

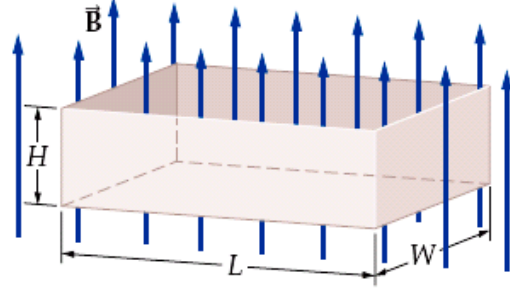
Solutions to Problems : Chapter 23

Problems appeared on the end of chapter 23 of the **Textbook**

2. **Picture the Problem:** The image shows a box immersed in a vertical magnetic field.

Strategy: Use equation 23-1 to calculate the flux through each side.

Solution: 1. The sides of the box are parallel to the field, so the magnetic flux through the sides is zero.



2. Calculate the flux through the bottom: $\Phi = BA \cos \theta = (0.0250 \text{ T})(0.325 \text{ m})(0.120 \text{ m}) \cos 0^\circ = \boxed{9.75 \times 10^{-4} \text{ Wb}}$.

Insight: The height of the box is not important in this problem.

6. **Picture the Problem:** A magnetic field of magnitude $5.9 \times 10^{-5} \text{ T}$ is directed 72° below the horizontal and passes through a horizontal region 130 cm by 82 cm.

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

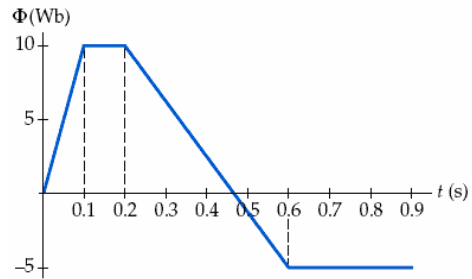
Solution: Calculate the flux: $\Phi = BA \cos \theta = (5.9 \times 10^{-5} \text{ T})(1.30 \text{ m})(0.82 \text{ m}) \cos(90^\circ - 72^\circ) = \boxed{6.0 \times 10^{-5} \text{ Wb}}$

Insight: Increasing the angle from the horizontal increases the flux through the desk top. For example, if the angle were increased to 80° from the horizontal the total flux would increase to $6.2 \times 10^{-5} \text{ Wb}$.

12. **Picture the Problem:** The image shows the emf through a single loop as a function of time.

Strategy: Use equation 23-3 to calculate the emf at the times $t = 0.25 \text{ s}$ and $t = 0.55 \text{ s}$

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



2. **(b)** The two emf values are the 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: $\frac{\Delta \Phi}{\Delta t} = \frac{-5 \text{ Wb} - 10 \text{ Wb}}{0.6 \text{ s} - 0.2 \text{ s}} = -37.5 \text{ Wb/s}$

4. Calculate the induced emf:

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

Insight: Note that the emf is zero for times $0.1 \text{ s} < t < 0.2 \text{ s}$ and $t > 0.6 \text{ s}$. The voltage is not determined by the magnitude of the flux but by the slope of the flux vs. time graph. For these two

time periods the slope is zero.

14. **Picture the Problem:** The image shows a single loop of area $7.4 \times 10^{-2} \text{ m}^2$ and resistance 110Ω . The loop is perpendicular to a magnetic field.

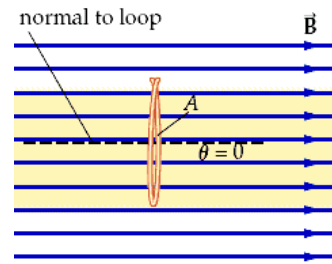
Strategy: Solve Ohm's Law (equation 21-2) for the necessary emf. Then insert the emf into equation 23-4 to calculate the rate of change in the magnetic field.

Solution: 1. Calculate the emf: $|\mathcal{E}| = |IR| = (0.32 \text{ A})(110 \Omega) = 35.2 \text{ V}$

2. Solve equation 23-4 for the change in magnetic field:

$$|\mathcal{E}| = N \left| \frac{\Delta \Phi}{\Delta t} \right| = N \left| \frac{A \Delta B}{\Delta t} \right|$$

$$\left| \frac{\Delta B}{\Delta t} \right| = \frac{|\mathcal{E}|}{NA} = \frac{35.2 \text{ V}}{1(7.4 \times 10^{-2} \text{ m}^2)} = 4.8 \times 10^2 \text{ T/s}$$



Insight: The magnitude of the magnetic field (0.28 T) is not important in this problem, only the change in the field.

19. **Picture the Problem:** The image shows a loop of wire dropping between the poles of a magnet.

