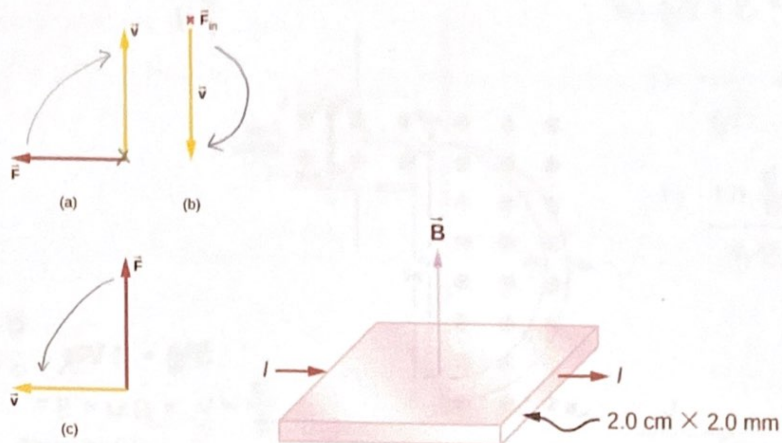


Figure 1: (Left) A current I experiences a force F in a B-field.

2 Chapter 11: Magnetic Forces and Fields

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

   - a: into page
   - b: left
   - c: out of page

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

a) $F = q\vec{v} \times B = FB = q\vec{v} \times B$

$$\Delta V = \frac{B \Delta x I}{n q_e A} \quad (1)$$

$FE = qB = \frac{\cancel{q}E}{\cancel{q}} = E = vB$

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.

$B = 1.33$

$\Delta x = 0.02m$

$I = 10 A$

$n = 2\times10^{28}$

$A = 1\times10^{-6}$

$q_E = 1.6\times10^{-19}$

$$\Delta V = \frac{(1.38)(0.02)(10)}{(2\times10^{22})(1.6\times10^{-19})(1\times10^{-19})} = \boxed{8.3\times10^{-5} V}$$

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.)

$I = 1.05\times10^4 A$

$\tau = IAB$

$B = 2.5 T$

$\tau = (1.05\times10^4)(1.3\times10^{-30})(2.50) = \boxed{3.4\times10^{-26} N\cdot m}$

$A = \pi r^2 = 3.14(0.65\times10^{-15})$

$= 1.3\times10^{-30}$

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) $B = \mu_0 n I = (4\pi\times10^{-7})(500)(0.3) = \boxed{1.88\times10^{-4} T}$

$\mu_0 = 4\pi\times10^{-7}$

$n = 500$

b) $B = ((5000(4\pi\times10^{-7}))(500)(0.3) = \boxed{0.94 T}$

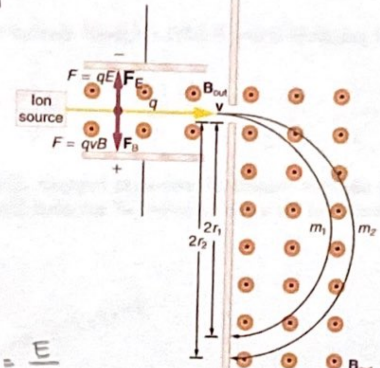
$I = 0.3 A$

$F \uparrow$

b) $q\vec{v} \times B = \frac{mv^2}{r}$

$r = \frac{mv}{qB} \leftarrow . \; v = \frac{E}{B}$

$r = \frac{m \frac{E}{B}}{qB} = r = \frac{mE}{qB^2}$



a) $F_{net} = 0$

$0 = qE - q\vec{v} \times B$

$+ q\vec{v} \times B = \cancel{q}vB = \cancel{q}E$

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

✓

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

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

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?

$r = \frac{(2.7 \times 10^{-26})(10)}{(1.6 \times 10^{-19})(0.01)^2} = \boxed{0.017\text{ m}}$

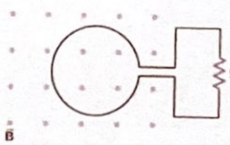
Emf = $10 \frac{V}{m}$

$B = 0.01$T

$m = 16(1.67 \times 10^{-27})$

$= 2.7 \times 10^{-26}$

4 Chapter 13: Electromagnetic Induction



← resistance

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?

a) $E = -N\left(\frac{d\Phi}{dt}\right) = \left|-1\left(\frac{d(BA)}{dt}\right)\right|$ with $N \to 1$, $A \to \pi r^2$

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

b) $\sin(2\pi f 0)$

$t = 0$

$\boxed{\text{emf} = 0}$

c) $B_0 = 0.1$T

$r = 0.1$m

$f = 10^3$

$T_0 = 1 \times 10^{-6}$

$t_1 = 0.16 \times 10^{-3}$

$\pi(0.1)^2\left(\frac{0.1}{1 \times 10^{-6}}\right)(\sin(2\pi)(10^3)(0.16 \times 10^{-3}))$

$\boxed{B = 0.055\text{V}}$

[1]Molecules that do not have this velocity will hit the sides of this portion of the instrument.

d) $V = IR$

$I = \frac{V}{R} = \frac{0.055}{5} = \boxed{0.011\text{ A}}$

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?

$emf = 0.150\ V$

$m = 0.50H$

$$emf = -M\left(\frac{dI}{dt}\right) = \frac{dI}{dt} = \frac{emf}{-M} = \frac{0.150}{-0.50} = \boxed{0.3\ \frac{amps}{s}}$$

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?

$I = 0.100A$

$m = 2.00mH = 0.002H$

$emf = 500$

$$emf = -M\left(\frac{dI}{dt}\right)$$

no (-) time

$$dt = \frac{-M(dI)}{emf} = \frac{(-0.002)(0.100)}{500} = \boxed{4 \times 10^{-7} s}$$