# CALCULUS-BASED PHYSICS-2: ELECTRICITY, MAGNETISM, AND THERMODYNAMICS (PHYS180-02): UNIT 5

Jordan Hanson

April 12, 2019

Whittier College Department of Physics and Astronomy

# UNIT 4 REVIEW

Suppose a bundle of wires is carrying current along what we call the $\hat{z}$ direction. Each wire runs along the z-axis and they are close enough to ignore the fact that the volume of each wire prevents it from being exactly on the z-axis. One wire carries +2.0 A, another carries +1.5 A, and a third carries -0.5 A. What is the B-field strength at a distance of 1 cm away in the x-y plane?

- A: 6 Gauss
- B: 0.6 Gauss
- C: 6 Tesla
- D: 0.6 Tesla

Suppose a loop of current exists in the x-y plane, and a uniform B-field is in the $\hat{z}$ direction. Which of the following will occur?

- A: The loop will not rotate - there is no torque.
- B: The loop will rotate 180 degrees - there is torque.
- C: The loop will rotate 90 degrees - there is torque.
- D: The loop will rotate -90 degrees - there is negative torque.

# SUMMARY

**Reading: Chapters 13 and 14**

*This weekend:*

1. 13.1-2: Faraday's and Lenz's Law
2. 13.3: Motional EMF
3. 13.4: Induced E-fields

*Next week:* Chapter 14.1-3

# FARADAY'S LAW AND LENZ'S LAW

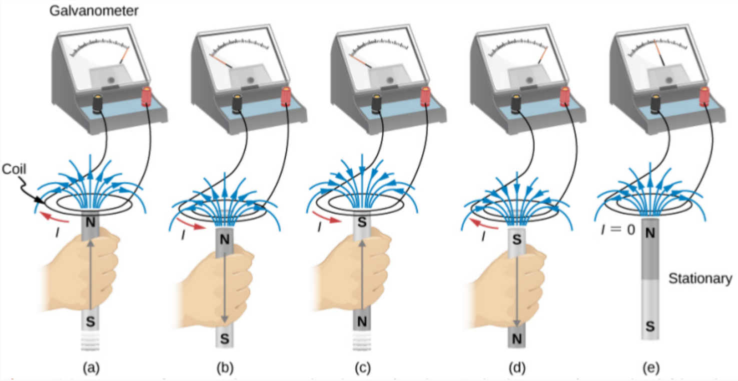


**Figure 1:** Not only does moving charge create B-fields, but B-fields can create moving charge. Study each of the cases above, and (Professor) define the concept of *magnetic flux*.

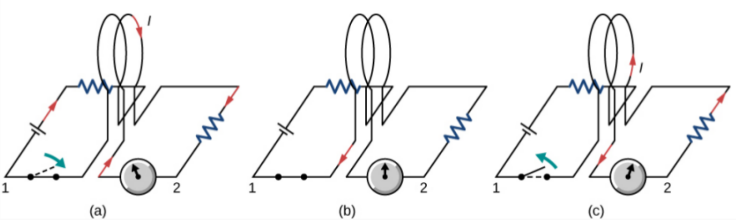


Figure 2: In addition to a moving magnetic field, *other circuits* can make current flow in a circuit. The effect must have something to do with *changing* magnetic fields.

### Faraday's Law

The emf $\epsilon$ induced is the negative change in the magnetic flux $\Phi_m$ per unit time. Any change in the magnetic field or change in orientation of the area of the coil with respect to the magnetic field induces a voltage (emf).

$$\phi_m = \int_S \vec{B} \cdot d\vec{A} \tag{1}$$

$$\epsilon = -\frac{d\phi_m}{dt} \tag{2}$$

*The unit of magnetic flux is the Webter, or 1 Wb = 1 T $m^2$.*

**Example:** A square coil has sides 0.25 m long and is tightly wound with 200 turns of wire. The resistance of the coil 5.0 Ohms. The coil is placed in a spatially uniform magnetic field that is directed perpendicular to the face of the coil and whose magnitude is decreasing by −0.040 T/s. (a) What is the magnitude of the emf induced in the coil? (b) What is the magnitude of the current circulating through the coil?

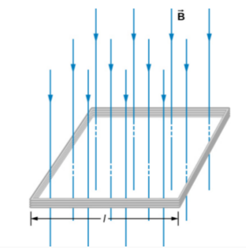


**Figure 3:** A 200 turn loop in a B-field.

**Lenz's Law**

The direction of the induced emf drives current around a wire loop to always oppose the change in magnetic flux that causes the emf.

**Example:** A magnetic field B is directed outward perpendicular to the plane of a circular coil of radius r = 0.50 m. The field is cylindrically symmetrical with respect to the center of the coil, and its magnitude decays exponentially according to

$$B(t) = B_0 \exp(-at) \tag{3}$$

with $B_0 = 1.5$ T and $a = 5.0\ \mathrm{s}^{-1}$. (a) Calculate the emf induced in the coil at the times $t_0 = 0$, $t_1 = 0.05$, and $t_2 = 1.0$ seconds. (b) Determine the current in the coil if the resistance is 10 Ohms.

# CONCLUSION

**Reading: Chapters 13 and 14**

*This weekend:*

1. 13.1-2: Faraday's and Lenz's Law
2. 13.3: Motional EMF
3. 13.4: Induced E-fields

*Next week:* Chapter 14.1-3

# ANSWERS - CHAPTER 13 AND UNIT 4 REVIEW

# ANSWERS

- B
- A

- ...

# ANSWERS - CHAPTER 14

# ANSWERS

- ...

- ...