Microphones, ground fault circuit interrupters, seismographs, and read/write heads for computer drives and tape recorders are applications of electromagnetic induction.

[*A changing current in a coil of wire will produce a changing magnetic field that induces an emf in a second coil placed nearby. The **mutual inductance**, M, is defined by

$$\mathscr{E}_2 = -M\frac{\Delta I_1}{\Delta t}. \qquad \textbf{(21–8)}]$$

[*Within a single coil, the changing B due to a changing current induces an opposing emf, $\mathscr{E}$, so a coil has a **self-inductance** L defined by

$$\mathscr{E} = -L\frac{\Delta I}{\Delta t}. \qquad \textbf{(21–9)}]$$

[*The energy stored in an inductance L carrying current I is given by $U = \frac{1}{2}LI^2$. This energy can be thought of as being stored in the magnetic field of the inductor. The energy density u in any magnetic field B is given by

$$u = \frac{1}{2}\frac{B^2}{\mu_0}. \qquad \textbf{(21–10)}]$$

[*When an inductance L and resistor R are connected in series to a source of emf, V, the current rises as

$$I = \frac{V}{R}(1 - e^{-t/\tau}),$$

where $\tau = L/R$ is the time constant. If the battery is suddenly switched out of the LR circuit, the current drops exponentially, $I = I_{\max}e^{-t/\tau}$.]

[*Inductive and capacitive **reactance**, X, defined as for resistors, is the proportionality constant between voltage and current (either the rms or peak values). Across an inductor,

$$V = IX_L, \qquad \textbf{(21–11a)}$$

and across a capacitor,

$$V = IX_C. \qquad \textbf{(21–12a)}$$

The reactance of an inductor increases with frequency

$$X_L = 2\pi fL, \qquad \textbf{(21–11b)}$$

whereas the reactance of a capacitor decreases with frequency f,

$$X_C = \frac{1}{2\pi fC}. \qquad \textbf{(21–12b)}$$

The current through a resistor is always in phase with the voltage across it, but in an inductor, the current lags the voltage by 90°, and in a capacitor the current leads the voltage by 90°.]

[*In an LRC series circuit, the total **impedance** Z is defined by the equivalent of $V = IR$ for resistance, namely,

$$V_0 = I_0 Z \quad \text{or} \quad V_{\text{rms}} = I_{\text{rms}}Z; \qquad \textbf{(21–14)}$$

Z is given by

$$Z = \sqrt{R^2 + (X_L - X_C)^2}. \qquad \textbf{(21–15a)}]$$

[*An LRC series circuit **resonates** at a frequency given by

$$f_0 = \frac{1}{2\pi}\sqrt{\frac{1}{LC}}. \qquad \textbf{(21–19)}$$

The rms current in the circuit is largest when the applied voltage has a frequency equal to f_0.]

Questions

1. What would be the advantage, in Faraday's experiments (Fig. 21–1), of using coils with many turns?
2. What is the difference between magnetic flux and magnetic field?
3. Suppose you are holding a circular ring of wire and suddenly thrust a magnet, south pole first, away from you toward the center of the circle. Is a current induced in the wire? Is a current induced when the magnet is held steady within the ring? Is a current induced when you withdraw the magnet? In each case, if your answer is yes, specify the direction.
4. Two loops of wire are moving in the vicinity of a very long straight wire carrying a steady current as shown in Fig. 21–43. Find the direction of the induced current in each loop.

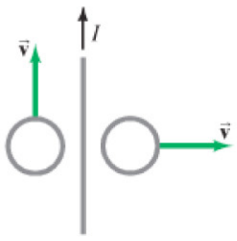

FIGURE 21–43 Question 4.

5. Suppose you are looking along a line through the centers of two circular (but separate) wire loops, one behind the other. A battery is suddenly connected to the front loop, establishing a clockwise current. (*a*) Will a current be induced in the second loop? (*b*) If so, when does this current start? (*c*) When does it stop? (*d*) In what direction is this current? (*e*) Is there a force between the two loops? (*f*) If so, in what direction?
6. In Fig. 21–44, determine the direction of the induced current in resistor R_A when (*a*) coil B is moved toward coil A, (*b*) when coil B is moved away from A, (*c*) when the resistance R_B is increased.

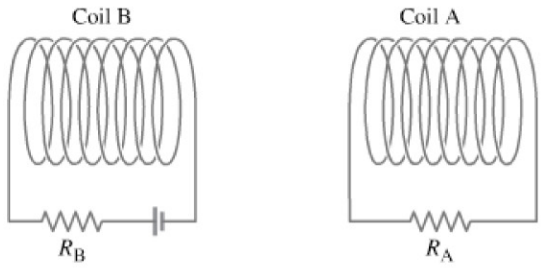

FIGURE 21–44 Question 6.

7. In situations where a small signal must travel over a distance, a "shielded cable" is used in which the signal wire is surrounded by an insulator and then enclosed by a cylindrical conductor carrying the return current. Why is a "shield" necessary?
8. What is the advantage of placing the two insulated electric wires carrying ac close together or even twisted about each other?

* 9. Explain why, exactly, the lights may dim briefly when a refrigerator motor starts up. When an electric heater is turned on, the lights may stay dimmed as long as the heater is on. Explain the difference.