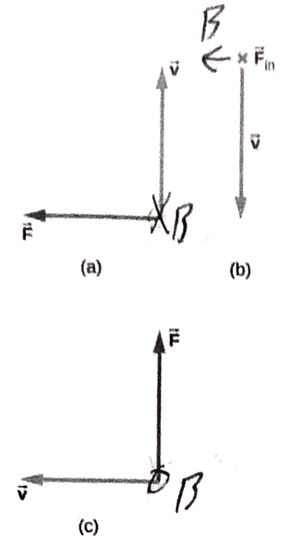
Jackson Diamond



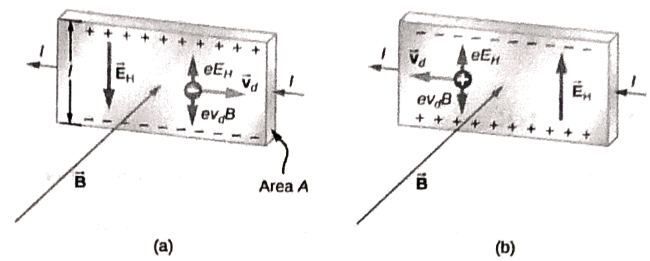


Figure 1: (Left) A current I experiences a force F in a B-field.

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 the page
   - b: Left
   - c: Out of the 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

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

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) $F_1 = qv \times B$ $\quad qE = qv \cdot B\sin(\theta)$ $\quad \theta = 90°$ $= 1$

$F_2 = qE$ $\quad E = v \cdot B$

if $F_1 = F_2$ $\quad v = E/B$

b) $v = I/nqA$ $\quad \Delta V = \frac{B\Delta x I}{nqA}$

$E = v \cdot B$

$E = \Delta V/\Delta x$

$\Delta V = E\Delta x$

$\Delta V = \vec{v} B \Delta x$

$= \frac{(1.33\,T \cdot .02\,m \cdot 10\,A)}{(2 \cdot 10^{28}\,m^{-3} \cdot 1.602 \cdot 10^{-19}\,C \cdot 1 \cdot 10^{-6}\,m)}$

$\boxed{\Delta V = .083\,V}$

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.)

$A = \pi r^2$

$\phi = B \cdot A$ $\quad \tau = FL$ $\quad \tau_{max} = B I (L \cdot L) = BIA$

$F = B \times IL$

$(1.05 \cdot 10^4) \cdot \pi \cdot (.65 \cdot 10^{-15})^2 \cdot 2.5 = \boxed{3.484 \cdot 10^{-26}\,N \cdot m}$

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?

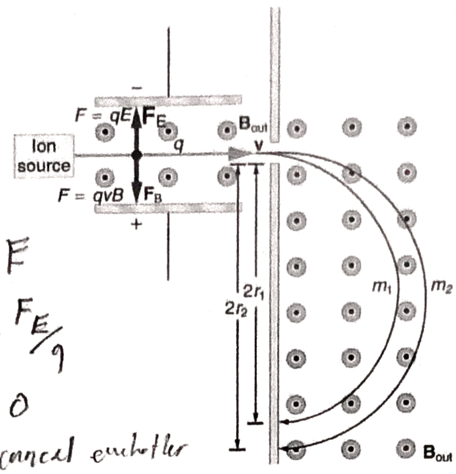
a) $B = \mu_0 n I$

$= (4\pi \cdot 10^{-7})(500)(.3)$

$= \boxed{1.885 \cdot 10^{-4}\,T}$

b) $B = 5000\,\mu_0 n I$

$= \boxed{.942\,T}$



a) $v = E/B \rightarrow vB = F$

$F_E = qE$ $\quad F_B/q = F_E/q$

$F_B = qvB$ $\quad F_{net} = 0$

bc they cancel eachother out

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?

b) $F = qv \times B$ $\quad r = \frac{mv^2}{qvB} = \frac{mE}{qB^2} = \frac{16(1.67 \cdot 10^{-27})(10)}{(1.602 \cdot 10^{-19})(.01)^2} = \boxed{1.67\text{ cm}}$

$F = mv^2/r$ $\quad r = \frac{mv^2}{F}$ $\quad v = E/B$

4 Chapter 13: Electromagnetic Induction

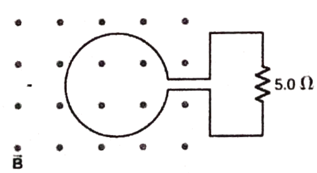


Figure 3: A voltage is induced on a loop by a changing B-field.

1. The magnetic field in Fig. 3 flows out of the page through a single ($N = 1$) loop, and is tuned to follow the form

$$B(t) = B_0\left(\frac{1}{2} + \frac{2}{\pi}\sin(2\pi ft) + \frac{2}{3\pi}\sin(6\pi ft) + \frac{2}{5\pi}\sin(10\pi ft)\right) \tag{3}$$

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, and $f = 10^3$ Hz, what is the induced emf at $t = 0$? (c) What is the current through the resistor at $t = 1$ ms? I graphed B(t) and it still was .05

a) $\mathcal{E} = -N\frac{d\phi}{dt}$

$\phi = B \cdot A$ $\quad A = \pi r^2$

$\mathcal{E} = -NA \cdot B(t)$

b) $B(0) = .1(1/2 + 0 + 0 + 0)$

$\mathcal{E} = (1) \cdot \pi \cdot (.1)^2 \cdot (.05)$

$\boxed{= .00157\text{ V} \;@\; t = 0}$

c) $\Delta V = IR$

$B(.001) = .05$

$\mathcal{E} = (1) \cdot \pi \cdot (.1)^2 \cdot (.05)$

$\mathcal{E} = .00157$

$\frac{.00157}{5} = \boxed{3.1416 \cdot 10^{-4}\text{ A or } \pi \cdot 10^{-4}\text{ A}}$

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

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?

$\Delta V = -L \frac{dI}{dt}$ $\quad \frac{\Delta V}{-L} \quad \left|\frac{.15}{-.5}\right| = \boxed{\frac{dI}{dt} = .3\ A}$

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?

$emf = -M \frac{dI}{dt}$

$\frac{500\ V}{-2 \cdot 10^{-3}\ H} = 250{,}000 = .1 / 4 \cdot 10^{-7}$

$\boxed{4 \cdot 10^{-7}\ s}$