Electromagnetic Induction

Topic 12—Section 1
Syll. Statements due Wednesday, Nov. 18

- In a mass spectrometer two ions with identical charge and speed are accelerated into two different semicircular arcs. Ion A's arc has a radius of 25.0 cm, and Ion B's arc has a radius of 50.0 cm. What can you say about their relative masses?
  - A. The two masses are equal to each other
  - B. The mass of ion B is double the mass of ion A
  - C. The mass of ion A is double the mass of ion B
  - D. You must know the speed and the charge of each to answer this question.

- You are looking directly into one end of a long solenoid. The magnetic field at its center points directly away from you. What is the direction of the current in the solenoid, as viewed by you?
  - A. Clockwise
  - B. Counter-Clockwise
  - C. Directly toward you
  - D. Directly away from you

A wire moving in a magnetic field

- Assume the wire is made of a conductor
- The magnetic field will exert a force on all the free electrons in the conductor
- The two ends of the wire will end up with a net charge—negative charge on the end of the wire that the electrons are pushed towards…the net charge remains zero!
- This means **an electric field is created in the wire because it is moved through the magnetic field**

Electric Field…

- Created by moving through the magnetic field can be calculated by: $E = \frac{\Delta V}{\Delta x} = \frac{V}{L}$
- V is the potential difference established in the wire by the movement of the electrons
- L is the length of the wire that was in the magnetic field

This can also be written as…

$$F_{electric} = F_{magnetic}$$

$$e \cdot E = e \cdot v \cdot B$$

$$e \cdot \frac{V}{L} = e \cdot v \cdot B$$

$$V = v \cdot B \cdot L$$

Known as ***motional emf***

Faraday's Law

- The relative motion between a magnet (and its magnetic field) and a conducting wire will create a current in the conducting wire
- Animation: http://www.radioelectronicschool.net/files/downloads/faradyanim.gif

Observations:

- The current registered by the galvanometer will increase when:
  - The relative speed of the magnet with respect to the coil increases
  - The strength of the magnet increases
  - The number of turns increases
  - The area of the loop increases
  - The magnet moves at right angles to the plane of the loop

Magnetic Flux (Φ)

$$\Phi = B \cdot A \cdot Cos(\theta)$$

- A = the area of the loop
- θ = the angle between the magnetic field direction and the direction *normal to the loop area*
- *Note: If the loop has N turns of wire around it, then the flux is given by:*

$$\Phi = N \cdot B \cdot A \cdot Cos(\theta)$$

Magnetic Flux Linkage

- The term used to describe the magnetic flux that develops from the use of a multi-turn loop of wire
- **Units** of magnetic flux (or magnetic flux linkage) = Weber (Wb)

$$1\ \mathrm{Wb} = 1\ \mathrm{T} \cdot \mathrm{m}^2$$

Visualize magnetic flux…

- It's the number of magnetic field lines that cross, or pierce, or go through the loop area.
- If the loop is in the same plane as the field, then no field lines go THROUGH the loop: flux = 0
- If the loop is normal to the field, then the maximum number of field lines go THROUGH the loop
- If only half of a loop is in the magnetic field, the overall flux will be proportional to half the total loop area…

- A loop of area 2.0 cm^2 is in a constant magnetic field of B = 0.10 T. What is the magnetic flux through the loop when:
  - The loop is perpendicular to the field?
  - The loop is parallel to the field?
  - The normal to the loop and the field have an angle of 60.0° between them?

Faraday's Law…in equation form

- The induced emf is equal to the negative rate of change of magnetic flux:

$$\varepsilon = -N \cdot \frac{\Delta\Phi}{\Delta t}$$

- We will typically ignore the negative sign and just calculate magnitudes of the induced emf
- The negative sign is required when using calculus and derivatives

- The magnetic field through a single loop of area 0.2 m^2 is changing at a rate of 4.0 $T \cdot s^{-1}$. What is the induced emf (in Volts)?

$$\Phi = BA$$

$$\varepsilon = \frac{\Delta\Phi}{\Delta t} = \frac{\Delta B}{\Delta t} \cdot A$$