Razmig Bartassian
4-27-20
PHYS 180

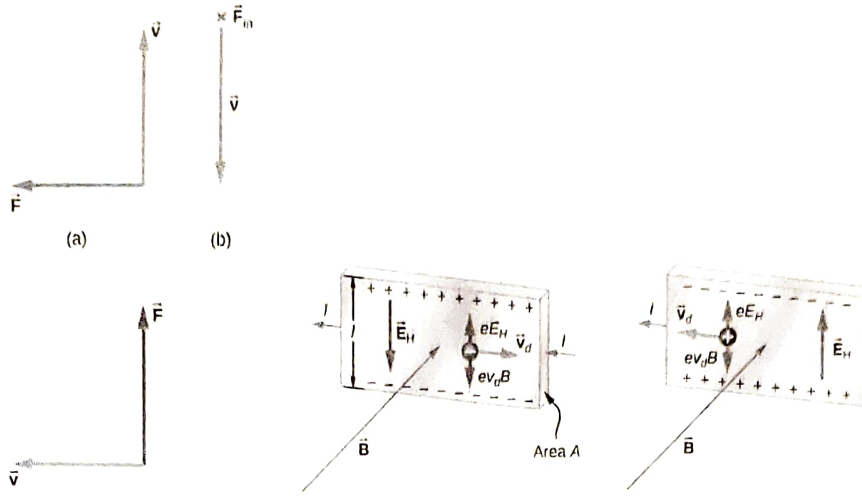

Figure 1: (Left) A current I experiences a force F in a B-field.

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 $\leftarrow$
   - 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

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

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) $F_L = q V_d B$ $\quad E_H = \frac{V_H}{l} \Rightarrow V_H = E_H l$

$F_E = q E_H$

$\cancel{q} V_d B = \cancel{q} E_H$

$E_H = V_d B$

$\frac{V_H}{l \cdot B} = \frac{V_d \cancel{B}}{\cancel{B}}$ $\quad \frac{E_H \cancel{l}}{\cancel{l} B} = V_d$ $\quad \boxed{V_d = \frac{E_H}{B}}$ ✓

b) $E_H = \frac{V_H}{l}$ $\quad E_H = V_d B$

$\frac{V_H}{l} = V_d B \longrightarrow V_H = V_d B l$

$I = n q A v_d$

$V_d = \frac{I}{nqA}$

$\boxed{V_H = \frac{B l I}{n q A}}$

c) $\boxed{8.3 \times 10^{-5}\, V}$

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.)

$T = \frac{kg}{s^2 A}$

$\tau = IANB\sin(\theta)$ $\quad \tau = (1.05 \times 10^4 A)(\pi (0.65 \times 10^{-15})^2)(1)(2.50\,T)$

$\tau_{max} = IANB$ $\quad = 3.48 \times 10^{-26}\, Am^2 T = \boxed{3.48 \times 10^{-26}\, Nm}$

$\cancel{A} m^2 \left(\frac{kg}{s^2 \cancel{A}}\right) = Nm$ ✓

Unit check

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) $B = \mu_0 n I = \left(4\pi \times 10^{-7} \frac{T \cdot \cancel{m}}{\cancel{A}}\right)\left(\frac{500}{\cancel{m}}\right)(0.3 \cancel{A}) = \boxed{1.88 \times 10^{-4}\, T}$

b) $(1.88 \times 10^{-4} T)(5000) = \boxed{9.4 \times 10^{-1}\, T}$

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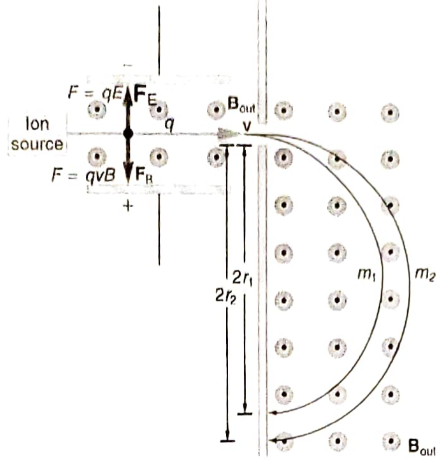

Figure 2: A basic diagram of a *toroid*, which is a solenoid wrapped into a circular tube.

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 $v = E/B$

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

a) $F_E = qE$ $\quad qE = q\frac{E}{\cancel{B}}\cancel{B}$

$F_B = qvB$ $\quad qE = qE$ ✓

b) $F_L = qvB\sin\theta$ $\quad qvB = \frac{mv^2}{r}$

$F_c = \frac{mv^2}{r}$ $\quad r = \frac{mv}{qB} = \boxed{\frac{mE}{qB^2}}$ ✓

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?

c) $r = \frac{(16)(1.67\times10^{-27}kg)(10V/m)}{(1.6\times10^{-19}C)(0.01T)^2} = 1.67\times10^{-2}\frac{kg\,V}{C\,m\,T^2}$

$= \boxed{1.67\times10^{-2}m}$

$\frac{kg\,V}{A s} \frac{s^3 A}{kg^2}\, kg\, m$

$\frac{s^3 A}{m\,kg}\left(\frac{kg\,m^2}{s^3 A}\right) = m$ ✓

Gotta Check them Units!

4 Chapter 13: Electromagnetic Induction

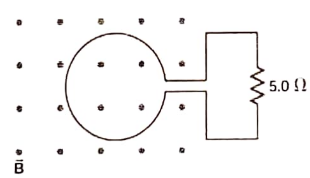

Figure 3: A voltage is induced on a loop by a changing B-field.

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

$$B(t) = B_0\left(\frac{1}{2} + \frac{2}{\pi}\overset{0}{\cancel{\sin(2\pi ft)}} + \frac{2}{3\pi}\overset{0}{\cancel{\sin(6\pi ft)}} + \frac{2}{5\pi}\overset{0}{\cancel{\sin(10\pi ft)}}\right) \tag{3}$$

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?

a) $\mathcal{E} = \frac{N\Delta\phi}{\Delta t}$

or

$\mathcal{E} = \frac{N\Delta(BA\cos\theta)}{\Delta t}$

b) $B(0) = (0.1T)(1/2) = 0.05T$

$\mathcal{E} = 1\left(\frac{0.05T}{0}\right)$

Undefined?

c) $B(1ms) = 0.05T$

$\mathcal{E} = 1\left(\frac{0.05(0.1)\pi}{10^{-3}-0}\right) = 1.57V$

$I = \frac{V}{R} = \frac{1.57V}{5\Omega} = \boxed{0.314A}$

[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?

a) $\mathcal{E} = L\frac{\Delta I}{\Delta t} \rightarrow \frac{\mathcal{E}}{L} = \frac{\Delta I}{\Delta t} \qquad \frac{0.150V}{0.50H} = \frac{\Delta I}{\Delta t} = \boxed{0.3\frac{A}{S}}$

$H = \frac{V}{A}$

$\frac{1}{H} = \frac{A}{\cancel{V}}$

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?

$2\ mH = 0.002\ H$

$\mathcal{E} = L\frac{\Delta I}{\Delta t} \qquad 500\ V = \frac{0.100A}{t}(0.002\ H)$

$t = \frac{(0.100A)(0.002\ H)}{500\ V} = \boxed{4 \times 10^{-7} s}$