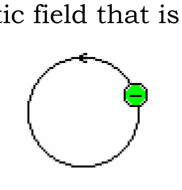
5.Magnetic Fields due to Currents(with Answers)

1. Suitable units for μ_0 ___________.

Ans: TmA^{-1} (Recall magnetic field inside a solenoid is B= $\mu_0 nI$. B is in tesla, n in number of turn per metre, I is current in amperes.

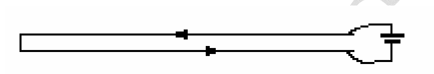
$$\mu_0 = \frac{B}{nI} = \frac{T}{m^{-1}A} = TmA^{-1}$$

2. Electrons are going around a circle in a counter clockwise direction. At the centre of the circle they produce a magnetic field that is _________.

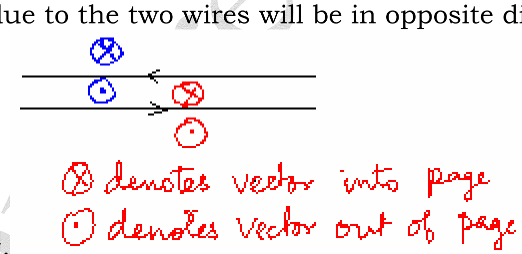


Ans. A negative charge circulating in counter clockwise direction is equivalent to a positive charge in clockwise direction. So using thumb rule we can say magnetic field is downwards, into the page.

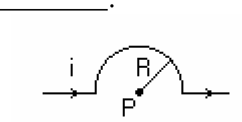
3. Explain why is there no magnetic field when a wire is simply doubled back on itself.



Ans. The magnetic field due to the two wires will be in opposite direction. So they will cancel each other out.

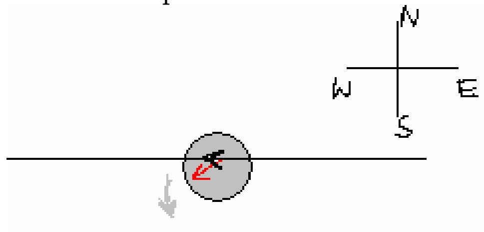


4. The magnitude of the magnetic field at point P, at the centre of the semicircle shown, is given by _________.



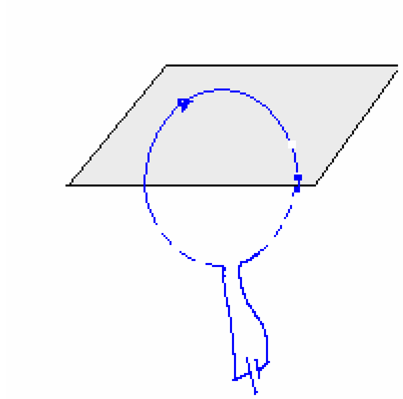
Ans. Magnetic field at the centre of a circular coil is halved to obtain the magnetic field due to a semi-circle. This is correct since the contribution due to each small element is added up to find the magnetic field due to the full coil. To find the field due to the semi circle the magnetic field due to a small element will be integrated over half the length. $B = \frac{\mu_0 i}{4R}$

5. A wire carrying a large current i from east to west is placed over an ordinary magnetic compass. The end of the compass needle marked 'N' will point __________.

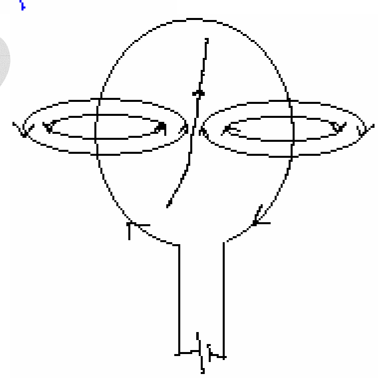


Ans.
The compass needle will point towards south.

6. Draw magnetic field lines around the coil.



Ans.



7. Two long parallel straight wires carry equal currents in opposite directions. At a point midway between the wires, the magnetic field they produce is _________.
Ans. Zero as the field due to current in opposite directions cancel each other out.

