zero just outside the tube |
| Q-30 | In a coaxial straight cable, the central conductor and the outer conductor carry equal currents in opposite directions. The magnetic field is zero –<br>(a) Outside the cable<br>(b) Inside the inner conductor<br>(c) Inside the outer conductor<br>(d) In between the conductor |
| Q-31 | A steady electric current is flowing through a cylindrical conductor.<br>(a) The electric field at the axis of the conductor is zero.<br>(b) The magnetic field at the axis of the conductor is zero.<br>(c) The electric field in the vicinity of the conductor is zero.<br>(d) The magnetic field in the vicinity of the conductor is zero |
| Q-32 | Using the formulae $\vec{F} = q\vec{v} \times \vec{B}$ and $B = \frac{\mu_0 i}{2\pi r}$, show that the SI unit of the magnetic field $B$ and the permeability constant $\mu_0$ may be written as $\mathrm{Nm^{-1}A^{-1}}$ and $\mathrm{NA^{-2}}$ respectively. |
| Q-33 | A current of 10 A is established in a long wire along the positive Z-axis. Find the magnetic field $\vec{B}$ at the point (1m,0,0). |
| Q-34 | A copper wire of diameter 1.6 mm carries a current of 20 A. Find the maximum magnitude of the magnetic field $\vec{B}$ due to this current. |
| Q-35 | A transmission wire carries a current of 100 A. What would be the magnetic field $\vec{B}$ at a point on the road if wire is 8m above the road? |
| Q-36 | A long straight wire carries a current 1.0 A is placed horizontally in a uniform magnetic field $B = 1.0 \times 10^{-5}$ T pointing vertically upward as shown in the figure. Find the magnitude of the resultant magnetic field at the points P and Q, both situated at a distance of 2.0 cm from the wire in the same horizontal plane. |
| Q-37 | A long straight wire of radius $R$ carries a current $I$ and is placed horizontally in a magnetic field $B$ pointing vertically upward. The current is uniformly distributed over its cross-section.<br>(a) At what points will the resultant magnetic field have maximum magnitude? What will be the maximum magnitude?<br>(b) What will be the minimum magnitude of the resultant magnetic field? |
| Q-38 | A long straight wire carrying a current of 30 A is placed in an external, uniform magnetic field of $4.0 \times 10^{-4}$T parallel to the current. Find the magnitude of the resultant magnetic field at a point 2.0 cm away from the wire. |
| Q-39 | A long vertical wire carrying a current of 10 A in the upward direction is placed in a region where horizontal magnetic field of magnitude $2.0 \times 10^{-3}$T exists from south to north. Find the point where the resultant magnetic field is zero. |
| Q-40 | Figure shows two parallel wires separated by a distance of 4.0 cm and carrying equal currents of 10 A in opposite directions. Find the magnitude of the magnetic field $B$ at the points $A_1$, $A_2$, $A_3$ and $A_4$.  |
| Q-41 | Two parallel wires carry equal currents 10 A along the same direction and are separated by a distance of 2.0 cm. Find the magnetic field at a point which is 2.0 cm away from each of the wires. |

