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

STUDY GUIDE #1

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

- The forces that point charges exert on each other (Coulomb's Law)
- The electric field of a point charge
- How to calculate the electric field of a system of point charges by the Principle of Superposition
- The motion of a point charge in a uniform electric field
- Electric field lines: their use and visualization
- The electric field in and around conductors

About vectors

The electric field is a vector, so we will be dealing with vectors in much of what we do. Make sure you know how to express a two-dimensional vector in each of the following forms:

(1) component form: $\vec{A} = A_x\hat{\text{i}} + A_y\hat{\text{j}}$, relative to unit vectors $\hat{\text{i}}$ and $\hat{\text{j}}$.

(2) Magnitude/direction form: $\vec{A} = A \angle \theta$, where A is the magnitude and θ the counterclockwise angle made by the vector with the x-axis (be careful about putting θ in the correct quadrant when you calculate it as the inverse of a trigonometric function!).

(3) Magnitude/unit vector form: $\vec{A} = A\hat{\text{u}}$, where A is the magnitude and $\hat{\text{u}} = \vec{A}/A$ is a unit vector in the direction of $\vec{A}$. $\hat{\text{u}}$ can be expressed in terms of $\hat{\text{i}}$ and $\hat{\text{j}}$ or as a counterclockwise angle from the x-axis.

Example: Given the vector $\vec{A} = 6\hat{\text{i}}\text{-}4\hat{\text{j}}\ \text{m}$, obtain the unit vector in the direction of $\vec{A}$.

Answer: $$\hat{\text{u}} = \frac{\vec{A}}{|\vec{A}|} = \frac{6\hat{\text{i}}\text{-}4\hat{\text{j}}\ \text{m}}{\sqrt{(6)^2 + (-4)^2}\ \text{m}} = 0.832\hat{\text{i}}\text{-}0.555\hat{\text{j}} = \angle 326.3^\circ$$

Note that the unit vector is dimensionless. Note also that we have given its components to 3 significant figures and its counterclockwise angle with the x-axis to the nearest tenth of a degree. These are the conventions you used in PH 1110, and we will use the same conventions here. The vector $\vec{A}$ can be expressed as 7.21 $\angle 326.3^\circ$ in magnitude/direction form or as $7.21\ \hat{\text{u}}$ in magnitude/unit vector form, where $\hat{\text{u}}$ is as given above.

You should also know how to calculate the unit vector pointing from one point in space to another. For example, given the points P and Q with position vectors $\vec{r}_P = 4\hat{\text{i}}\text{-}5\hat{\text{j}}$ and $\vec{r}_Q = -2\hat{\text{i}}+3\hat{\text{j}}$, suppose that we wish to calculate the unit vector from P to Q. We can do this by first obtaining the displacement vector from P to Q as $\vec{r}_Q - \vec{r}_P = [-2-4]\hat{i} + \left[3-(-5)\right]\hat{j} = -6\hat{i} + 8\hat{j}$ and then calculating the desired unit vector as $\hat{u} = \frac{-6\hat{i}+8\hat{j}}{\sqrt{(-6)^2+(8)^2}} = \frac{-6\hat{i}+8\hat{j}}{10} = -0.6\hat{i}+0.8\hat{j}$ = ∠143.1°. Note that the displacement vector from one point to another is obtained by subtracting the position vector of the initial point from that of the final point.

We will deal mainly with planar (i.e. two-dimensional) vectors in the first part of the course, but three dimensional vectors will become important in our study of magnetism. Vectors in space can be expressed in component form in terms of the unit vectors $\hat{i},\hat{j},\hat{k}$. You will find a thorough discussion of vectors in Ch.1 of the text. You will also need to know about the dot and cross products of vectors for this course. The dot product will be needed when we study the electric potential, but the cross product won't be needed until we begin our study of magnetism.

Objectives 1 and 2: Coulomb's law and Unit Vectors

Suggested Study Procedure:

Study Ch. 21-1, 2, 3, and all of the worked examples in Ch. 21-3. The preceding paragraphs of this Study Guide provide a review of how to determine unit vectors.

Suggested Problems:

Problems 21-6, 8, 13, 15, 21, 39.

Objective 3: Electric Fields and the Principle of Superposition

Suggested Study Procedure:

Study Ch. 21-4, and particularly Ch. 21-5 for the Principle of Superposition.

Suggested Problems:

Problems 21-31, 43, 45, 49, 77.

Objective 4: Motion of a charged particle in a uniform electric field

Suggested Study Procedure:

Study Ch. 21-4, and particularly Example 21.7.

Suggested Problems:

Problems 21-25, 27, 33, 35, 41.

Objective 5: Field lines

Suggested Study Procedure:

Study Ch. 21.6, and Fig. 21.28 in particular. In Exp. 2 of Lab you will have the opportunity to study field lines for various combinations of point charges and you will also become familiar with the following Rules pertaining to Field Lines:

Rules for Drawing Field Lines

- Field lines begin and end only on charges or at infinity (in other words, field lines never just start or end at any empty point in the active area but on charges in the active area or else beyond the edge of the active area).

- The number of lines beginning at a positive charge or ending at a negative charge is proportional to the charge magnitude.
- At each point along a field line the tangent to the field line is parallel to the direction of the force a small positive test charge would experience if placed at that point (in other words, parallel to the electric field at that point).
- The density of field lines (the number of field lines per area) is proportional to the magnitude of the electric field represented by those field lines.
- No two field lines can ever cross.
- Under electrostatic conditions (nothing moving!), field lines always meet the surface of a conductor perpendicularly and no field lines penetrate a conductor.

<u>Suggested Problems:</u>

Lab Exp. 2 will help you become familiar with the field line diagrams for various collections of point charges. Be sure you can handle diagrams for single point charges in the vicinity of conducting surfaces of various shapes as part of your preparation.

<u>Objective 6: The Electric Field in and near conductors</u>

<u>Suggested Study Procedure:</u>

All the essential points stated in the objective will be gone over in class, and a summary sheet of the conclusions will be shown and posted under the course lecture notes. Look at Ch.22-5 for additional information on this topic. A rigorous mathematical treatment of this topic is possible only with the aid of Gauss's law, which is beyond the scope of this course. However an intuitive justification of many of the results can (and will) be given in lecture without difficult mathematics. The physical applications of these results are very important, as will be pointed out in lecture.

<u>Suggested Problems:</u>

P1. Explain the principle of electrostatic shielding and give one or two examples of its applications.
P2. What is corona discharge? Give some examples of both its harmful and useful effects.

HOMEWORK FOR STUDY GUIDE 1

Please refer to the link "MASTERING PHYSICS: instructions for registration" on course website to learn how to register for the online homework. **Please note that the instructions are slightly different from those you followed in PH1110 in A Term. You now have to register by individual conference sections.**

Those of you who are new to Mastering Physics should first complete Introduction to Mastering Physics – Assignment 0, a brief, noncredit tutorial on how to enter answers in Mastering Physics.

In Assignment #1, you will get 4 chances to submit a correct answer. If your first answer is incorrect, you should consider making use of the hints. The same rules will apply to all the later assignments. Note that each assignment is due by noon on the specified day.

There are four assignments that go with this Study Guide, and the first of them is due Thu, Oct 27. Please look up the due dates of all future assignments (we would suggest doing this after every lecture), and make sure that you submit them on time. In case of any difficulties with Mastering Physics, please contact Prof.Aravind and mention the conference section you are in.