

Study Guide for Midterm 3 for Algebra-Based Physics: Electricity and Magnetism

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1 Equations and constants

1. Kirchhoff's Rules: 1) $I_{in} + I_{out} = 0$ (Junction Rule) 2) $\sum_{loop} V_i = 0$ (Loop Rule)
2. Power from current and voltage: $P = iV$
3. Power from current and resistance: $P = I^2 R$
4. Definition of magnetic flux: $\phi = \vec{B} \cdot \vec{A}$. The units are T m^2 , which is called a Weber, or Wb.
5. Faraday's Law: $emf = -N \frac{\Delta\phi}{\Delta t}$
6. Faraday's Law using **Inductance**, M: $emf = -M \Delta I / \Delta t$.
7. Magnetic permeability: $\mu_0 = 4\pi \times 10^{-7} \text{ T m A}^{-1}$
8. Units of inductance: V s A^{-1} , which is called a Henry, or H.

2 Exercises

1. Review Problem (similar exercise on the final)

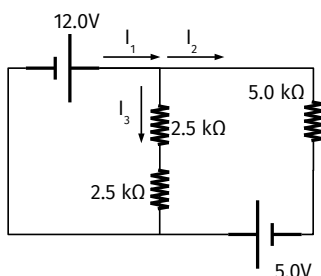


Figure 1: A circuit with three resistors.

- (a) Solve for the currents I_1 - I_3 in Fig. 1.

$$I_3 = 12/5 \text{ mA}, I_2 = 17/5 \text{ mA}, \text{ and } I_1 = 29/5 \text{ mA}.$$

- (b) What is the power consumed by each resistor in Fig. 1?

Two of the resistors (the ones with $2.5 \text{ k}\Omega$) each consume $P = IV = I_3 \times V_1 = 2.5 \times 10^{-3} \times 12.0 \text{ W}$ which is 30 mW . The other resistor consumes $P = I^2 R = I_2^2 \times 5.0 \text{ k}\Omega$, so $(17/5 \times 10^{-3})^2 5.0 \times 10^3 = 57.8 \text{ mW}$.

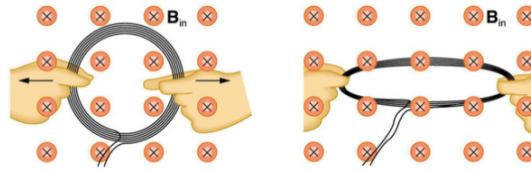


Figure 2: (Left) A magnetic field passes through loops of wire. (Right) The loops are stretched, reducing the area.

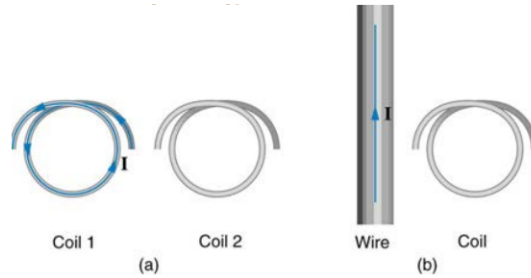


Figure 3: (a) The coils lie in the same plane. (b) The wire is in the plane of the coil.

2. Chapter 23: Magnetic Induction, Faraday's Law, and AC power

- (a) In Fig. 2 (left) a uniform magnetic field passes through loops of wire. In Fig. 2 (right) the **area** of the loops is reduced by stretching the loops. Which of the following is true?
- A: No current flows through the wires.
 - B: Current does flow through the wires, but there is no induced emf in the wires.
 - C: Current flows through the wires, because the induced emf is caused by a change in electric flux.
 - D: Current flows through the wires, because the induced emf is caused by a change in magnetic flux.
- (The answer is D. Magnetic flux $\phi = \vec{B} \cdot \vec{A} = BA$ in this case. If the area changes, so does the flux.

- (b) Consider again the system in Fig. 2. The initial area is $A_i = 0.02 \text{ m}^2$, the final area is one-half, or $A_f = 0.01 \text{ m}^2$, and the transition from A_i to A_f takes 0.1 seconds. The B-field strength is 0.1 T. What is $\Delta\phi/\Delta t$?

The change in flux is $\Delta\phi = B\Delta A$, because the B-field is not changing. Thus, $\phi_f = BA_f$ and $\phi_i = BA_i$. Subtracting, we get the change in flux: $\Delta\phi = B(A_f - A_i) = 0.1 \times (0.02 - 0.01) = 0.1 \times 0.01 = 10^{-3} \text{ Wb}$. That makes $\Delta\phi/\Delta t = 10^{-3}/0.1 = 10^{-2} \text{ Wb/s}$, or 10^{-2} V (10 mV).

- (c) Continuing with Fig. 2, if $\Delta\phi/\Delta t$ gives 10 mV, and the coil of wire has 100 turns, what is the induced emf in the coil?

Apply Faraday's Law: $-N\Delta\phi/\Delta t = -100 \times 10 \text{ mV}$, or -1.0 V .

- (d) Consider Fig. 3 (left). In which direction is the current in the right-hand coil induced, if the current in the left-hand coil (a) increases? (b) decreases?

(a) If the counter-clockwise current on the left *increases*, the corresponding flux *into the page* in the right-hand coil will increase. Therefore, the right-hand coil will resist the change. That means that the B-field generated will have to be *out of the page* and therefore we get a **counter-clockwise** current. (b) The exact opposite will happen if the current at left decreases, so we get a **clockwise** current.

- (e) Assume that the current in the wire in Fig. 3 (right) is not changing. (a) Is there any induced emf in the coil at right? (b) Suppose the current changes at a rate of 25.0 A/s, and the mutual inductance M in the system is 0.1 mH. What is the induced emf in the coil?

(a) No - only if the current changes will there be any induced emf. (b) Applying Faraday's law with inductance, we have $\text{emf} = -M\Delta I/\Delta t = 0.1 \times 10^{-3} \times 25 = 2.5 \times 10^{-3} = 2.5 \text{ mV}$.