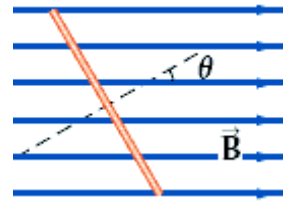# Chapter 23: Magnetic Flux and Faraday's Law of Induction

3. The image shows a rectangular loop oriented 42 degrees from a magnetic field.

    Solve equation 23-1 for the magnetic field.

    Calculate
    the magnetic field:

    $$B = \frac{\Phi}{A\cos\theta} = \frac{4.8\times10^{-5}\ \text{Tm}^2}{(0.051\ \text{m})(0.068\ \text{m})\cos 47°} = \boxed{0.020\ \text{T}}$$

4. A house has a floor of dimensions 22 m by 18 m. The local magnetic field due to Earth has a horizontal component 2.6×10^{-5} T and a downward vertical component 4.2×10^{-5} T.

    The horizontal component of the magnetic field is parallel to the floor, so it does not contribute to the flux. Use equation 23-1 to calculate the flux using the vertical component.

    Calculate the magnetic flux:

    $$\Phi = BA\cos\theta = B_\perp A = (4.2\times10^{-5}\ \text{T})(22\ \text{m})(18\ \text{m}) = \boxed{1.7\times10^{-2}\ \text{Wb}}$$

6. A magnetic field of magnitude 5.9×10^{-5} T is directed 72° below the horizontal and passes through a horizontal region 130 cm by 82 cm.

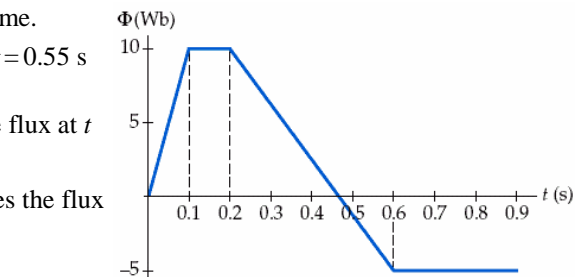   Use equation 23-1 to calculate the flux, where the angle from the vertical is $\theta = 90° - 72°$.

    Calculate the flux:

    $$\Phi = BA\cos\theta = (5.9\times10^{-5}\ \text{T})(1.30\ \text{m})(0.82\ \text{m})\cos(90° - 72°) = \boxed{6.0\times10^{-5}\ \text{Wb}}$$

14. The image shows the emf through a single loop as a function of time.

    Use equation 23-3 to calculate the emf at the times $t = 0.25$ s and $t = 0.55$ s

    1. (a) The flux at $t = 0.25$ s is about 8 Wb. This is $\boxed{\text{greater}}$ than the flux at $t = 0.55$ s, which is about −3 Wb.

    2. (b) The two emf values are the $\boxed{\text{same}}$, because at those two times the flux is changing at the same rate.

    3. (c) Calculate the slope of the flux between 0.2 s and 0.6 s:

    $$\frac{\Delta\Phi}{\Delta t} = \frac{-5\ \text{Wb} - 10\ \text{Wb}}{0.6\ \text{s} - 0.2\ \text{s}} = -37.5\ \text{Wb/s}$$

    $$\varepsilon = -N\frac{\Delta\Phi}{\Delta t} = -1(-37.5\ \text{Wb/s}) = \boxed{0.04\ \text{kV}}$$

    4. Calculate the induced emf :

17. A coil with 120 loops is oriented perpendicular to a changing magnetic field.

    Solve equation 23-4 for the emf, where the magnetic flux is given by equation 23-1.

    Calculate the emf :

    $$|\varepsilon| = N\left|\frac{\Delta\Phi}{\Delta t}\right| = N\left|\frac{BA - (-BA)}{\Delta t}\right| = N\left|\frac{2BA}{\Delta t}\right| = 120\left|\frac{2(0.20\ \text{T})(0.050\ \text{m}^2)}{0.34\ \text{s}}\right| = \boxed{7.1\ \text{V}}$$

19. A number of circular loops of wire are oriented perpendicular to a changing magnetic field.

Strategy: Solve equation 23-4 for the number of coils, with the flux given by equation 23-1. The radius of the loops is $r = \frac{1}{2}d = \frac{1}{2}(0.12 \text{ m}) = 0.060 \text{ m}$.

Find the number of coils:

$$|\mathcal{E}| = N\left|\frac{\Delta\Phi}{\Delta t}\right| \Rightarrow N = |\mathcal{E}|\left|\frac{\Delta t}{\Delta\Phi}\right| = |\mathcal{E}|\left|\frac{\Delta t}{BA}\right| = 6.0 \text{ V}\left|\frac{1.8 \text{ s}}{(0.25 \text{ T})\pi(0.060 \text{ m})^2}\right| = \boxed{3.8\times10^3}$$

26. The image shows a loop of wire dropping between the poles of a magnet.

Use Lenz's Law to determine the direction of the induced current.

1. **(a)** When the loop is above the magnet, the magnetic field is increasing and directed out of the page. The current in the loop will oppose the increasing field by flowing clockwise.

2. **(b)** When the loop is below the magnet, the magnetic field is decreasing and is directed out of the page. The current in the loop will oppose the decreasing field by flowing counterclockwise.
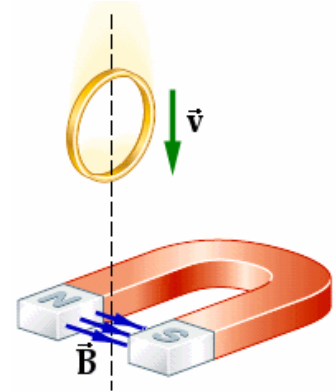
30. The image shows a loop with resistance R to the left of a current that switches from upward to downward.

