Physics by fiziks

Learn Physics in Right Way

4. MOVING CHARGES AND MAGNETISM

PGT Physics-Practice Set

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SUMMARY

1. The total force on a charge q moving with velocity $\vec{v}$ in the presence of magnetic and electric fields $\vec{B}$ and $\vec{E}$, respectively is called the *Lorentz force*. It is given by the expression:

$$\vec{F} = q\left(\vec{v}\times\vec{B}+\vec{E}\right)$$

The magnetic force $q\left(\vec{v}\times\vec{B}\right)$ is normal to $\vec{v}$ and work done by it is zero.

2. A straight conductor of length l and carrying a steady current I experiences a force $\vec{F}$ in a uniform external magnetic field $\vec{B}$,

$$\vec{F} = I\left(\vec{l}\times\vec{B}\right)$$

where $\left|\vec{l}\right| = l$ and the direction of $\vec{l}$ is given by the direction of the current.

3. In a uniform magnetic field $\vec{B}$, a charge q executes a circular orbit in a plane normal to $\vec{B}$. Its frequency of uniform circular motion is called the *cyclotron frequency* and is given by:

$$\nu_c = \frac{qB}{2\pi m}$$

This frequency is independent of the particle's speed and radius. This fact is exploited in a machine, the cyclotron, which is used to accelerate charged particles.

4. The *Biot-Savart* law asserts that the magnetic field $d\vec{B}$ due to an element $d\vec{l}$ carrying a steady current I at a point P at a distance r from the current element is:

$$d\vec{B} = \frac{\mu_0}{4\pi} I \frac{d\vec{l}\times\vec{r}}{r^3}$$

To obtain the total field at P, we must integrate this vector expression over the entire length of the conductor.

5. The magnitude of the magnetic field due to a circular coil of radius R carrying a current I at an axial distance x from the center is

$$B = \frac{\mu_0 I R^2}{2\left(x^2+R^2\right)^{3/2}}$$

At the center this reduces to

$$B = \frac{\mu_0 I}{2R}$$

6. *Ampere's Circuital Law*: Let an open surface S be bounded by a loop C. Then the Ampere's law states that $\oint_C \vec{B}\cdot d\vec{l} = \mu_0 I$ where I refers to the current passing through S. The sign of I is determined from the right-hand rule. We have discussed a simplified form of this law. If $\vec{B}$ is directed along the tangent to every point on the perimeter L of a closed curve and is constant in magnitude along perimeter then, $BL = \mu_0 I_e$ where I_e is the net current enclosed by the closed circuit.

7. The magnitude of the magnetic field at a distance R from a long, straight wire carrying a current I is given by:

$$B = \frac{\mu_0 I}{2\pi R}$$

The field lines are circles concentric with the wire.

8. The magnitude of the field B inside a *long solenoid* carrying a current I is

$$B = \mu_0 n I$$

where n is the number of turns per unit length. For a *toroid* one obtains,

$$B = \frac{\mu_0 N I}{2\pi r}$$

where N is the total number of turns and r is the average radius.

9. Parallel currents attract and anti-parallel currents repel.

10. A planar loop carrying a current I, having N closely wound turns, and an area A possesses a magnetic moment $\vec{m}$ where,

$$\vec{m} = NI\vec{A}$$

and the direction of $\vec{m}$ is given by the right-hand thumb rule: curl the palm of your right hand along the loop with the fingers pointing in the direction of the current. The thumb sticking out gives the direction of $\vec{m}$ (and $\vec{A}$)

When this loop is placed in a uniform magnetic field $\vec{B}$, the force $\vec{F}$ on it is: $\vec{F} = 0$

And the torque on it is,

$$\vec{\tau} = \vec{m}\times\vec{B}$$

In a moving coil galvanometer, this torque is balanced by a counter torque due to a spring, yielding

$$k\phi = NI\,AB$$

where ϕ is the equilibrium deflection and k the torsion constant of the spring.

