8.02 - ESG Independent Study Fall 2004

Physics II - Introduction to Electricity and Magnetism

Walking across a carpet on a dry day and touching a metal water fountain gives a shock. A magnetic compass indicates more or less the North direction. This direction crossed into the upward vertical gives the East direction, whence comes the first light of a nearby star after an eight–minute journey. A watch held by someone moving towards us through this space seems to run slower than ours, and the LEDs on the watch have a greenish tinge. These seemingly disparate phenomena are actually different manifestations of electricity, magnetism, and their union in electromagnetic waves and the propagation of light.

In this subject, $\mathbf{F} = d\mathbf{p}/dt$ is still valid, but forces will be seen to be associated with electric and magnetic fields. These fields themselves are dynamic quantities dependent on each other in a way that allows them to exist, independently of matter, in the form of waves which propagate with a predictable speed. Since matter is not necessary for propagation, this speed is the same in any inertial frame. But that means that when a spaceship coming towards us switches on the high beams, we must disagree with the ship's occupants about the time it takes the light to travel; time is relative.

It would appear that electricity and magnetism is either very simple or very complicated. Many physicists might prefer to believe that it is both, in that it is quite profound.

The **Independent Study** version of E&M allows you to learn the subject at your own pace and at a level of profundity that suits you. You will be tested on the material, but how you learn E&M is pretty much up to you. The unit study guides give suggestions, not constraints. We have some laboratory equipment available if you would like to investigate the immediately practical side of E&M.

For use at MIT, any E&M text must be calculus-based. Earlier or previous editions of any of the texts listed below may be used, but keep in mind that the problem numbers have certainly been changed. We appreciate the fact that textbooks are expensive, and for our purposes used copies may well be adequate.

The unit material has been recently updated for use with *University Physics*, eleventh edition (denoted as UP11).

- Sears, Zemansky & Young, *University Physics, Part II*, eleventh edition (Addison-Wesley). The first edition was the standard on which physics texts were based for some time. The later editions have been rewritten to involve more calculus (but still at the 18.02 level). Many of the problems are superb.

- Purcell, *Electricity and Magnetism*, second edition (McGraw-Hill). Purcell's book (Volume 2 of the Berkeley series) is a good text for those whose interest in physics extends beyond the 8.02 requirement. The differences between this and other texts are discussed below.
- Halliday & Resnick, *Physics, Part 2.* H&R assumes a concurrent vector calculus course (18.02 level), and the text nicely combines explanations with the corresponding mathematics. The end-of-chapter questions are quite good, and the problems are varied in difficulty. Supplementary chapters are included for further study involving advanced mathematics and additional topics.
- Marion & Hornyak, *Physics for Science and Engineering, Part 2* (Saunders College Publishing). M&H has concurrent self-contained vector calculus notes in the text, which is an advantage if your 18.02 class presents material in a different order than the order in which you need to use it. Many important concepts are presented through examples, so don't skip over them.

The study guides will refer to chapters and material from UP11 or Purcell. If you use a different text, or an earlier edition, you'll want to check with a staff member to make sure you study the proper chapters and sections.

The text by Purcell is usually used in 8.022 and differs from the other texts mentioned in several notable respects. Most noticeable is the presumed level of mathematical sophistication. Partial differentiation and vector calculus are used throughout, so you'd want a good leg up on the 18.02 – level calculus as you begin. The early explanation of the relation between electric and magnetic forces requires either a knowledge of or religious faith in special relativity (included in a supplementary chapter).

The major (according to many) point of departure is the choice of units. Purcell's use of Gaussian (also known as cgs) units, as opposed to MKSA, is justified by the stunning simplicity of Maxwell's equations in their final form. Gaussian units also bring out the marvelous interrelation of electric fields, magnetic fields, forces, and light at an early stage in the course.

From the above paragraph, you've probably guessed which system of units is preferred by physicists. To restore some pretense of objectivity, consider the following advice from the 1975 8.02 notes written by the late Prof. George Valley, founder and former director of ESG.

“Quick advice:

(a) If you’re going to be an engineer, stick to MKSA. If you’re going to design and build a piece of electrical apparatus, regardless of what profession you think you belong to [sic], you will probably make fewer numerical errors, blow fewer fuses, and have a significantly smaller catastrophe if you use MKSA.

(b) If you seek a clearer and possibly more intuitive understanding of what Electricity and Magnetism is all about [sic again], then use cgs whenever you are deriving theorems or other less important formulae. This system also has clear advantages when you are doing problems in atomic physics and chemistry.”

Engineers are encouraged to prove us wrong by using and appreciating cgs units, thereby establishing a bridgehead for conversion of other engineers.