ECE1813 Fall 2015 Assignment #8 Solutions

Exercises and Problems from chapter 31

31.76. Model: Assume the battery and the connecting wires are ideal.
Visualize: Please refer to Figure CP31.76.
Solve: (a) If the switch has been closed for a long time, the capacitor is fully charged and there is no current flowing through the right branch that contains the capacitor. Therefore, a voltage of 60 V appears across the $60\ \Omega$ resistor and a voltage of 40 V appears across the $40\ \Omega$ resistor. That is, maximum voltage across the capacitor is 40 V. Thus, the charge on the capacitor is

$$Q_0 = \varepsilon C = (40\text{ V})(2.0\times10^{-6}\text{ F}) = 80\ \mu\text{C}$$

(b) Once the switch is opened, the battery is disconnected from the capacitor. The capacitor C has two resistances ($10\ \Omega$ and $40\ \Omega$, which give a $50\ \Omega$ equivalent resistance) in series and discharges according to $Q = Q_0 e^{-t/RC}$. For $Q = 0.10Q_0$,

$$0.10Q_0 = Q_0 e^{-t/[(50\ \Omega)(2.0\ \mu\text{F})]} \Rightarrow \ln(0.10) = -\frac{t}{(50\ \Omega)(2.0\ \mu\text{F})}$$

$$t = -(50\ \Omega)(2.0\ \mu\text{F})\ln(0.10) = 0.23\text{ ms}$$

Conceptual Questions from chapter 32

32.5. The magnetic field is into the page on the left of the wire and it is out of the page on the right of the wire. Grab the wire with your right hand in such a way that your fingers point out of the page to the right of the wire. Since the thumb now points down, the current in the wire is down.

32.6. (a) The force on a charge moving in a magnetic field is

$$\vec{F}_{\text{on q}} = q\vec{v}\times\vec{B} = (qvB\sin\alpha,\text{ direction of right-hand rule})$$

A *positive* charge moving to the right with $\vec{B}$ into the page gives a force that is *up*.
(b) The direction of the force on a negative charge is opposite the direction determined by the right-hand rule. A *negative* charge moving up with $\vec{B}$ out of the page gives a force to the left.

32.9. (a) The force on a charge moving in a magnetic field is

$$\vec{F}_{\text{on q}} = q\vec{v}\times\vec{B} = (qvB\sin\alpha,\text{ direction of right-hand rule})$$

The direction of the force on a negative charge is opposite the direction determined by the right-hand rule. Since the force $\vec{F}$ is *out of the page* and the velocity of the negative charge is to the left and up in the plane of the paper, the magnetic field $\vec{B}$ must be in the plane of the page, 45° clockwise from straight up.
(b) The magnetic field on the positive charge is in the plane of the page, 45° counterclockwise from straight down.

Exercises and Problems from chapter 32

32.2. Model: A magnetic field is caused by an electric current.
Solve: The current in the wire is directed to the right. $B_2 = 20\text{ mT} + 20\text{ mT} = 40\text{ mT}$ because the two overlapping wires are carrying current in the same direction and each wire produces a magnetic field having the same direction at point 2. $B_3 = 20\text{ mT} - 20\text{ mT} = 0\text{ mT}$, because the two overlapping wires carry currents in opposite directions and each wire produces a field having opposite directions at point 3. The currents at 4 are also in opposite directions, but the point is to the right of one wire and to the left of the other. From the right-hand rule, the field of both currents is out of the page. Thus $B_4 = 20\text{ mT} + 20\text{ mT} = 40\text{ mT}$.

