PH 1120
Electricity and Magnetism   **Term B, 2011**

STUDY GUIDE #4

In this part of the course we will study the following topics:

- Motion of a charged particle in electric and magnetic fields
- Magnetic field of a current element, a long straight wire, a circular loop and a solenoid
- Force between current carrying conductors
- Flux of the magnetic field
- Electromagnetic induction -- Faraday's law and Lenz's law

In this fourth and final segment of the course, we complete our discussion of the basic principles of electromagnetic theory. With this background you should be able to better appreciate the many applications of electromagnetism that are now a part of our everyday life. A few examples of devices that use electric fields, magnetic fields, electromagnetic waves or some combination of these are xerox machines, laser printers, mass spectrometers, Van de Graaf generators, camera flash units, television picture tubes, automobile air bags, magnetic credit card readers, metal detectors, MRI machines, computer read heads, cell phones, Ipods, etc.. You will find discussions of some of these devices scattered throughout your text and you can learn still more about them from a variety of internet sources.

The main laws of electromagnetism, which are associated with the names of Coulomb, Gauss, Ampere and Faraday, can be summarized as a set of four partial differential equations known as Maxwell's equations. Maxwell's equations provide an explanation of all known electromagnetic phenomena, including light and other types of electromagnetic radiation (such as radio waves, microwaves and x-rays). Along with Newton's laws of motion and of universal gravitation, Maxwell's equations are one of the crowning achievements of classical (i.e. pre-twentieth century) physics. Those of you who proceed further with your study of electromagnetism will definitely encounter Maxwell's equations and learn about their many applications.

If you want to see what Maxwell's equations look like, look at p.1093 of your text. The equations are given there in integral form, but with the use of vector calculus they can be transformed into a set of four partial differential equations for the electric and magnetic fields. Solving these equations subject to the appropriate boundary conditions allows one to understand all possible electromagnetic phenomena, even those that no one has dreamt of to date. Once you have reached this summit, an incredible voyage awaits you!

Maxwell is widely regarded as one of the greatest physicists of all time, along with Galileo, Newton and Einstein. You can read more about him by following the link bearing his name under "Biographies of Pioneers in Electricity and Magnetism" on the PH1120 website. You can also read the excellent biography *The Man Who Changed Everything* by Basil Mahon (Wiley, 2004). In addition to explaining Maxwell's many contributions to science (such as his explanation of the rings of Saturn), it also gives a fascinating portrait of Maxwell, the man.

Objective 14: Motion of a charged particle in electric and magnetic fields
Suggested Study Procedure:
Read Ch.27.4 for motion of charged particles in a uniform magnetic field. Study both the worked examples at the end of this section. Read Ch27.5 for the velocity selector and the mass spectrometer. Study both the worked examples at the end of this section.
Suggested Problems: Exercises 27-15, 21,24,31 Problem 27-64

Objective 15: Use of Biot-Savart law
Suggested Study Procedure:
Read Ch.28.2 for the Biot-Savart law. The essential results are contained in Eqs. (28.6) and (28.7). Study worked example 28.2. Read Ch.28.3 for the magnetic field of a long wire; the basic result is given in Eq.(28.9). Study worked examples 28.3 and 28.4.
Suggested Problems: Exercises 28-11,25,27 Problem 28-67

Objective 16: Forces between parallel current carrying conductors
Suggested Study Procedure:
Read Ch.28.4, note the result in Eq.(28.11) and study worked example 28.5.
Suggested Problems: Exercises 28-31,33 Problem 28-69

Objective 17: Magnetic fields of simple current configurations
Suggested Study Procedure:
Read Ch.28.5 for the magnetic field of a circular current loop and note the results Eq.(28.15) and (28.17). The derivation of these formulae is not as important as knowing how to apply them. Study worked example 28.6. You should be familiar with the field of a solenoid, discussed in worked example 28.9 of the text. You should be familiar with the result (28.23), which describes the field inside an ideal solenoid, and know how to apply it. You should also know how to calculate the magnetic field due to combinations of straight line and circular arcs of wire, as occur in the suggested problems below.
Suggested Problems: Exercises 28-37,39 Problem 28-74,80

Objective 18: Magnetic flux
Suggested Study Procedure:
Read Ch.27.3 and study worked example 27.2.
Suggested Problems: Exercises 27-11,14

Objective 19: Electromagnetic Induction
Suggested Study Procedure:
Read Ch.29-1,2,3,4. To determine the direction of the induced emf, study the procedure described in Fig.29.6 of the text. Study worked examples 29.1, 29.2, 29.3, 29.4 (a bit more challenging, but a truly useful application), 29.6, 29.7, 29.8, 29.9. These examples cover the sorts of problems you should be able to do.
Suggested Problems:
Exercises 29-1,5,9,15,17,27