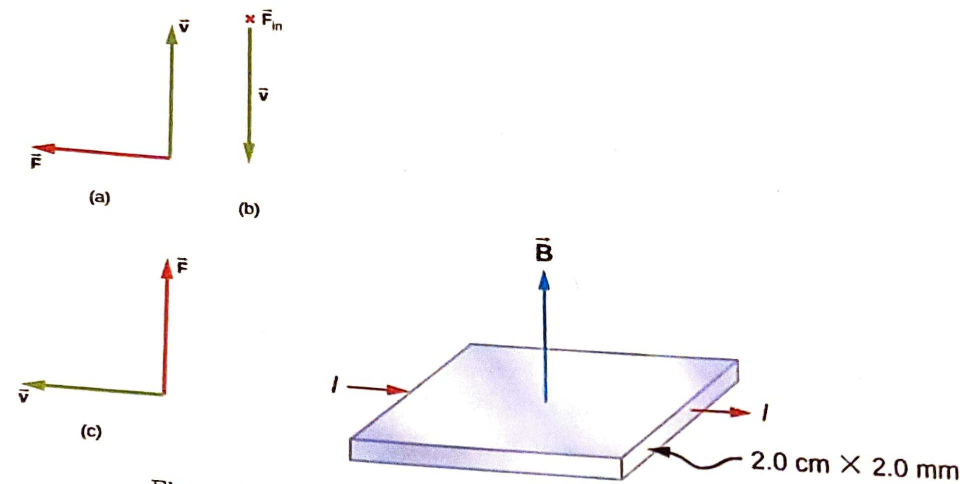


Figure 1: (Left) A current I experiences a force F in a B-field.

2 Chapter 11: Magnetic Forces and Fields

1. Consider Fig. 1 (left). In each of the three cases, determine the direction of the current given that F is the Lorentz force.

B - field

- a: in
- b: left
- c: out

2. Consider Fig. 1 (right). **The Hall Effect.** An E-field exists in the vertical direction and a B-field is perpendicular to the direction of charge velocity. (a) Show that if the E-field force on a charge balances the Lorentz force on a charge, that $v = E/B$. (b) If the E-field is constant, $E = \Delta V/\Delta x$. Show that

90°

$$\Delta V = \frac{B \Delta x I}{n q_e A} \tag{1}$$

where n is the charge carrier density, q_e is the electron charge, A is the cross-sectional area of the conductor, and I is the current. Plug in $B = 1.33$ T, $\Delta x = 2$ cm, $I = 10$ A, $n = 2 \times 10^{28}$ m^{-3}, $A = 1$ mm^2, and q_e is the charge of an electron.

(a) Force of B-field : $F_B = qvB\sin\theta$

$F_B = qvB\sin 90° \Rightarrow F_B = qvB$

Force of E field : $F_E = qE$

$qvB = qE$

$v = E/B$

(b) $\Delta x = 2cm \rightarrow 0.02\,m$

$A = 1\,mm^2 \rightarrow 0.001\,m$

$q_e = 1.6 \times 10^{-19}\,C$

$$\Delta V = \frac{(1.33T)(0.02\,m)(10\,A)}{(2 \times 10^{28}\,m^{-3})(1.6 \times 10^{-19}c)(0.001m)}$$

$\Delta V = 8.31 \times 10^{-8}$

3. A proton has a magnetic field due to its spin. The field is similar to that created by a circular current loop 0.65×10^{-15} m in radius with a current of 1.05×10^4 A. Find the maximum torque on a proton in a 2.50-T field. (This is a significant torque on a small particle.)

$\tau = NIAB\sin\theta$

$\tau = (1)IAB\sin 90$

$\tau = IAB$

$A = \pi r^2$

$A = \pi(0.65 \times 10^{-15})^2$

$A = 1.33 \times 10^{-30}\,m^2$

$\tau = IAB$

$\tau = (1.05 \times 10^4 A)(1.33 \times 10^{-30} m^2)(2.50T)$

$\tau = 3.49 \times 10^{-26}\,Nm$

3 Chapter 12: Sources of Magnetic Fields

1. (a) What is the B-field inside a solenoid with 500 turns per meter, carrying a current of 0.3 A? (b) Suppose we insert a piece of metal inside the solenoid, boosting μ_0 by a factor of 5000. What is the new B-field?