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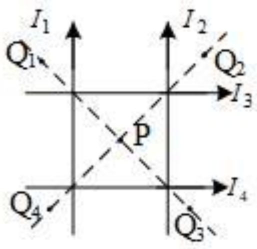
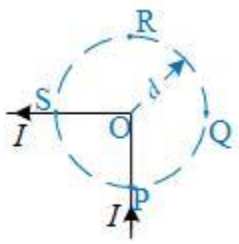
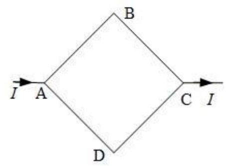
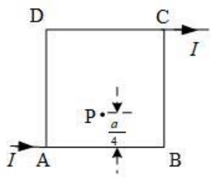
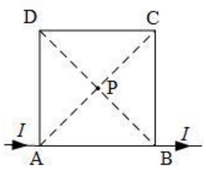
| Q-42 | Two long straight wires each carrying a current of 5 A are placed along X and Y axes respectively. The currents point along the positive directions of the axes. Find the magnetic fields at the points –<br>(a) (1m,1m) (b) (-1m, 1m) (c) (-1m, -1m) (d) (1m,-1m) |
| Q-43 | Four long straight wires each carrying a current of 5.0 A are placed in a plane as shown in figure. The points of intersection form a square of side 5.0 cm.<br>(a) Find the magnetic field at the center of the square<br>(b) $Q_1$, $Q_2$, $Q_3$, and $Q_4$ are situated on the diagonals of the square at a distance from P that is equal to the length of the diagonal of the square. Find the magnetic field at these points.<br> |
| Q-44 | Figure shows a long wire bent at the middle to form a right angle. Show that magnitude of the magnetic fields at the points P, Q, R and S are equal and find this magnitude.<br> |
| Q-45 | Consider a straight piece of length $l$ of a wire carrying current $I$. Let P be a point on the perpendicular bisector of the piece, situated at a distance $d$ from its middle point. Show that for $d \gg l$, the magnetic field at P varies as $\frac{1}{d^2}$ whereas for $d \ll l$, it varies as $\frac{1}{d}$. |
| Q-46 | Consider a 10cm long piece of a wire which carries a current of 10 A. Find the magnitude of the magnetic field due to the piece at a point which makes an equilateral triangle with the ends of the piece. |
| Q-47 | A long straight wire carries a current $I$. Let $B_1$ be the magnetic field at a point P at a distance $d$ from the wire. Consider a section of length $l$ of this wire such that the point P lies on a perpendicular bisector of the section. Let $B_2$ be the magnetic field at this point due to this section only. Find the value of $\frac{d}{l}$ so that $B_2$ differs from $B_1$ by 1%. |
| Q-48 | Figure shows a square loop ABCD with edge length $a$. The resistance of the wire ABC is $r$ and that of ADC is $2r$. Find the magnetic field $B$ at the center of the loop assuming uniform wires.<br> |
| Q-49 | Figure shows a square loop of edge $a$ made of a uniform wire. A current $I$ enters the loop at the point A and leaves it at the point C. Find the magnetic field at the point P which is on the perpendicular bisector of AB at a distance $\frac{a}{2}$ from it.<br> |
| Q-50 | Figure shows a square loop of edge $a$ made of a uniform wire. A current $i$ enters the loop at the point A and leaves it at the point B. Find the magnetic field at the center of the loop.<br> |
| Q-51 | The wire ABC shown in the figure forms an equilateral triangle. Find the magnetic field B at the center O of the triangle assuming the wire to be uniform. |
| Q-52 | A wire of length $l$ is bent in the form of an equilateral triangle and carries an electric current $i$. |

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| | (a) Find the magnetic field $B$ at the center.<br>(b) If the wire is bent in the form of a square, what would be the value of $B$ at the center? |
| Q-53 | A long wire carrying current $i$ is bent to form a plane angle $\alpha$. Find the magnetic field $B$ at a distance $x$ from the vertex. |
| Q-54 | Find the magnetic field $B$ at the center of a rectangular loop of length $l$ and width $b$, carrying a current $i$. |
| Q-55 | A regular polygon of $n$ sides is formed by bending a wire of total length $2\pi r$ which carries a current $i$.<br>(a) Find the magnetic field $B$ at the center of the polygon.<br>(b) By letting $n \rightarrow \infty$, deduce the expression for the magnetic field at the center of a circular current. |

**Important Note:** You may encounter need of clarification on contents and analysis or an inadvertent typographical error. We would gratefully welcome your prompt feedback on mail ID: subhashjoshi2107@gmail.com. If not inconvenient, please identify yourself to help us reciprocate you suitably.

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