8. Two parallel wires carrying equal currents of 10A attract each other with a force 1mN. If both currents are doubled, the force of attraction will be __________.
Ans. The force will become 4 times as $Force$ per unit length is, $f = \mu_0 \frac{i_1 i_2}{2\pi r}$

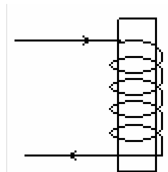
9. In Ampere's law $\oint \vec{B}.d\vec{s} = \mu_0 i$, the integration must be over ___________.
Ans. A closed loop

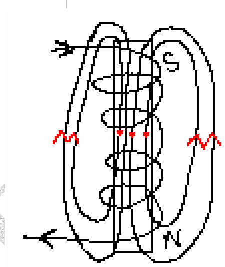
10. The magnetic field B inside a long ideal solenoid depends on ________.
Ans. $B = \mu_0 ni$ so the magnetic field depends on the number of turns per unit length, the current through the solenoid and permeability of medium within the solenoid. For instance if an iron core is placed inside the solenoid the permeability will increase so the magnetic field will also increase.

11. A solenoid is 3.0 cm long and has a radius of 0.50 cm. It is wrapped with 500 turns of wire carrying a current of 2.0 A. The magnetic field in tesla at the centre of the solenoid is _________.

$$B = \mu_0 ni = 4\pi \times 10^{-7} \times \frac{500}{3.0 \times 10^{-2}} \times 2T$$

12. Draw the magnetic field lines inside the solenoid for current shown below:





Ans.

13. If R is the distance from a magnetic dipole, then the magnetic field it produces is proportional to ___________.
Ans. It is proportional to $1/R^3$.

14. Two parallel wires, 4 cm apart, carry currents of 2 A and 4 A respectively, in the same direction. The force per unit length is N/m of one wire on the other is _________.

Ans. $$B = \frac{4\pi \times 10^{-7} \times 2 \times 4}{2\pi \times 4 \times 10^{-2}}$$

15. A loop of current-carrying wire has a magnetic dipole moment of $5 \times 10^{-4} A.m^2$. The moment initially makes an angle of 90^0 with a 0.5 T magnetic field. As it turns to become aligned with the field, the work done by the field is __________.

$$U = -mB\cos\theta$$

$$Work\ \text{done} = -mB\cos 90^0 - (-mB\cos 0^0)$$

$$= \text{mB} = 5 \times 10^{-4} \times 0.5J$$

16. The units of magnetic dipole moment are ________.

Ans. Am^2

17. A current of 3.0 A is clockwise around the outside edge of this page, which has an area of $5.8 \times 10^{-2} m^2$. The magnetic dipole moment is ________.

Ans. $m = IA = (3.0A)(5.8 \times 10^{-2} m^2)$

18. A cyclotron operates with a given magnetic field and at a given frequency. If R denotes the radius of the final orbit, the final particle energy is proportional to _________.

$$\frac{mv^2}{r} = qvB$$

$$v = \frac{qBr}{m}$$

$$KE = \frac{1}{2}mv^2 = \frac{1}{2}m\left[\frac{qBr}{m}\right]^2 = \frac{q^2B^2r^2}{m}$$

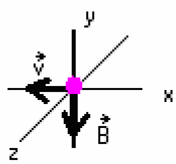
The final kinetic energy of the particle will depend on its charge to mass ratio, magnetic field and radius of the orbit.

19. A proton, travelling perpendicular to a magnetic field, experiences the same force as an alpha particle which is also travelling perpendicular to the same field. Find the ratio of their speeds $\frac{v_{proton}}{v_{alpha}}$

$$q_p v_p B = q_a v_a B$$

$$\frac{v_{proton}}{v_{alpha}} = \frac{q_{alpha}}{q_{proton}} = \frac{2}{1}$$

20. An electron moves in the negative x direction through a uniform magnetic field in the negative y direction. The magnetic force on the electron is along _______.



Ans. Force is along vxB (v cross B) so it will be along –z direction.

