Introductory Electricity, Magnetism, and Optics Practice Problems

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March 21, 2013

Contents

Useful Constants

Electron Mass = 9.11×10^{-31} kg
Proton Mass = 1.67×10^{-27} kg
Elementary Charge = 1.602×10^{-19} C
Coulomb's Constant = 8.99×10^{9} Nm^2/C^2
Avogadro's Number = 6.02×10^{23} atoms/mole

1 Gauss's Law for Magnetism

1.1 Magnetic Monopoles

True or False? Since magnetic monopoles cannot exist in nature, Gauss's law for magnetism predicts that the closed surface integral of the magnetic field in a region of space must always equal zero.

⇒ True

1.2 Magnetic Flux #1

True or False? The magnetic flux through a closed Gaussian surface must always equal zero.

⇒ True

1.3 Magnetic Flux #2

True or False? The magnetic flux through an open surface must always equal zero.

⇒ False

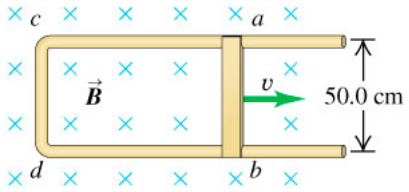
2 Faraday's Law of Induction

2.1 Definition of Faraday's Law of Induction

Faraday's Law of Induction tells us how a changing magnetic flux produces a(n) ____. ⇒ Voltage/EMF

2.2 Bar in a Magnetic Field #1

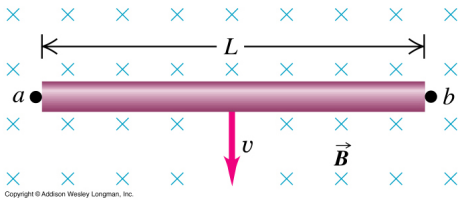
A bar of length 50.0 cm is moving to the right with a velocity v = 10.0 m/s in a constant magnetic field of magnitude B = 1.00 T. In which direction is the induced current in the wire connecting points a and b?



⇒ It flows from b to a

2.3 Bar in a Magnetic Field #2

A bar of length L is moving in a magnetic field B with a constant velocity v, as shown below. What is the electric potential developed between the ends of the bar? Which end(s) of the bar would become positively charged?



⇒ $\epsilon = BLv$, The right side (b) will develop a positive charge

2.4 Transformer

A transformer has 100 turns in the primary coil and 10,000 turns in the secondary coil. If I apply a sinusoidal voltage (V_{max} = 10 V), what is the maximum output voltage from the secondary coil?

⇒ 1000 V

2.5 Changing Magnetic Field

Suppose I put a wire loop with resistance R = 100 Ω and radius r = 0.1 m into a uniform magnetic field such that the area vector of the loop and the magnetic field vector are parallel. The magnetic field begins to decrease according to the equation $B(t) = 10e^{-t}$. What is the magnitude of the current in the wire loop at time t = 10 s?

$\Rightarrow 0.1426\ \mu$A

3 RL Circuits

3.1 Energy Stored in an RL Circuit

An series RL circuit (R = 10 Ω, L = 5.0 H, V = 10 V) is initially uncharged. At time t = 0 s, the elements are connected together and current is allowed to flow in the circuit. What is the energy stored in the inductor at time t = 1 s?

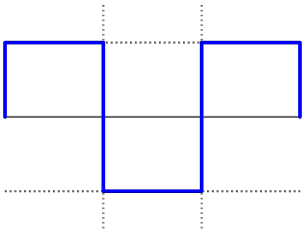
$\Rightarrow$ 1.87 J

4 AC Circuits

4.1 RMS Voltage

A square wave (shown below) has an amplitude of 2 units and a period of 3 units. What is the RMS value of this wave?

$\Rightarrow$ 2 units



4.2 LC Oscillator

Suppose you have a 10 mH inductor and box of various capacitors. What capacitor should you use to make an oscillator with frequency 920kHz? This is approximately the center of the medium wave AM radio band.

$\Rightarrow$ 3 pF

4.3 Resonance With and Without a Resistor

Suppose I have a capacitor (C) connected to an inductor (L) in a circuit (i.e. an LC Circuit). It has a certain resonant frequency (ω). I now attach a resistor (R) in series with the inductor and the capacitor. What is the new resonant frequency?

$\Rightarrow \omega_{new} = \omega$

4.4 Resonant Frequency of Series RLC Circuit

A series RLC circuit contains a resistor (R = 200 Ω), a capacitor (C = 2.00 μF), an inductor (L = 2.00 H), and a battery with some voltage V. The amplitude of the current going through the circuit is I = 1.00 A. Determine the resonant frequency of the circuit.

$\Rightarrow$ 500 rad/s

4.5 RMS Power in a Series RLC Circuit

A series RLC circuit contains a resistor (R = 200 Ω), a capacitor (C = 2.00 μF), an inductor (L = 2.00 H), and a battery with some voltage V. The amplitude of the current going through the circuit is I = 1.00 A. Determine the RMS power going through the resistor.

$\Rightarrow$ 100 W

4.6 Phase Angle of Series RLC Circuit

Suppose I have an a AC circuit with a reactance of 100 ohms and an impedance of 150 ohms. What is the phase angle of the circuit in degrees?

$\Rightarrow \phi = 33.69^\circ$