Electromagnetic Induction

E-M Induction

- If you move a magnet in and out of a stationary coil of wire, a voltage is created in the wire.
- If you move a wire in and out of a stationary magnetic field a voltage is created in the wire.
- The induction is the same because it is the relative motion of the two objects.
- Slow motion, low voltage, quick motion, high voltage.
- The more loops , the more voltage would be induced.

Faraday's Law

- The amount of induced voltage is proportional to the product of the number of loops and the rate at which the magnetic field changes in those loops.
- Where does the energy come from if there is no voltage source?
- Mechanical energy to electrical energy.
- Remember that voltage is induced, but current depends on the resistance of the wire and the circuit.

Resistance of Induction

- As you push the magnet into the coil of wire, a current is created.
- Since a current is created a magnetic field is formed.
- That magnetic field will repel the magnet and make it harder to move the magnet in.
- The more coils, the harder it is to move the magnet in.

AC Generators

- If you push a magnet into a coil of wire, the current goes in one direction, when you pull it out, the direction of the current reverses.
- It's easier to move a wire than a heavy magnet.
- If you turn a wire coil in a stationary magnetic field it generates electricity. (Generator)
- Since the coil is turning 360^{o} within the magnetic field, the current goes first one way, and then the other. This is AC!

Motor vs. Generator

- A motor is when a moving current within a stationary magnetic field causes a wire or spool to move or deflect since there is no conduction in that direction..
- It will deflect 90^{o} from both the direction of the magnetic field and the electric current.
- A generator is when a moving wire or coil perpendicular to a stationary magnetic field and the direction of the wire, creates a current that runs through the wire.

Transformers

- If two coils are side by side with one hooked up to a power supply, then a current will be created in the other coil when the switch is opened or closed.
- This creates a change in the magnetic field, first in one direction when opened, then in the other when closed.
- Which the switch stays closed, there is no change in the magnetic field, so no current in the second coil.
- If you continue the process quickly you can create AC voltage.

Transformers Continued

- If an iron core is put in the coils, then the magnetic field is intensified by the domains so it transfers more energy to the second coil.
- AC power works better at this rather than closing and opening a switch. Automatically changes magnetic field.
- The change rate is equal to the frequency of the AC circuit. This is a transformer.
- A better transformer has an iron core in a loop with the primary and secondary wire coils on opposite sides.

Stepping Up

- If a 1 volt AC current is in a single loop of the primary wire, then 1V would be transferred to a single loop of secondary wire.
- If the 1V AC current is in a single loop of primary wire, then 2V would be transferred to a double loop of the secondary wire.
- Each loop has 1V induced. This is stepping up.
- If there is a 1:10 ratio of loops in the primary wire vs the secondary wire then the voltage would step up 10 times.

Stepping Down

- If the secondary has fewer loops than the primary, then less voltage will be induced.
- This is stepping down.
- Eqn: $\frac{\text{primary voltage}}{\text{\# primary loops}} = \frac{\text{secondary voltage}}{\text{\# secondary loops}}$
- Something for nothing? Nope
- Energy is conserved because the power output of the primary equals the power output of the secondary. (P=IV)
- If voltage is stepped up, current is stepped down.

Power Transmission

- AC current is used to transmit power since it is so easy to step up and down with transformers.
- Since high voltage gives low current, less energy is lost when the energy is transferred through the wires due to heating.
- Voltage is stepped up from the power plant for transmission which lowers current.
- Voltage is stepped down before it reaches the house which increases current.
- Radio antennas work the same way, as does the sun transferring energy to the Earth.

Maxwell and His Equations

- Any changing electric field creates a magnetic field the magnitude of which is proportional to the rate at which the electric field changes. The two fields are perpendicular to each other.
- Shake any charged object and you create an electric current which creates a magnetic field, which creates an electric field, which creates a magnetic field, which creates…..
- What speed must the waves travel in order to maintain this? You guessed it!

EM Radiation

- The speed must equal $3x10^8$m/s, speed of light!
- Any slower and the waves will be lessened each cycle and vanish; any faster and they would grow in size and violate the conservation of energy.
- Maxwell calculated the speed of light exactly, over and over again. Its his discovery!
- Radio waves, Microwaves, IR, Light, UV, X-rays, and gamma rays all travel this way. Therefore they all have electrical and magnetic properties.