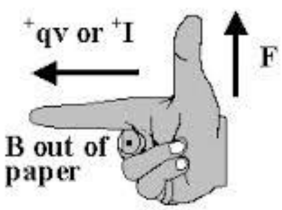
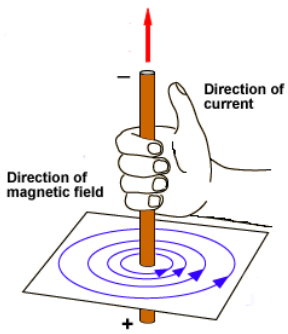
PH 202
Test II: Magnetic fields, magnetic flux, electromotive force, inductors.
Chapters 21-23
This guide is not meant to be all-inclusive. I just thought it might be nice to put a lot of stuff together in one place. This is by no means the only thing you should study. I have not seen the test and can't guarantee that all of this or only this will be on the test.

Magnetic force: force, magnetic field, and movement of the charge are always all perpendicular to each other.
$F = Bvqsin\theta$
$F = BILsin\theta$
*θ for both of these equations is the angle between the movement of the charge/current and the magnetic field B

Know the right-hand-rules:



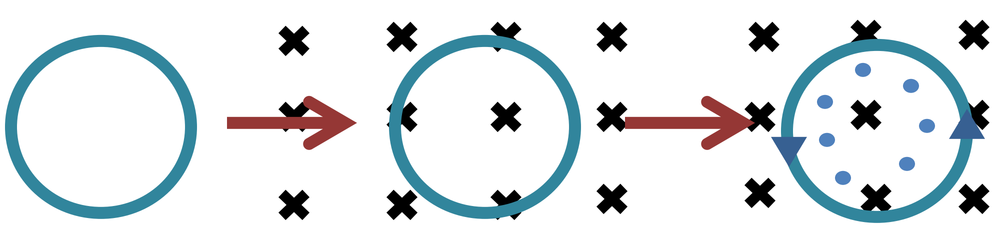


*The right-hand-rules only work for positive charges and current. If you want to know directions of force or magnetic fields when negative charges or electrons are involved, you pick the opposite direction or you use your left hand where you would use your right.

Circular motion and magnetic force:
When a charge enters a uniform magnetic field, the magnetic force will cause that charge to begin to move in a circle. When this occurs, we can find the radius of that motion using the formula:
$r = \frac{mv}{qB}$, where m is mass of the charge, v is velocity, q is charge.

Currents induce magnetic fields
$\boldsymbol{B} = \frac{\mu_0 I}{2\pi r}$ →magnetic field generated by a long straight wire
$\boldsymbol{B} = N\frac{\mu_0 I}{2R}$ →magnetic field generated by loops of wire
$\boldsymbol{B} = \mu_0 In$ →magnetic field generated by a solenoid

Magnetic fields also induce currents
Lenz's Law → When you increase or decrease the magnetic flux through a loop of wire, a current will be induced in that loop of wire. This current will create a magnetic field INSIDE the loop of wire that will oppose the change in flux.



Electromotive Force

Currents are associated with voltages. A battery in a circuit will supply a voltage that produces a current. When a magnetic field induces a current, there's a voltage present as well. That voltage is referred to as electromotive force (which is not a force). This force can be referred to as EMF or represented with the symbol: $\mathcal{E}$.

EMFs occur when we

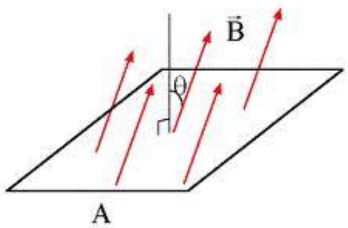
- move conductors or wires through magnetic fields
- or when we change magnetic flux, which happens when we
  - change magnitude of a magnetic field a conductor or wire is placed in
  - change the area of a conductor or loop or wire
  - change the angle between the magnetic field and the conductor or loop of wire

EMF depends on flux

Magnetic flux is represented with the letter phi: Φ

The formula for magnetic flux is the same as the formula for electric flux. It depends on the area of the object you're measuring flux through as when as the field flowing through the object. It also depends of the angle between the field and a line NORMAL to the surface of the object. Flux is greatest when this angle is zero.

$\boldsymbol{\Phi = ABcos\varphi}$



EMF can be calculated using 2 equations:

$\mathcal{E} = \boldsymbol{vBL} \rightarrow$ used for a conductor (like a metal bar or metal rod) moving through a magnetic field

$\mathcal{E} = -\boldsymbol{N}\frac{\Delta\boldsymbol{\Phi}}{\Delta \boldsymbol{t}} \rightarrow$ used for a loop (or number of loops, N) placed in an environment where field is changing or area of loop is changing

NO EMF is generated in a loop of wire if the magnetic field, area, or angle is not changing.

Inductors

- Capacitors in circuits will create electric fields. Inductors in circuits will create magnetic fields. An inductor is typically a solenoid.
- Like capacitors can be described by "capacitance," inductors can be described by their "inductance."
  - Inductance for a solenoid is based on the unique properties of the solenoid: length, area, and number of loops.
  - $\boldsymbol{L = \frac{\mu_0 N^2 A}{l}}$
- Inductance depends on the magnetic flux through the solenoid as well as the amount of current running through the solenoid.
  - $\boldsymbol{\Phi = LI}$
- The EMF generated by the inductor is also related to the inductance
  - $\mathcal{E} = -\boldsymbol{L}\frac{\Delta \boldsymbol{I}}{\Delta \boldsymbol{t}}$
- The unit for inductance (L) is the Henry (H).
- Inductors, like capacitors, store energy. Energy stored in an inductor is related to inductance and current through an inductor.
  - $\boldsymbol{W = \frac{1}{2}LI^2}$

Alternating current:

- In a circuit with direct current, the voltage supplied by a battery is constant. However, in a circuit with alternating current, the voltage oscillates like a sine wave. Voltage varies with time according to the formula: $\boldsymbol{V = V_0 \sin(\omega t)}$ where **ω = 2πf** (f is frequency of the current).
- Current is dependent on voltage, so it also varies with time according to the formula: $\boldsymbol{I = I_0 \cos(\omega t)}$**.**
- If we wanted to find average voltage or average current, we would divide the maximum voltage or current by √2.
- Average current and average voltage are related in a similar way as voltage and current are related in DC circuits. In an AC circuit: $\boldsymbol{V_{rms} = I_{rms} X}$, where X is capacitive reactance or inductive reactance (measured, like resistance, in ohms).
- $\boldsymbol{X_L = \omega L}$ and $\boldsymbol{X_C = \frac{1}{\omega C}}$