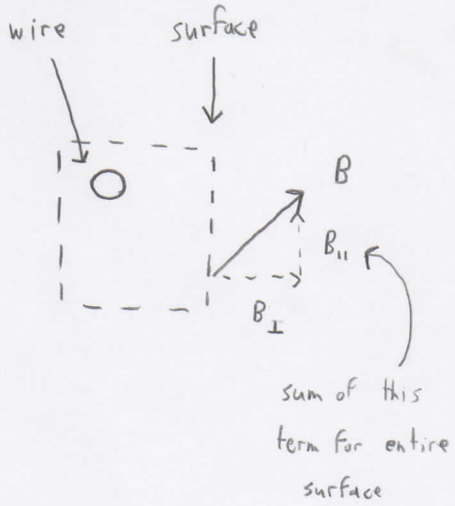
PH202-1G
Spring 2014



Worksheet February 17

Ampere's law

Describe Ampere's law qualitatively. What two quantities does it relate?

Ampere's law relates the magnetic field along a surface (not through a surface) to the enclosed current.

Give a mathematical expression for Ampere's law.

$$\sum (B_{\parallel} \Delta \ell) = \mu_0 I_{enc}$$

Induced current

What is an induced current?

Induced current is current produced in a conductor due to an external magnetic field

What three things can be changed to induce an electric current?

1) Magnitude of magnetic field 2) Area of loop of wire 3) angle between magnetic field and normal to loop area

For a wire moving in a magnetic field, give a mathematical expression for the magnitude of the induced emf.

emf $= vLB$ where v is the speed of the wire

Give a mathematical expression for the force required to move a wire through a magnetic field at constant speed.

$F = ILB$ Notice that this is the force on a current-carrying wire in a magnetic field.

Magnetic flux

Give a mathematical definition of magnetic flux and give its units of measurement.

$\Phi_B = BA\cos\phi$ where ϕ is the angle between the magnetic field and the normal to the loop area.

Describe Faraday's law qualitatively. What quantities does it relate?

Faraday's law relates the induced emf to the change in magnetic flux

Give a mathematical expression for Faraday's law.

$$\text{emf} = -N\frac{\Delta \Phi_B}{\Delta t}$$

↑ why negative? We will see when we study Lenz's law

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Problems

1. A long, straight wire carries a current of 18 A. a) Find the magnitude of the magnetic field at a distance of 12 cm from the wire. b) A second wire is placed next to the first, and the magnitude of the magnetic field is now measured to be $2 \cdot 10^{-5}$ T. What is the magnitude and direction of the current in the second wire?

a) $B = \frac{\mu_0 I}{2\pi r} = \frac{4\pi \cdot 10^{-7}\, T \cdot m \cdot A^{-1} \cdot 18 A}{2\pi \cdot 0.12 m} = 30\ \mu T$

b) Ampere's law states that the magnetic field is proportional to total current.

$$I_T = \frac{2\pi r B}{\mu_0} = \frac{2\pi \cdot 0.12 m \cdot 20\ \mu T}{4\pi \cdot 10^{-7}\, T \cdot m \cdot A^{-1}} = 12 A$$

$I_2 = I_T - I_1 = 12 A - 18 A = -6 A$ ← opposite direction since sign is negative

2. A wire 0.50 m long is at rest in a magnetic field of 0.20 T. A mechanical force begins to move the wire at a constant speed of 4.0 m/s. If the internal resistance of the wire is 5.0 Ω, how large must the mechanical force be to maintain the wire's speed in the magnetic field?

Motion of wire produces an emf given by $emf = vBL = 0.40 V$

Emf produces a current given by $I = \frac{V}{R} = \frac{0.40 V}{5.0\ \Omega} = 0.080 A$

Driving force must equal magnetic force on wire $F_B = ILB$

$$F_B = 0.080 A \cdot 0.50 m \cdot 0.20 T = 0.0080 N$$

3. A coil of wire with a cross-sectional area of 0.15 m^2 containing 6 turns is under the influence of a magnetic field produced by a bar magnet. Initially, the field is directed perpendicular to the coil and has a strength of 50 mT. Then, the bar magnet is moved so that the magnetic field is directed 30° from the normal to the coil and has a strength of 40 mT. If the average emf produced in the wire during the motion is 0.5 V, over what period of time did the motion take place?

Faraday's law: $emf = -N \frac{\Delta \Phi_B}{\Delta t} = -NA \frac{\Delta (B \cos \phi)}{\Delta t}$

$$\Delta t = \frac{-(B_2 \cos \phi_2 - B_1 \cos \phi_1) \cdot NA}{emf} = \frac{-(0.040 T \cos 30° - 0.050 T \cos 0°) \cdot 6 \cdot 0.15 m^2}{0.5 V}$$

$\Delta t = 0.028$ s