Fields and Waves I

Name ________________ ECSE-2100 Spring 2001 Section _____________

Preparation Assignments for Homework #2

Due at the start of class.

Reading Assignments

Please see the handouts for each lesson for the reading assignments.

Due 22 January (5 points) Lesson 2.2

1. Write down the mathematical expression for the electric field of a point charge, which can be found in section 3.3 of the text. Show that this expression has neither a divergence nor a curl for all points in space except possibly at the origin.

2. The magnitude of the magnetic field outside of a long straight wire is given in equation 12.15 of the text. Write the vector form of this expression, given that the field is in the phi direction. Show that your expression has neither a divergence nor a curl.

3. State Gauss' Law for electric fields in your own words.

The first two problems will be worth 2 pts each. The last will be worth 1 pt. Note also that the magnetic field of a wire and the electric field of a point charge are also given in unit I of Connor and Salon. Finally, there will also be a very short mini-quiz on Monday. You will be given only 5 minutes to complete this quiz. It will be based on material you will have completed in lessons 2.1 and 2.2.

Due 24 January (5 points) Lesson 2.3

1. Two identical point charges $+Q$ are separated by a distance of 1 meter. How large must Q be for the charges to experience a force of 1 Newton? Assume that one of the charges is now negative. Does the distance change?

2. Sketch a few electric field lines for the two cases considered in the previous question. Show the direction of the force in each case.

3. A line charge $r_L = +Q' \, Coulombs / meter$ is surrounded by a surface charge located at $r = a$. (Note that we have used both the notation in the class notes r_L and in the text $+Q'$ (i.e. *Q primed*) for clarity.) What must the surface charge density be to have no net charge in this configuration? Both r_S and s are used to represent charge density.

4. Give an example of a common electrical device in which you might find cylindrical charge distributions. Give an example of a device in which you might find a rectangular charge distribution.

5. Inside an imaginary closed surface S the total charge is zero. Does this mean that at all points of S, the electric field vector $\vec{E}$ is zero?

Class time 25 January
Open shop to work on Homework 2. Due at 6 pm on 25 January

Due 29 January (5 points) Lesson 2.4

1. A point charge of 1 Coulomb creates an electric field that is radially directed away from the charge. This electric field also produces a potential. At what distance from this charge will the potential be equal to 1 volt?

2. In figure 5.3 of the text assume that all the charges are equal and positive. Determine the total electric flux through each of the three surfaces.

3. Two parallel charged plates have equal and opposite surface charges $r_S = s = \pm 8.85x10^{-10}$ *Coulombs/meter*^{2}. What is the magnitude of the electric field in the region between these plates?

4. A spherical rubber balloon is charged by friction uniformly over its surface. How does the electric field inside and outside the balloon change if it is periodically inflated and deflated to change its radius?

5. Find the dielectric strength and the dielectric constant of Plexiglass at 60 Hz?. *Hint: Look in textbook and on the course web pages.*

Class time 31 January
Open shop time to study for Quiz 1. Quiz 1 will be held from 7-9 pm.

Homework #2

Problem 1 – (10 points) Gauss' Law

It is given that the electric field is a constant in each of the three coordinate systems we are using in this course. That is

In Rectangular Coordinates: $\vec{E} = E_o \hat{a}_x$ for $0 \le x \le d$

In Cylindrical Coordinates: $\vec{E} = E_o \hat{a}_r$ for $0 \le r \le a$

In Spherical Coordinates: $\vec{E} = E_o \hat{a}_r$ for $0 \le r \le a$

a) Find the divergence $\nabla \cdot \vec{E}$ in each case. Use your answer to find the volume charge density r_V, if there is one.

b) For the rectangular case, assume that there are equal and opposite surface charge densities at *x=0* and *x=d*. Find the values of the surface charge densities in terms of E_o, using the results of example 5.4..

c) For the cylindrical case, assume that there is a surface charge density at *r=a* such that there is no electric field for the region $a < r$. Find the value of this surface charge density.

d) Repeat part c for the spherical case where the surface charge density is at the radius *r=a* and, again, there is no electric field outside of the surface charge.

e) Using your expressions for the volume and surface charge densities, apply the integral form of Gauss' Law (equation 5.4 of the text) to show that you can obtain the original expressions for the electric field in the cylindrical and spherical cases. That is, the electric field should be the same constant and point in the correct direction. Show all steps.

f) Find the electric potential *V* as a function of position for each of the three cases using equation 4.15 of the text.

g) Show that your answer for the potential is correct by applying equation 4.21 of the text.

Problem 2 – (10 points) Electric Fields and Potentials

Four equal point charges *+Q* are located at the corners of a square at *(5,5), (5,-5), (-5,5)* and *(-5,-5)*, in centimeters.

a) For what numerical value of *+Q* will the potential be equal to *100 Volts* at the origin *(0,0)*? Give your answer to 3 significant digits.

b) For this value of *+Q*, determine the potential at *(0,2.5)*.

c) Determine the electric field $\vec{E}$ at both of these locations. Since this is a vector, you must determine both the magnitude and the direction.

d) Using Matlab, Maple, Excel or some other program, plot from 10-20 representative equipotential contours for this charge configuration. On your plot, sketch a representative set of electric field lines. Discuss the features of your plot and explain why you think it makes sense. Change the sign of any two of the charges and generate a new contour plot. Discuss the differences between the two cases.

e) Pick any equipotential in each of the two cases and determine the total electric flux passing through the closed surface formed by the equipotential. Recall that the equipotential line you are showing indicates where the surface intersects the plane of your drawing.