21. State Biot-Savart Law.

22. What are the SI units of
   a) magnetic field
   b) flux
   c) $\frac{\mu_0}{4\pi}$

Ans a) tesla T
   b) weber Wb
   c) T.m/A

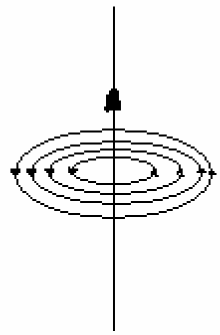
23. Define magnetic field lines.

Ans.The direction of the tangent to the magnetic field line gives the direction of the magnetic field at that point. The spacing of the lines represents the magnitude of the magnetic field, they are closely spaced where the field is strong and converse.

24. Derive the expression for the magnetic field due to long straight current carrying wire. From the expression for the magnetic field, state the direction of the field lines.

Ans. Take a small element of the wire. Write the magnetic field due to it at a distance r from the wire. Then integrate it to find the magnetic field due to the entire wire.

The direction of the field lines can be drawn as shown in the figure.



25. Derive the expression for the magnetic field due to a current carrying circular loop. From the expression, derive the field at large distances from the loop and at the center of the loop.

Ans. The magnetic field due to a small element of the loop is written using Biot-Savart's law. Then the total field is obtained by integrating over the loop.

At large distances from the loop the field is like the field due to a magnetic dipole, if the distance is measured along the axis of the loop, the field will be

$$\frac{\mu_0}{4\pi}\frac{2m}{r^3}$$

Here m is the dipole moment and r is the distance from the centre of dipole

26. State Fleming's left-hand rule.

Ans.Stretch the thumb, forefinger and middle finger of your left hand such that they are mutually perpendicular. If the first finger points in the direction of magnetic field and the second finger in the direction of current, then the thumb will point in the direction of motion or force acting on the conductor.

27. Write the expression for the force between 2 short parallel current carrying wires separated by a distance much larger than their length.

Ans.To find force, find magnetic field at one wire due to current in other wire. Now you are placing the second current carrying wire in a magnetic field due to the first wire. This wire will now experience a force given by F = i l x B.

$$\textit{Force} \text{ per unit length is, } f = \mu_0 \frac{i_1 i_2}{2\pi r}$$

28. Fill in the blanks _______
   a) Force between two parallel current carrying wires is _______.attractive
   b) Force between 2 anti-parallel current carrying conductors ______.repulsive
   c) Lorentz force is _____.q v x B
   d) Ampere's circuital law is the __line_____ integral of _magnetic field______ around any closed circuit is equal to _ μ_0 _____ times the _current_____threading on passing through this circuit.
   e) Magnetic field for a straight solenoid n turns per unit length is _ $\mu_0 ni$ _____.
   f) Units of magnetic dipole moment m is _Am^2______.
   g) The direction of the magnetic moment is given as follows:
   If the current in the circular loop is directed along the curved fingers of the hand, the magnetic moment is directed __along____ the thumb sticking out.
   h) The torque on a magnetic dipole m in a uniform field B is given as _m x B______.
   i) Current sensitivity of a moving coil galvanometer is defined as _ $\frac{\phi}{I}$ ______.
   j) Voltage sensitivity of a moving coil galvanometer is defined as _ $\frac{\phi}{V}$ ______.
   k. In the cyclotron resonance condition, the frequency ω is $\frac{qB}{m}$ _____ .

29. Describe the principle and working of a moving coil galvanometer.

Ans. A current carrying coil is placed in a uniform radial magnetic field. It is mounted so that it can rotate about an axis. For any orientation of the coil, the net magnetic field through the coil is perpendicular to the normal vector of the coil, or parallel to the plane of the coil. A spring provides a counter torque that balance the rotating torque, so that a steady current I in the coil will cause a steady deflection ϕ. The more the current, the more the deflection in the coil.

$$NiAB\sin\theta = \kappa\phi$$

$$\phi = \frac{NiAB\sin\theta}{\kappa}$$

30. Derive the expression for the path followed by a moving charged particle in a uniform magnetic field. What is the
   (i) radius of the path for an electron
   (ii) frequency of the revolution of the electron

$$1)\frac{mv^2}{r} = qvB$$

$$v = \frac{qBr}{m}$$

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

$$2) w = \frac{v}{r} = \frac{qB}{m}$$

Please let me know if you find any typing errors or other errors.