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11. An electron moving around the central nucleus has a magnetic moment μ_l given by:

$$\mu_l = \frac{e}{2m} l$$

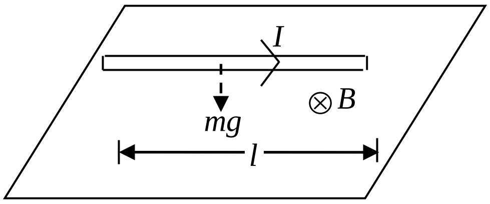
where l is the magnitude of the angular momentum of the circulating electron about the central nucleus. The smallest value of μ_l is called the Bohr magneton μ_B and it is $\mu_B = 9.27 \times 10^{-24}$ J/T.

12. A moving coil galvanometer can be converted into a ammeter by introducing a shunt resistance r_s, of small value in parallel. It can be converted into a voltmeter by introducing a resistance of a large value in series.

Physical Quantity	**Symbol**	**Nature**	**Dimensions**	**Units**	**Remarks**
Permeability of free space	μ_0	Scalar	$[\text{MLT}^{-2}\text{A}^{-2}]$	T m A^{-1}	$4\pi \times 10^{-7} \text{T m A}^{-1}$
Magnetic Field	$\vec{B}$	Vector	$[\text{MT}^{-2}\text{A}^{-1}]$	T (telsa)	
Magnetic Moment	$\vec{m}$	Vector	$[\text{L}^2\text{A}]$	A m^2 or J/T	
Torsion Constant	k	Scalar	$[\text{ML}^2\text{T}^{-2}]$	N m rad^{-1}	Appears in MCG

Question 1:

A straight wire of mass $200\,g$ and length $1.5\,m$ carries a current of $2A$. It is suspended in mid-air by a uniform horizontal magnetic field $\vec{B}$ (Fig. 4.3). What is the magnitude of the magnetic field?



Question 2:

What is the radius of the path of an electron (mass $9\times10^{-31}kg$ and charge $1.6\times10^{-19}C$) moving at a speed of $3\times10^{7}\,m/s$ in a magnetic field of $6\times10^{-4}T$ perpendicular to it? What is its frequency? Calculate its energy in keV. $\left(1eV = 1.6\times10^{-19}J\right)$.

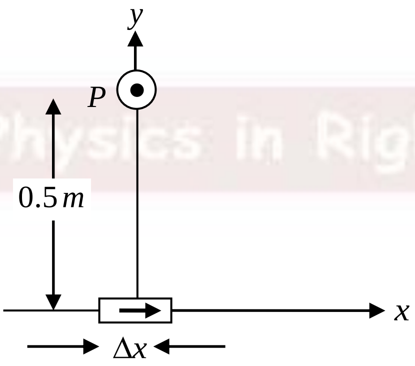
Question 3:

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

$\left(e = 1.60\times10^{-19}C, m_p = 1.67\times10^{-27}kg, 1MeV = 1.6\times10^{-13}J\right)$.

Question 4:

An element $\Delta\vec{l} = \Delta x\hat{i}$ is placed at the origin and carries a large current $I = 10\,A$ (Fig. 4.10). What is the magnetic field on the y-axis at a distance of $0.5\,m$. $\Delta x = 1\,cm$.



Question 5:

Consider a tightly wound 100 turn coil of radius $10\,cm$, carrying a current of $1\,A$. What is the magnitude of the magnetic field at the center of the coil?

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Question 6:

A long straight wire in the horizontal plane carries a current of $50\,A$ in north to south direction. Give the magnitude and direction of $\vec{B}$ at a point $2.5\,m$ east of the wire.

Question 7:

What is the magnitude of magnetic force per unit length on a wire carrying a current of $8A$ and making an angle of 30° with the direction of a uniform magnetic field of $0.15T$?

Question 8:

Two long and parallel straight wires A and B carrying currents of $8.0\,A$ and $5.0\,A$ in the same direction are separated by a distance of $4.0\,cm$. Estimate the force on a $10\,cm$ section of wire A.

Question 9:

A long straight wire of a circular cross-section (radius a) carrying steady current I. The current I is uniformly distributed across this cross-section. Calculate the magnetic field in the region $r < a$ and $r > a$.

Question 10:

A solenoid of length $0.5\,m$ has a radius of $1\,cm$ and is made up of 500 turns. It carries a current of $5\,A$. What is the magnitude of the magnetic field inside the solenoid?

Question 11:

A closely wound solenoid $80\,cm$ long has 5 layers of windings of 400 turns each. The diameter of the solenoid is $1.8\,cm$. If the current carried is $8.0\,A$, estimate the magnitude of $\vec{B}$ inside the solenoid near its center.

