Portland State University
General Physics Workshop
Problem Set 5 **Electromagnetic Induction**

Equations and Relations:

Force on a moving charged particle:
$F = qvB\sin(\theta)$

Force on wire carrying a current I:
$F = IlB\sin(\theta)$

Torque on current loop: $\tau = NIAB\sin(\theta)$

Ampère's law: $\sum B_{||}\Delta l = \mu_0 I$

Permeability of free space:
$\mu_0 = 4\pi * 10^{-7}\frac{Tm}{A}$

Magnetic field of a straight wire:
$B = \frac{\mu_0 I}{2\pi r}$

Force between two wires:
$F = \frac{\mu_0 I_1 I_2}{2\pi d}L$

Solenoid: $B = \mu_0 nI$

Conductor moving through magnetic field:
$emf = Blv$

Coil rotating in a magnetic field:
$emf = \omega NBA\sin(\omega t)$

Faraday's law: $emf = -\frac{\Delta\Phi}{\Delta t}$

Ideal transformer:
$\frac{emf_s}{emf_p} = \frac{V_s}{V_p} = \frac{N_s}{N_p} = \frac{I_p}{I_s}$

Self-inductance: $emf = -L\frac{\Delta I}{\Delta t}$

Energy stored in an Inductor: $U = \frac{1}{2}LI^2$

Energy density: $u_B = \frac{1}{2\mu_0}B^2$

Time constant: $\tau = \frac{L}{R}$

Current after closing LR circuit:
$I(t) = I_0\left(1 - e^{-t/\tau}\right)$

Current after opening LR circuit:
$I(t) = I_0 e^{-t/\tau}$

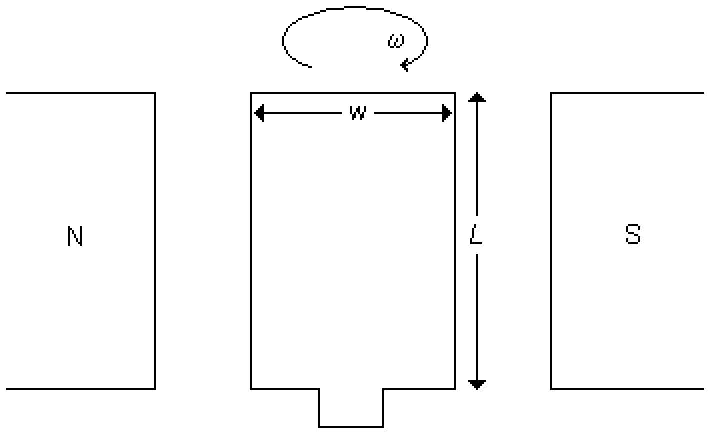
1. Two long parallel wires are 8.0 cm apart and carry currents of 4.0 A and 12 A in the same direction. What is the force per unit length between the wires?

   - *Is the force attractive or repulsive?*

2. A 25-mH inductor is connected in series with a 20-Ω resistor through a 15-V dc power supply and a switch. If the switch is closed at t = 0 s, what is the current after 3.0 ms?

3. A solenoid with 500 turns has a radius of 0.040 m and is 40 cm long. If this solenoid carries a current of 12 A, what is the magnitude of the magnetic field at the center of the solenoid?

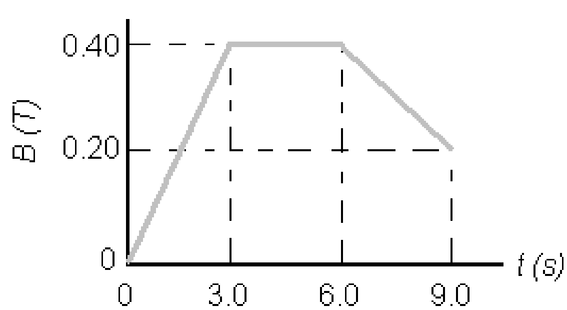
4. A rectangular coil of N turns, length L = 25 cm, and width w = 15 cm, as shown in the Figure, is rotating in a magnetic field of 1.6 T with a frequency of 75 Hz. If the coil develops a sinusoidal emf of maximum value 56.9 V, what is the value of N?