(a)

$B = \mu_0 n I$

$I = 0.3\ A$

$n = 500\ t/m$

$\mu_0 = 4\pi \times 10^{-7}\ N/A$

$B = (4\pi \times 10^{-7}\ N/A)(500\ t/m)(0.3\ A)$

$B = 1.88 \times 10^{-4}\ T$

$B = \mu_0 n I$

$(6.28 \times 10^{-3})(500)(0.3)$

$B = 0.942\ T$

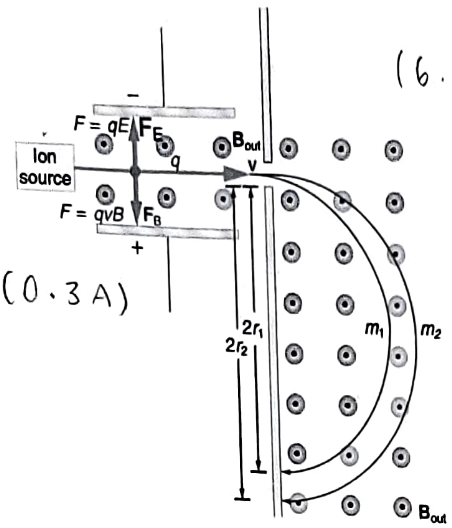


Figure 2: A basic diagram of a *toroid*, which is a solenoid wrapped into a circular tube.

2. Consider Fig. 2. **Mass spectrometer.** Suppose that the velocity of the charged particles moving to the right is $v = E/B$. (a) Show that if $v = E/B$, $F_{net} = 0$ in the region in the top left[1]. (b) Recall that the centripetal force on a particle of mass m is mv^2/r. Set this equal to the magnitude of the Lorentz force to prove that

(a) F electrical + F mag. = 0

$q[E + \vec{v}\,\vec{B}] = 0$ downward (vB)

$F_{total} = q[E - vB] = 0$

$E = vB \Rightarrow v = \frac{E}{B}$

$$r = \frac{mE}{qB^2} \tag{2}$$

The mass of an oxygen nucleus is 16 times that of a proton (mass of proton: 1.67×10^{-27} kg). Suppose oxygen ions with the charge of 1 proton are sent through the mass-sepctrometer. The E-field is 10 V/m, and the B-field is 0.01 T. What is the distance r?

Lorentz force $\Rightarrow F = qvB$ $\quad qvB = \frac{mv^2}{r}$

Centripital $\Rightarrow mv^2/r$

$v = \frac{E}{B}$ $\quad r = \frac{mv}{qB} \Rightarrow \frac{m\frac{E}{B}}{qB} \Rightarrow r = \frac{mE}{qB^2}$

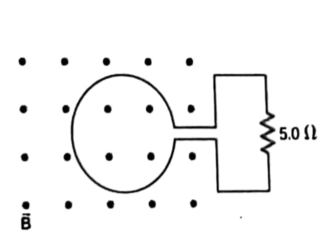
$\frac{(16)(1.67 \times 10^{-27})(10)}{1.602 \times 10^{-19}(0.01)^2} = 0.0167\ m$

4 Chapter 13: Electromagnetic Induction

(a) Induced voltage, $e = \left|\frac{d\Phi}{dt}\right|$

$= \frac{d(BA)}{dt} \Rightarrow e = A\frac{dB}{dt}$

$e = \pi r^2 \times \frac{B_0}{T_0} \sin(2\pi f t)$



(b) $e = \pi(0.1)^2 \times \frac{0.1}{1} \sin(2\pi 10^3 0)$

emf = 0

Figure 3: A voltage is induced on a loop by a changing B-field.

1. The magnetic field in Fig. 3 flows out of the page through a single ($N = 1$) loop, and changes in magnitude according to

$$\frac{\Delta B}{\Delta t} = \frac{B_0}{T_0}(\sin(2\pi f t)) \tag{3}$$

The loop has a radius r. (a) In terms of the given variables, what is the induced voltage in the circuit? (b) If $B_0 = 0.1$ T, $r = 0.1$ m, $f = 10^3$ Hz, and $T = 1$ ms, what is the induced emf at $t = 0$? (c) What about $t_1 = 0.16$ ms? (d) What is the current through the resistor at t_1?

(c) $e = \pi(0.1)^2 \left(\frac{(0.1)^3}{1}\right) \sin(2\pi(10^3)(0.16 \times 10^{-3}))$

$e = 0.055\ V$

(d) $I = \frac{e}{R} = \frac{0.055}{5} \Rightarrow 0.011\ A$

5 Chapter 14: Inductance

1. What is (a) the rate at which the current though a 0.50-H coil is changing if an emf of 0.150 V is induced across the coil?

$$\varepsilon = -L\frac{dI}{dt} \Rightarrow \left|-\frac{\varepsilon}{L}\right| = \frac{0.150\,V}{0.50\,H} = 0.3\,A/s$$

2. When a camera uses a flash, a fully charged capacitor discharges through an inductor. In what time must the 0.100-A current through a 2.00-mH inductor be switched on or off to induce a 500-V emf?

$$dt = \frac{L(dI)}{\varepsilon}$$

$$dt = \frac{(0.002\,H)(0.100\,A)}{500\,V}$$

$dI = 0.100\,A$

$L = 2.00\,mH \rightarrow 0.002\,H$

$dt = 4\times10^{-7}\,s$

$\varepsilon = 500\,V$