NUMERICAL PROBLEMS

Problem 13.1 At what distance from a long straight wire carrying a current of 10 A is the magnetic field is equal to the earth's magnetic field of 5×10^{-5} T?

Solution

r = ? i = 10 A $B = 5 \times 10^{-5}$ T

Using Ampere's circuital law $B = \frac{\mu_o i}{2\pi r}$

$$r = \frac{\mu_o i}{2\pi B} = \frac{(4\pi \times 10^{-7})(10)}{2\pi(5 \times 10^{-5})} = 0.04\text{m}$$

Problem 13.2 A long solenoid has 1000 turns uniformly distributed over a length of 0.5m produces a magnetic field of 2.5×10^{-3}T at the center. Find the current in the solenoid?

Solution

N = 1000 $\ell = 0.5$ m $B = 2.5 \times 10^{-3}$T i = ?

For a solenoid $B = \mu_o n i$

$$i = \frac{B}{\mu_o n} = \frac{B\ell}{\mu_o N} = \frac{(2.5 \times 10^{-3})(0.5)}{4\pi \times 10^{-7}(1000)} = 1\text{ A}$$

Problem 13.3 A proton moving at right angle to magnetic field of 0.1T experience a force of 2×10^{-12} N. what is the speed of the proton?

Solution

$\theta = 90^0$ B = 0.1 T $F = 2 \times 10^{-12}$ N V = ? q = e (proton)

Force on a charge entering in a magnetic field is

$$F = q v B \sin\theta$$

⇒

$$v = \frac{F}{q B \sin\theta} = \frac{2 \times 10^{-12}}{(1.6 \times 10^{-19})(0.1)(\sin 90)}$$

$$v = 1.25 \times 10^{8}\text{ m/s}$$

Problem 13.4 An 8 MeV proton enters perpendicularly into a uniform magnetic field of 2.5 T. Find (a) the force on the proton (b) what will be the radius of the path of proton?

Solution

$K.E = 8\text{ MeV} = 8 \times 10^{6}$ eV $\theta = 90^0$ B = 2.5 T

m (mass of proton) = 1.67×10^{-27} kg (a) F = ? (b) r = ?

(a) $F = q v B \sin\theta$ ---------------------------------- (1)

Velocity "v" is unknown in above equation. We find it by following way;

Given that kinetic energy $K.E = \frac{1}{2} m v^2$

$$v = \sqrt{\frac{2(K.E)}{m}} = \sqrt{\frac{2(8 \times 10^{6})(1.6 \times 10^{-19})}{1.67 \times 10^{-27}}} = 3.9 \times 10^{7}\text{ m/s}$$

Put value of "v" in equation (1) =>

$$F = q\,v\,B\,\sin\theta = (1.6 \times 10^{-19})(3.9 \times 10^{7})(2.5)\sin 90^{0}$$
$$F = 1.6 \times 10^{-11}\ N$$

(b) The force F that the magnetic field exerts on proton provides necessary centripetal force given by $F = \frac{m\,v^2}{r}$

$$r = \frac{m\,v^2}{F} = \frac{(1.67 \times 10^{-27})(3.9 \times 10^{7})^2}{(1.6 \times 10^{-11})} = 0.16\ m$$

Problem 13.5 A wire carrying current 10 mA experiences a force of 2 N in a uniform field. What is the force on it when current rises to 30 mA?

Solution

$i_1 = 10\ mA$ $F_1 = 2\ N$ $i_2 = 30\ mA$ $F_2 = ?$

$F = i\,\ell\,B$

For first conductor $F_1 = i_1\,\ell\,B$

$$\Rightarrow \quad \ell B = \frac{F_1}{i_1} = \frac{2}{10 \times 10^{-3}} = 200\ NA^{-1}$$

Now for second conductor $F_2 = i_2\,\ell\,B$

Putting value of "ℓB" in above equation we get

$$F_2 = (30 \times 10^{-3})(200) = 6\ N$$

Problem 13.6 What is the time period of an electron projected into a uniform magnetic field of 10 mT and moves in a circle of radius 6 cm?

Solution

$T = ?$ $B = 10 \times 10^{-3}\ T$ $r = 6\ cm = 6 \times 10^{-2}\ m$

As magnetic field provides centripetal force to a charged particle

$$q\,v\,B = \frac{m.v^2}{r} \text{ ---------------------------- (1)}$$

also $v = r\,w = r\left(\frac{2\pi}{T}\right)$ -------------------- (2)

putting eq (2) in eq (1) and re-arranging them we get

$$T = \frac{2\pi m}{q B} = \frac{2(3.14)(9.11 \times 10^{-31})}{(1.6 \times 10^{-19})(10 \times 10^{-3})}$$

$$T = 3.6 \times 10^{-9}\ sec = 3.6\ n.sec$$

Problem 13.7 A 0.2 m wire is bent into a circular shape and is placed in uniform magnetic field of 2T, if the current in the wire is 20 mA then find the maximum torque acting on loop?

Solution

$\ell = 0.2\ m$ $B = 2\ T$ $i = 20\ mA$ $\tau_{max} = ?$

$$\tau = B\,i\,N\,A\cos\theta$$

N = 1 and for maximum torque $\cos\theta = 1$

$\tau_{max} = B\,i\,A$ Area for a wire is $A = \pi r^2$

$\tau_{max} = B\,i\,\pi r^2$ .... (1)

When wire is bent into circle then its length is equal to circumference

$$\ell = 2\pi r$$

$$\Rightarrow \quad r = \frac{\ell}{2\pi} = \frac{0.2}{2(3.14)} = 0.0318 \text{ m}$$

Now putting this value of r in eq (1) above we get

$$\tau_{max} = 2\,(20 \times 10^{-3})\,(3.14)\,(0.0318)^2 = 1.27 \times 10^{-4} \text{ N m}$$

Problem 13.8 Full scale deflection for galvanometer is 10 mA. Its resistance is 100 Ω. How it be converted into ammeter of range 100 A?

Solution

$i_g = 10\text{mA} = 0.01\text{A}$ $R_g = 100\ \Omega$ $R_s = ?$ for $i = 100$ A

In order to convert a galvanometer into an ammeter, we need a shunt resistor r_s in parallel with galvanometer given by

$$R_s = \frac{i_g R_g}{(i - i_g)} = \frac{(10 \times 10^{-3})\ 100}{(100 - 0.01)}$$

$$R_s = 0.01\ \Omega$$

Problem 13.9 How 5mA, 100Ω galvanometer converted to 20V voltmeter?

$i = 5$ m A $R_g = 100\ \Omega$ $R_h = ?$ for V = 20 Volts

Solution

In order to convert galvanometer into a voltmeter of 20 V range we connect a high resistance r_h in series with galvanometer and is given by

$$R_h = \frac{V}{i} - R_g = \frac{20}{0.005} - 100 = 3900\ \Omega$$

Problem 13.10 Two parallel wires 10 cm apart carry current in opposite direction of 8 A. what is the magnetic field halfway between them?

Solution

d = 10 cm i = 8 A B = ? at mid point

At mid-point

$$r = d / 2 = 5 \text{ cm}$$

Now B can be determined by Ampere's circuital law

$B = B_1 + B_2$

$$\Rightarrow \quad B = \frac{\mu_o\, i}{2\pi r} + \frac{\mu_o\, i}{2\pi r} = \frac{\mu_o\, i}{\pi r} = \frac{(4\pi \times 10^{-7})\,(8)}{\pi\,(5 \times 10^{-2})}$$

$$B = 6.4 \times 10^{-5} \text{ T}$$