Question 12:

A toroid has a core (non-ferromagnetic) of inner radius $25\,cm$ and outer radius $26\,cm$, around which 3500 turns of a wire are wound. If the current in the wire is $11\,A$, what is the magnetic field (a) outside the toroid (b) inside the core of the toroid, and (c) in the empty space surrounded by the toroid.

Question 13:

The horizontal component of the earth's magnetic field at a certain place is $3.0\times10^{-5}T$ and the direction of the field is from the geographic south to the geographic north. A very long straight conductor is carrying a steady current of $1A$. What is the force per unit length on it when it is placed on a horizontal table and the direction of the current is (a) east to west: (b) south to north?

Question 14:

A square coil of side $10\,cm$ consists of 20 turns and carries a current of $12\,A$. The coil is suspended vertically and the normal to the plane of the coil makes an angle of 30^0 with the direction of a uniform horizontal magnetic field of magnitude $0.80\,T$. What is the magnitude of torque experienced by the coil?

Question 15:

(a) A circular coil of 30 turns and radius $8.0\,cm$ carrying a current of $6.0\,A$ is suspended vertically in a uniform horizontal magnetic field of magnitude $1.0\,T$. The field lines make an angle of 60^0 with the normal of the coil. Calculate the magnitude of the counter torque that must be applied to prevent the coil from turning.

Question 16:

A 100 turn closely wound circular coil of radius $10\,cm$ carries a current of $3.2\,A$. (a) What is the field at the center of the coil? (b) What is the magnetic moment of this coil?

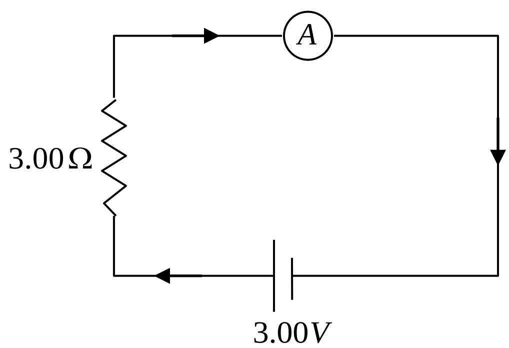
The coil is placed in a vertical plane and is free to rotate about a horizontal axis which coincides with its diameter. A uniform magnetic field of $2T$ in the horizontal direction exists such that initially the axis of the coil is in the direction of the field. The coil rotates through an angle of 90^0 under the influence of the magnetic field. (c) What are the magnitudes of the torques on the coil in the initial and final position? (d) What is the angular speed acquired by the coil when it has rotated by 90^0? The moment of inertia of the coil is $0.1\,kg\,m^2$.

Question 17:

An electron emitted by a heated cathode and accelerated through a potential difference of $2.0\,kV$, enters region with uniform magnetic field of $0.15\,T$. Determine the trajectory of the electron if the field (a) is transverse to its initial velocity, (b) makes an angle of 30^0 with the initial velocity.

Question 18:

In the circuit given below the current is to be measured. What is the value of the current if the ammeter shown (a) is a galvanometer with a resistance $R_G = 60.00\,\Omega$; (b) is a galvanometer described in (a) but converted to an ammeter by a shunt resistance $r_s = 0.02\,\Omega$; (c) is an ideal ammeter with zero resistance?



Question 19:

A galvanometer coil has a resistance of 12Ω and the meter shows full scale deflection for at current of $3mA$. How will you convert the meter into a voltmeter of range 0 to$18V$?

Question 20:

A galvanometer coil has a resistance of 15Ω and the meter shows full scale deflection for a current of $4mA$. How will you convert the meter into an ammeter of range 0 to $6A$?

Question 21: Two moving coil meters, M_1 and M_2 have the following particulars:

$R_1 = 10\Omega, N_1 = 30,\ A_1 = 3.6\times10^{-3}m^2, B_1 = 0.25T$

$R_2 = 14\Omega, N_2 = 42, A_2 = 1.8\times10^{-3}m^2, B_2 = 0.50T$

(The spring constants are identical for the meters).

Determine the ratio of (a) current sensitivity and (b) voltage sensitivity of M_2 and M_1.