Chapter 29 - Magnetic Fields

1. The force on a charge moving through a magnetic field is $\vec{F} = q\vec{v} \times \vec{B}$.
2. The force on a current carrying wire is $\vec{F} = i\vec{L} \times \vec{B}$.
3. A current carrying loop acts like a permanent magnet and has a magnetic dipole moment $\vec{\mu} = Ni\vec{A}$. The direction of $\vec{\mu}$ is given by the right-hand rule.
   (a) When the magnetic moment is placed in an uniform magnetic field, it experiences a torque given by $\vec{\tau} = \vec{\mu} \times \vec{B}$ and the moment attempts to line up with the field.
   (b) The potential energy of the magnetic moment is given by $U = -\vec{\mu} \cdot \vec{B}$.
4. When we compare electric and magnetic forces we find a lot of differences.
   (a) Electric forces are parallel to the electric fields. Magnetic forces are perpendicular to the magnetic fields.
   (b) Electric forces can do work and, thereby, change the kinetic energy of a charge. Magnetic forces never do any work. The kinetic energy is constant.
   (c) A charge passing through a uniform electric field travels in a parabolic trajectory. In a uniform magnetic field a charge travels in a helical path which simplifies to a circle when the velocity is perpendicular to the magnetic field.

Chapter 30 - Magnetic Fields due to Currents

1. Magnetic fields are created by currents. Fields can be calculated using the Biot-Savart law:
$$d\vec{B} = \frac{\mu_0}{4\pi} \frac{i\, d\vec{s} \times \vec{r}}{r^3}.$$
2. Ampere's law is
$$\oint \vec{B} \cdot d\vec{s} = \mu_0 i_{enclosed}.$$
3. There are different magnetic fields for different geometries.
   (a) A long straight wire
$$B = \frac{\mu_0 i}{2\pi r}.$$
   (b) At the center of circular arc ϕ
$$B = \frac{\mu_0 i \phi}{4\pi r}.$$

(c) Along the axis of a circular loop

$$B = \frac{\mu_0 I R^2}{2(z^2 + R^2)^{3/2}}.$$

(d) A solenoid

$$B = \mu_0 n i.$$

(e) A toroid

$$B = \frac{\mu_0 N i}{2\pi r}.$$

(f) A magnetic dipole

$$\vec{B} = \frac{\mu_0}{2\pi}\frac{\vec{\mu}}{z^3}.$$

Chapter 31 - Induction and Inductance

1. The magnetic flux is defined $\Phi_B = \int \vec{B} \cdot d\vec{A}$.
2. Faraday's law states the magnitude of the emf induced in a conducting loop is equal to the rate at which the magnetic flux Φ_B changes with time:

$$\mathcal{E} = \frac{d\Phi_B}{dt}.$$

3. Lenz's law says that an induced current has a direction such that the magnetic field due to *the induced current* opposes the change in the magnetic flux that induces the current:

$$\mathcal{E} = -\frac{d\Phi_B}{dt}.$$

4. A changing magnetic field produces an electric field:

$$\oint \vec{E} \cdot d\vec{s} = -\frac{d\Phi_B}{dt}.$$

5. Electric potential has meaning only for electric fields that are produced by static charges; it has no meaning for electric fields that are produced by induction.
6. The self-inductance of an inductor is defined as

$$L = \frac{N\Phi}{i}.$$

7. An induced emf appears in any coil in which the current is changing:

$$\mathcal{E}_L = -L\frac{di}{dt}.$$

The emf in the inductor is in the *same direction* as the current if the *current is decreasing*.
The emf in the inductor is in the *opposite direction* as the current if the *current is increasing*.

8. RL circuits have similar behavior to RC circuits.

   (a) The circuit has a characteristic time $\tau_L = L/R$. Initially, an inductor acts to oppose changes in the current through it. A long time later, it acts like ordinary connecting wire.

   (b) When the battery is connected the current increases according to the equation

   $$i = \frac{\mathcal{E}}{R}(1 - e^{-t/\tau_L}).$$

   (c) When the battery is disconnected, the current decays according to

   $$i = \frac{\mathcal{E}}{R}e^{-t/\tau_L}.$$

9. Analogous to a capacitor, energy is stored in an inductor. This time the energy is stored in the magnetic field.

   (a) The magnetic energy is $U_B = \frac{1}{2}Li^2$.

   (b) The energy density is $u_B = B^2/2\mu_0$.

10. If two coils are close together, the magnetic field from one could link the coils of the other. It can be shown that the mutual inductance is the same regardless of which coil we consider to be the primary (source) or secondary (receiver). The induced emf in one coil because of the change in the other coil is

$$\mathcal{E}_2 = -M\frac{di_1}{dt}.$$