32.11. Model: The magnetic field is that of a current loop.
Solve: **(a)** From Equation 32.7, the magnetic field strength at the center of a loop is

$$B_{\text{loop center}} = \frac{\mu_0 I}{2R} \Rightarrow I = \frac{2RB_{\text{loop center}}}{\mu_0} = \frac{2(0.50\times10^{-2}\text{ m})(2.5\times10^{-3}\text{ T})}{4\pi(10^{-7}\text{ T m/A})} = 20\text{ A}$$

(b) For a long, straight wire that carries a current I, the magnetic field strength is

$$B_{\text{wire}} = \frac{\mu_0 I}{2\pi d} \Rightarrow 2.5\times10^{-3}\text{ T} = \frac{4\pi(10^{-7}\text{ T m/A})(20\text{ A})}{2\pi d} \Rightarrow d = 1.6\times10^{-3}\text{ m}$$

32.16. Solve: **(a)** The magnetic dipole moment of the superconducting ring is

$$\mu = (\pi R^2)I = \pi(1.0\times10^{-3}\text{ m})^2(100\text{ A}) = 3.1\times10^{-4}\text{ A m}^2$$

(b) From Example 32.5, the on-axis magnetic field of the superconducting ring is

$$B_{\text{ring}} = \frac{\mu_0}{2}\frac{IR^2}{(z^2+R^2)^{3/2}} = \frac{2\pi(10^{-7}\text{ T m/A})(100\text{ A})(1.0\times10^{-3}\text{ m})^2}{\left[(0.050\text{ m})^2 + (0.0010\text{ m})^2\right]^{3/2}} = 5.0\times10^{-7}\text{ T}$$

32.34. Model: Assume that the magnetic field is uniform over the 10 cm length of the wire. Force on top and bottom pieces will cancel.
Visualize: The figure shows a 10-cm-segment of a circuit in a region where the magnetic field is directed into the page.
Solve: The current through the 10-cm-segment is

$$I = \frac{\varepsilon}{R} = \frac{15\text{ V}}{3\ \Omega} = 5\text{ A}$$

and is flowing *down*. The force on this wire, given by the right-hand rule, is to the right and perpendicular to the current and the magnetic field. The magnitude of the force is

$$F = ILB = (5\text{ A})(0.10\text{ m})(50\text{ mT}) = 0.025\text{ N}$$

Thus $\vec{F} = (0.025\text{ N, right})$.

32.36. Model: Two parallel wires carrying currents in opposite directions exert repulsive magnetic forces on each other. Two parallel wires carrying currents in the same direction exert attractive magnetic forces on each other.

Solve: The magnitudes of the various forces between the parallel wires are

$$F_{2\text{ on }1} = \frac{\mu_0 L I_1 I_2}{2\pi d} = \frac{(2\times10^{-7}\text{ T m/A})(0.50\text{ m})(10\text{ A})(10\text{ A})}{0.02\text{ m}} = 5.0\times10^{-4}\text{ N} = F_{2\text{ on }3} = F_{3\text{ on }2} = F_{1\text{ on }2}$$

$$F_{3\text{ on }1} = \frac{\mu_0 L I_1 I_3}{2\pi d} = \frac{(2\times10^{-7}\text{ T m/A})(0.50\text{ m})(10\text{ A})(10\text{ A})}{0.04\text{ m}} = 2.5\times10^{-4}\text{ N} = F_{1\text{ on }3}$$

Now we can find the net force each wire exerts on the other as follows:

$$\vec{F}_{\text{on }1} = \vec{F}_{2\text{ on }1} + \vec{F}_{3\text{ on }1} = (5.0\times10^{-4}\,\hat{j})\text{ N} + (-2.5\times10^{-4}\,\hat{j})\text{ N} = 2.5\times10^{-4}\,\hat{j}\text{ N} = (2.5\times10^{-4}\text{ N, up})$$

$$\vec{F}_{\text{on }2} = \vec{F}_{1\text{ on }2} + \vec{F}_{3\text{ on }2} = (-5.0\times10^{-4}\,\hat{j})\text{ N} + (+5.0\times10^{-4}\,\hat{j})\text{ N} = 0\text{ N}$$

$$\vec{F}_{\text{on }3} = \vec{F}_{1\text{ on }3} + \vec{F}_{2\text{ on }3} = (2.5\times10^{-4}\,\hat{j})\text{ N} + (-5.0\times10^{-4}\,\hat{j})\text{ N} = -2.5\times10^{-4}\,\hat{j}\text{ N} = (2.5\times10^{-4}\text{ N, down})$$