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

Solution: 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.

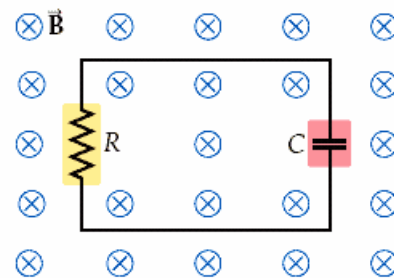
2. (b) When the loop is below the magnet, the magnetic field is decreasing and is directed out of the page. The current in the loop will oppose the decreasing field by flowing counterclockwise.

Insight: When the loop is directly between the two poles the flux is a maximum, and therefore momentarily not changing. At this point the induced current is zero.

25. **Picture the Problem:** The image shows a circuit containing a resistor and capacitor. A magnetic field initially pointing into the page reverses to point out of the page.

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

Solution: Since the field changes from in to out of the page, the induced current in the circuit will flow clockwise to generate a field directed into the page. Therefore, the top plate will become positively charged.

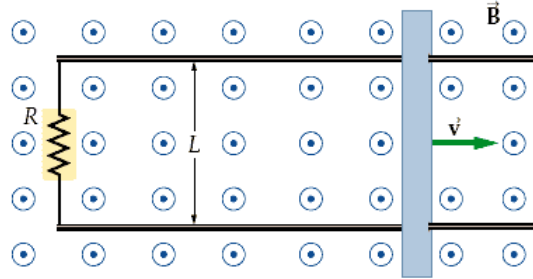


Insight: As the capacitor plate becomes charged it opposes the induced current. The emf around the loop is still the same as given by equation 23-3, but the voltage across the capacitor ($V = Q/C$) must

be subtracted to calculate the current through the resistor.

30. **Picture the Problem:** 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.

Strategy: 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.



Solution: 1. (a)

$$|\mathcal{E}| = IR$$

Calculate \mathcal{E} :

$$= (0.125 \text{ A})(12.5 \Omega)$$

$$|\mathcal{E}| = 1.5625 \text{ V}$$

2. Solve for v :

$$v = \frac{\mathcal{E}}{BL} = \frac{1.5625 \text{ V}}{(0.750 \text{ T})(0.45 \text{ m})} = \boxed{4.6 \text{ m/s}}$$

3. (b) The equation for v is independent of the direction of motion of the bar, so the answer to part (a) would not change.

Insight: Lenz's law says that as the bar moves to right, the current flows upward in the resistor. If the bar moved at the same speed to the left, the same current would flow downward through the resistor.

34. **Picture the Problem:** The emf produced by a rotating coil is proportional to the speed of the coil rotation.

Strategy: Use equation 23-11 to determine the maximum emf as a function of the rotation speed. Place all of the constants on the right side of the equation and develop a ratio for the maximum emf and rotation speed. Solve the resulting ratio for the unknown rotation speed.

Solution: 1. Create a ratio using equation 23-11:

$$\frac{\mathcal{E}_{\max 1}}{\omega_1} = NBA = \frac{\mathcal{E}_{\max 2}}{\omega_2}$$

2. Solve for the final rotation speed:

$$\omega_2 = \frac{\mathcal{E}_{\max 2}}{\mathcal{E}_{\max 1}} \omega_1 = \frac{55 \text{ V}}{45 \text{ V}} (210 \text{ rpm}) = \boxed{260 \text{ rpm}}$$

Insight: The emf is linearly proportional to the rotation speed. Doubling the rotation speed will double the emf.

38. **Picture the Problem:** A set of coils with area 0.016 m² rotate at 3600 rpm in a 0.050-T magnetic field. The coils produce an emf of 170 V.

Strategy: Solve equation 23-11 for the number of turns N .

Solution:

Calculate the number of turns:

$$N = \frac{\mathcal{E}_{\max}}{BA\omega} = \frac{170 \text{ V}}{(0.050 \text{ T})(0.016 \text{ m}^2)(3600 \text{ rev/min})} \left(\frac{\text{rev}}{2\pi \text{ rad}} \right) \left(\frac{60 \text{ s}}{\text{min}} \right) = \boxed{560 \text{ turns}}$$

Insight: Note that the magnetic field and number of turns are inversely proportional. To produce the

same emf at the same frequency with half the number of coils it would be necessary to double the magnetic field.

60. **Picture the Problem:** A transformer converts a primary voltage $V_p = 120 \text{ V}$ to a secondary voltage $V_s = 6.0 \text{ V}$.

Strategy: 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.

Solution: 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:

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

Insight: Care must be taken to ensure that the transformer is properly installed. A reversed transformer will easily damage the circuit and possibly start a fire!