Use Lenz's Law to determine the direction of the induced current in the loop.

When the current in the wire changes direction, the direction of the magnetic field is reversed, changing its direction from out of the page to into the page (it is shown in its final condition). According to Lenz's Law, the current induced in the circuit will oppose this change by flowing counterclockwise, generating a field that is directed out of the page.

33. The image shows a circuit containing a resistor and capacitor. A magnetic field pointing into the page increases in magnitude.

Use Lenz's Law to determine the direction of current flow. As the current flows onto the capacitor plate it becomes positively charged.

If the magnetic field increases into the page, the current in the circuit will flow counterclockwise to generate a field to oppose the increase. So, the bottom plate will become positively charged.
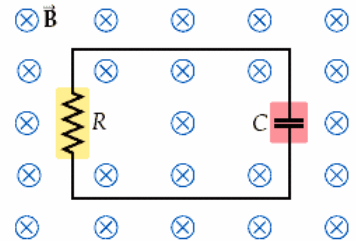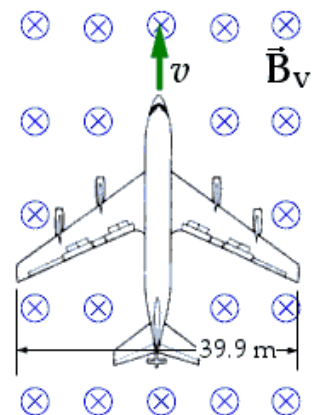

37. The image shows an airplane with wingspan 39.9 m flying northward at 850 km/h through a magnetic field with vertical component of $B_v = 5.0\times10^{-6}$ T.
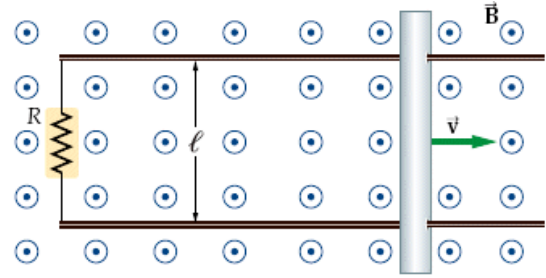
Solve equation 23-5 for the induced emf.

Calculate the induced emf :

$$\mathcal{E} = vB\ell = \left(850 \frac{\text{km}}{\text{h}}\right)\left(\frac{1 \text{ h}}{3600 \text{ s}}\right)(5.0 \ \mu\text{T})(39.9 \text{ m})$$

$$= \boxed{47 \text{ mV}}$$

38. The image shows a frictionless rod sliding across two rails separated by 0.45 m. A magnetic field of 0.750 T points out of the page.

   Calculate the emf using Ohm's Law (equation 21-2). Insert the emf into equation 23-3 and solve for the speed of the rod.

   1. (a) Calculate ε:

   $$|\varepsilon| = IR$$
   $$= (0.155\text{ A})(12.5\ \Omega)$$
   $$|\varepsilon| = 1.94\text{ V}$$

   2. Solve for v:

   $$v = \frac{\varepsilon}{B\ell} = \frac{1.94\text{ V}}{(0.750\text{ T})(0.450\text{ m})} = \boxed{5.75\text{ m/s}}$$

   3. (b) $\boxed{\text{No}}$, the answer to part (a) would not change because the equation for v is independent of the direction of motion of the bar.

45. A coil with 155 turns of diameter 22.0 cm rotates at 1250 rpm in Earth's magnetic field.

   Use equation 23-11 to calculate the maximum emf.

   1. (a) Only the $\boxed{\text{horizontal}}$ component of the magnetic field is important. The vertical component is parallel to the plane of the circular coil at all times. Thus, it does not contribute to the flux through the coil.

   2. (b) Calculate ε_{max}:

   $$\varepsilon_{max} = NBA\omega = 155(3.80\times10^{-5}\text{ T})\pi(0.11\text{ m})^2\left(1250\ \frac{\text{rev}}{\text{min}}\right)\left(\frac{2\pi\text{ rad}}{1\text{ rev}}\right)\left(\frac{1\text{ min}}{60\text{ s}}\right) = \boxed{29.3\text{ mV}}$$

70. A transformer that has a turns ratio of 1:13 is used to step down a 120-V voltage source.

   Solve equation 23-22 for the voltage in the secondary coil.

   Calculate the secondary voltage:

   $$V_s = V_p\left(\frac{N_s}{N_p}\right) = 120\text{ V}\left(\frac{1}{18}\right) = \boxed{6.7\text{ V}}$$

72. A transformer converts a primary voltage $V_p = 120\text{ V}$ to a secondary voltage $V_s = 6.0\text{ V}$.

   Use equation 23-22 to calculate the ratio of the primary turns to secondary turns when the primary is 120 V and the secondary is 6.0 V. Then solve the equation for the primary voltage if the secondary voltage is 120 V.

   1. Calculate the turn ratio:

   $$\frac{N_p}{N_s} = \frac{V_p}{V_s} = \frac{120\text{ V}}{6.0\text{ V}} = 20$$

   2. Solve for the primary voltage:

   $$V_p' = V_s\left(\frac{N_p}{N_s}\right) = (120\text{ V})(20) = \boxed{2.4\text{ kV}}$$