5. A constant current I exists in a solenoid whose inductance is L. The current is then reduced to zero in a certain amounts of time.
   (a) If the wire from which the solenoid is made has no resistance, is there a voltage across the solenoid during the time when the current is constant?
   (b) Is there an emf across the solenoid during the time that the current is being reduced to zero?
   (c) Does the solenoid store energy when the current is constant? If so, express this energy in terms of the current and the inductance.
   (d) A solenoid has an inductance of L = 3.0 H and carries a current of I = 12.5 A. If the current goes from 12.5 to 0 A in a time of 70 ms.
      (i) What is the emf induced in the solenoid?
      (ii) How much energy is stored in the magnetic field of the solenoid?

   - *If it take s the energy E to increase the current in an solenoid from 0 to 100mA, does it take the same energy to increase the current from 100mA to 200mA?*

6. A magnetic field passes through a stationary wire loop and its magnitude changes in time according to the graph. The direction of the field remains constant. There are three equal time intervals indicated in the graph: 0-3.0 s, 3.0-6.0 s, and 6.0-9.0 s.

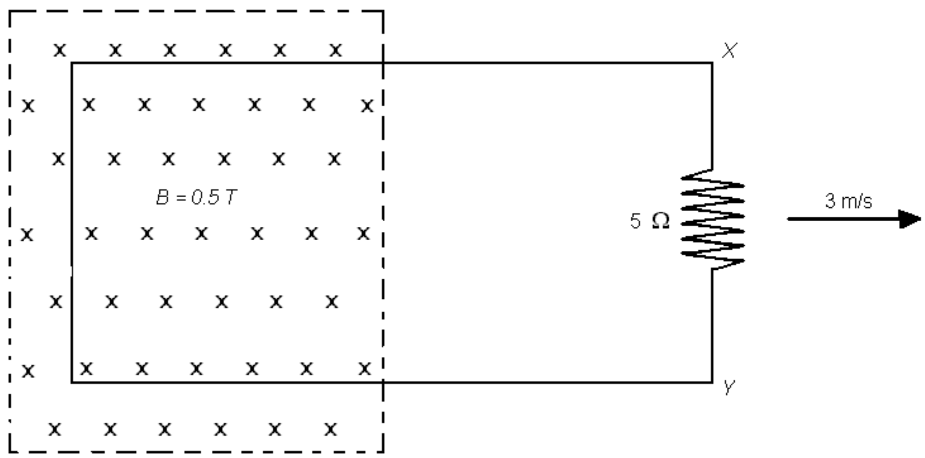


(a) Is the induced emf equal to zero during any of the intervals?

(b) During which interval is the magnitude of the induced emf the largest?
(c) If the direction of the current induced during the first interval is clockwise, what is the direction during the third interval?
(d) The loop consists of 50 turns of wire and has an area of 0.13 m^2. The magnetic field is oriented parallel to the normal to the loop. For each interval determine the magnitude of the induced emf.
(e) The wire has a resistance of 0.48 Ω. Determine the induced current for the first and third intervals.

- *Why should you swipe your credit card fast through the card read to be able to encode the information stored on the magnet strip?*

7. A wire loop, 2 meters by 4 meters, of negligible resistance is in the plane of the page with its left end in a uniform 0.5-tesla magnetic field directed into the page, as shown. A 5-ohm resistor is connected between points *X* and *Y*. The field is zero outside the region enclosed by the dashed lines. The loop is being pulled to the right with a constant velocity of 3 m/s. Make all determinations for the time that the left end of the loop is still in the field, and points *X* and *Y* are not in the field.



(a) Determine the potential difference between points *X* and *Y*.
(b) On the figure show the direction of the current induced in the resistor.
(c) Determine the force required to keep the loop moving at 3 m/s.
(d) Determine the rate at which work must be done to keep the loop moving at 3 m/s.

Additional Questions

1. Discuss the similarities and differences between Gauss' law and the Ampere law.
2. What happens to the motor in a electric mixer when the beaters are jammed and turn only very slowly?