Unit 5 Review

General Guidelines

- Reading the book or notes (even these below) is passive studying. It doesn't help much.
- Active studying means putting all of your faculties to work so write things down, test yourself, get *involved* in your studying!
- Study your unit 5 quizzes by retaking them. Rewrite the questions if you need to.
- Make flash cards out of the information below. Put a question on the back of each one and test yourself.
- Make sure you understand the standards for this unit. Go to the Course Standards and click on 'Unit 5'.

Unit Review

- Electrical Force – Coulomb's Law

$$F = \frac{kq_1q_2}{R^2} \tag{1}$$

  where k is Coulomb's constant ($k = 8.99 \cdot 10^9 \mathrm{N\,m^2/\,C^2}$), q_1 and q_2 are charges and R is the distance between the charges.
  - The force on particle is towards or away from the charge center of the other particle (don't forget equal and opposite).
  - Doubling either charge doubles the force.
  - Doubling the distance cuts the force to one quarter.
- The Three Rules of Electrostatics
  - There are only two kinds of charge.
  - Two objects charged alike repel each other
  - Two objects charged oppositely attract each other.
- Fields
  - A field is a representation of a function throughout space; a function of x, y and z.
  - A force field represents a force that would affect an appropriate object placed in the field.
  - A scalar field just has a single value at every point.
  - A vector field has a value and a direction at every point. **All force fields are vector fields!**
- Force due to an electric field:

$$\vec{F} = q\vec{E} \tag{2}$$

  - The electric field vector points in the direction that it would push a positive charge.
  - The electric field exists at all points in space.
  - The electric field at some point in space (x, y, z) due to many charges is just the vector sum of the electric field at that point due to each charge (principle of superposition).

- Voltage is the electrical potential difference between two points. The electrical potential *energy* between two points is the voltage times the charge (voltage is independent of the charge).
- Voltage related to electrical potential energy: $\Delta\text{PE} = qV$
- In a constant electric field, the change in potential energy is: $\Delta\text{PE} = qEd$
- Ohm's Law states that the current in a circuit is the voltage driving a circuit divided by the resistance, $I = V/R$, where I is the current in Amperes (A), V is the electrical potential difference in volts (V) and R is the resistance in ohms (Ω).
  - Increasing the voltage *increases* the current.
  - Increasing the resistance *decreases* the current.
- The force on a moving charge in a magnetic field is:

$$\vec{F} = kq\vec{v} \times B = kqv_{\perp}B \tag{3}$$

- The direction of the force is found using the right hand rule.
  1. Point your fingers in the direction of the velocity of the charged particle.
  2. Curl your fingers in the direction of the magnetic field.
  3. Your thumb points in the force direction.
- A voltmeter measures the potential difference (voltage) between two points in a circuit. The voltmeter should not disturb a circuit because it has very high internal resistance.
- An ammeter measures the current in a portion of the a circuit. The ammeter must be made part of the circuit (*i.e.*, the current to be measured must pass through the ammeter). A good ammeter should not disturb the circuit because its internal resistance is very low (as close to zero as possible).
- Electrical power is mostly created by generators. They turn mechanical energy into electrical energy.
- Electric motors turn electrical energy into mechanical energy. The chart below should illustrate the differences:

device	**Alternating Current (AC)**	**Direct Current (DC)**
Motor	Electrical Energy → Mechanical Energy. No commutator (requires AC input)	Electrical Energy → Mechanical Energy. Has a commutator (requires DC input)
Generator	Mechanical Energy → Electrical Energy. No commutator (produces AC output)	Mechanical Energy → Electrical Energy. Has a commutator (produces DC output)

- Maxwell used the idea of a displacement current to develop many of his ideas about the interactions of electric and magnetic fields in empty space. A displacement current is caused by a changing electric field in an insulating material.
- As an example, he stated that an electric field that is changing in time is always accompanied by a magnetic field.

- Four principles of Electromagnetism
  - An electric current in a conductor produces magnetic lines of force that circle the conductor.
  - When a conductor moves across externally set-up magnetic lines of force, a current is induced in the conductor.
  - A changing electric field in space produces a magnetic field.
  - A changing magnetic field in space produces a electric field.

- An electromagnetic wave is
  - one of the predictions of Maxwell's theory.
  - a series of fluctuating, interlocked electric and magnetic fields that propagate through space.
  - a transverse wave with the displacement of the electric field separated 90° from the displacement of the magnetic field.
  - a phenomenon that comes in an infinite variety of frequencies (a spectrum) of which visible light is a very small part.

- Maxwell and the Electromagnetic wave
  - Maxwell calculated what he thought the speed of the EM wave should be using wave notions of density (magnetic field) and stiffness (electric field).
  - He found that the strength of the fields did not affect the speed.
  - He found that the frequency of the wave did not affect the speed.
  - His calculated speed matches the speed of light!

- Scientific Progress

Faraday	Discovered a new phenomenon (induction).
Maxwell	Developed theory that explained all known phenomenon of electricity and magnetism (including Faraday's). Put forth *new* predictions of his theory.
Herz	Tested Maxwell's new predictions. The positive results cemented Maxwell's theory as the main focus of electromagnetic theory.

- The Electromagnetic Spectrum

Region	**Wavelength (meters)**	**Frequency (Hz)**
Radio	> 0.1	$< 3 \cdot 10^9$
Microwave	$0.1 \rightarrow 0.0001$	$3 \cdot 10^9 \rightarrow 3 \cdot 10^{12}$
Infrared	$0.0001 \rightarrow 7 \cdot 10^{-7}$	$3 \cdot 10^{12} \rightarrow 4.3 \cdot 10^{14}$
Visible	(red) $7 \cdot 10^{-7} \rightarrow 4 \cdot 10^{-7}$ (blue)	(red)$4.3 \cdot 10^{14} \rightarrow 7.5 \cdot 10^{14}$(blue)
Ultraviolet	$4 \cdot 10^{-7} \rightarrow 10^{-9}$	$7.5 \cdot 10^{14} \rightarrow 3 \cdot 10^{17}$
X-Rays	$10^{-9} \rightarrow 10^{-11}$	$3 \cdot 10^{17} \rightarrow 3 \cdot 10^{19}$
Gamma Rays	$< 10^{-11}$	$> 3 \cdot 10^{19}$

- Uses and Sources of the Electromagnetic Spectrum
  - **Radio**: Produced in electrical systems using accelerated charges. Used for commercial radio and television broadcasting. Also used for some short-range applications such as bluetooth, older cordless phones and garage-door openers.
  - **Microwave**: Produced by magnetrons. Used in short-range communications such as cell phones and newer cordless phones. Also used in microwave ovens which use a frequency strongly absorbed by water.
  - **Infrared**: Produced by many methods which heat objects. Used in remote-control units and in physical therapy.
  - **Visible**: Produced by systems which excite electrons in atoms (which then give off visible light when they return to their ground state). Used mainly for reading email SPAM and playing video games.
  - **Ultraviolet**: Produced mostly by electronic interactions similar to visible (see above). Used by some insects for navigation and individual recognition. Mainly used to get sun-burned in the pursuit of a tan.
  - **X-Rays**: Produced by smashing electron beams into metal. Used in medical diagnostics (*e.g.*, X-rays, CAT scans). Also used in some cancer therapies.
  - **Gamma Rays**: Produced in certain nuclear decays (*i.e.*, certain radioactive elements produce gamma rays). Used in nuclear medicine (*i.e.*, for treating certain cancers).

  All of these types of electromagnetic radiation are also produced by astronomical objects from stars to black holes. Astronomers use this radiation to study the universe.