These are due Friday, 21 March.

1. In Figure 1, the paths of some charged particles are traced through a uniform magnetic field directed into the page. What are the charges on the particles?

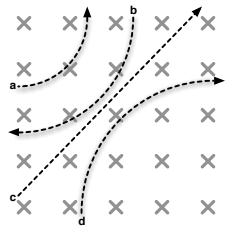

Figure 1: The paths of some charged particles.

Solution

(a) positively charged
(b) negatively charged
(c) neutral
(d) negatively charged

2. Figure 2 shows the motion of electrons in a wire that is near the **S** pole of a magnet. In which direction will the wire experience a force?

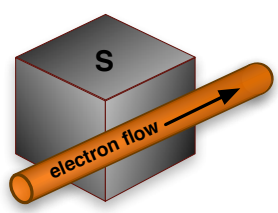

Figure 2: A wire passing near a magnet.

Solution

The figure is poorly drawn. The intent is for the magnetic field lines to be entering the body of the magnet at the face closest to the current-carrying wire. For that configuration, the wire would naturally experience a downward force according to

$$\mathbf{F} = I\mathbf{L} \times \mathbf{B},$$

where $\mathbf{L}$ is oriented *opposite* the flow of electrons.

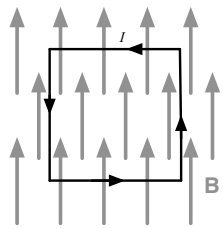

Figure 3: A current-carrying loop in a uniform magnetic field.

3. A rectangular current-carrying loop is placed in a uniform magnetic field with the plane of the loop parallel to the direction of the field as in Figure 3. What net force will the loop experience?

   Solution

   Applying

$$\mathbf{F} = I\mathbf{L} \times \mathbf{B}$$

   to each segment of the rectangular loop reveals that the top and bottom segments experience a force into and out of the page, respectively. The vertical segments experience no magnetic force, since the angles between $\mathbf{L}$ and $\mathbf{B}$ are π and 0 ($\sin\pi = \sin 0 = 0$). The resultant torque on the rectangular loop is in line with

$$\boldsymbol{\tau} = \boldsymbol{\mu} \times \mathbf{B},$$

   where the magnetic dipole moment of the loop

$$\boldsymbol{\mu} \equiv I\mathbf{A}.$$

   Thus, the loop experiences a net torque, but no net force—there is no displacement of the center of mass of the loop.

4. In Figure 4, a closed loop of wire travels at constant speed parallel to a long straight current-carrying wire. Will current be induced in the loop, and if so, in what direction?

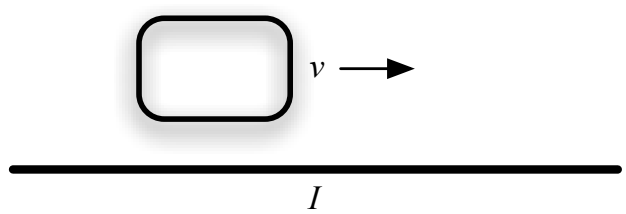

Figure 4: A wire loop traveling alongside a current-carrying wire.

   Solution

   There is no change in flux through the loop as it travels parallel to the wire, therefore no induced current.

5. A circular loop of radius 20 cm sits in a uniform magnetic field. The magnetic field is perpendicular to the plane of the coil and varies at a rate of 150 mT/s. What is the magnitude of the emf induced in the coil?

   Solution

   This is a simple problem involving Faraday's Law of Induction

$$\begin{aligned}\mathcal{E} &= -\frac{d\Phi_B}{dt} \\ &= \left|-\frac{d}{dt}\mathbf{B}\cdot\mathbf{A}\right| \\ &= \left|-\frac{d}{dt}BA\cos\theta\right| \\ &= \left|-A\frac{dB}{dt}\right| \\ &= \left|-\pi r^2\frac{dB}{dt}\right| \\ &= \left|-\pi(0.2)^2(0.150)\right| \\ &= \boxed{18.8\,\mathrm{mV}}.\end{aligned}$$

6. A solenoid of length 0.125 m and 225 loops carries a current of 0.55 A. What is the magnitude of the magnetic field inside the solenoid?

   Solution

   The magnetic field inside a solenoid is given by

$$\begin{aligned}B &= \mu_0 nI \\ &= \frac{\mu_0 NI}{L} \\ &= \frac{(4\pi\times10^{-7})(225)(0.55)}{0.125} \\ &= \boxed{1.24\,\mathrm{mT}}.\end{aligned}$$

7. The segment of wire in Figure 5 carries a current of 1.3 A. The curved portion is a section of a circle with the center at point **C**. If $r = 0.04$ m, what is the magnitude of the magnetic field at point **C**?

   Solution

   We can use the Biot-Savart Law to find the field at **C**, but Serway provides a ready-made expression on page 841:

$$\begin{aligned}B &= \frac{\mu_0 I}{4\pi r}\theta \\ &= \frac{(\cancel{4\pi}\times10^{-7})(1.3)}{\cancel{4\pi}(0.04)}\frac{\pi}{2} \\ &= \boxed{5.1\,\mu\mathrm{T}}.\end{aligned}$$

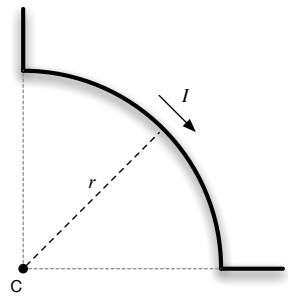

Figure 5: A segment of current-carrying wire.

8. In a region of space, the electric potential in volts is given by $V = 3y^2 - 4x^2z$. What is the electric field in this region?

   Solution

   The electric field is given by

$$\begin{aligned}\mathbf{E} &= -\nabla V \\ &= -(\frac{\partial V}{\partial x}\mathbf{i} + \frac{\partial V}{\partial y}\mathbf{j} + \frac{\partial V}{\partial z}\mathbf{k}) \\ &= \boxed{8xz\mathbf{i} - 6y\mathbf{j} + 4x^2\mathbf{k}}.\end{aligned}$$

9. The terminals of a 12 V battery are connected by a copper wire with resistivity 1.68×10^{-8} Ω·m and cross-sectional area 2.00×10^{-5} m^2. If the power dissipated is 1.90×10^3 W, what is the length of the wire?

   Solution

   The length l of a segment of wire is related to its resistivity ρ by

$$R = \rho\frac{l}{A}.$$

   Solving for l, we have

$$l = \frac{AR}{\rho}.$$

   To find the resistance, we solve for R in

$$\mathscr{P} = \frac{(\Delta V)^2}{R},$$

and we have

$$\begin{aligned} l &= \frac{A(\Delta V)^2}{\mathscr{P}\rho} \\ &= \frac{(2.00 \times 10^{-5})(12)^2}{(1.9 \times 10^3)(1.68 \times 10^{-8})} \\ &= \boxed{90\,\mathrm{m}}. \end{aligned}$$

10. (Bonus) For two extra points, on a separate sheet of paper, make a list of all the equations you used in solving the above problems. Define each variable in the context of that equation, just as we did in Homework 9. This time, also include the SI units for the value represented by each variable.