Exam 1

Your Name:

Instructions

Solve each of the following problems to the best of your abilities. The exam is worth 100 points total and is calibrated for 90 minutes. Once you have completed the exam, hand it to me, and you can take a break before lab.

Good luck!

Problem 1

(25 points) A positive point charge (q = +2.0 mC) is placed at the point (2.1 m, 2.2 m). A negative point charge (Q = -2.0 mC) is placed at the point (3.1 m, -1.3 m). Together, the two points form an electric dipole.

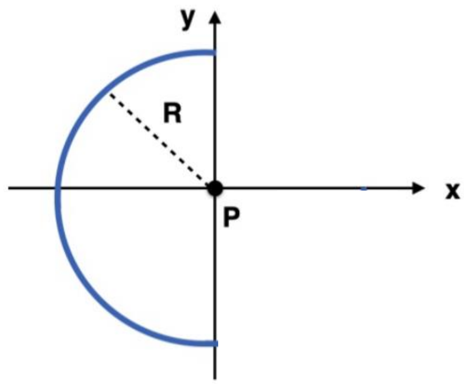
a) (5 points) What is the electric force on the negative point charge (Q) from the positive point charge (q) in this configuration? Be sure to include both the magnitude / direction or give me the components of the force.

In this problem, you are going to use Coulomb's law to calculate the force between the point charges. The hardest part of the analysis is likely determining the direction of the unit vector between the two charges. In this case, the unit vector between the charges starts at the +q charge and points towards the –Q charge. Since one of the charges is negative, the electric field will point in the opposite direction (i.e. the charges will attract each other).

b) (5 points) What is the dipole moment of the configuration? Be sure to include both the magnitude / direction or give me the components of the dipole moment.
c) (5 points) If I were to decrease the distance between the point charges, would the magnitude of the dipole moment increase, decrease, or stay the same? Why?
d) (5 points) Sketch the electric field lines around the electric dipole. Be sure to label the coordinate axes, the point charges, and the field lines.
e) (5 points) Is there a spot around the electric dipole (other than infinitely far away) where the net electric field is equal to zero? Support your answer with an explanation and / or equations from our study of electric fields.

Problem 2

(30 points) Consider a half thin ring with a radius R and a total charge +Q. Our goal is to find the electric field at the center of the ring (point P) using Coulomb's law for continuous charge distributions:



$$d\vec{E} = \frac{k\,dq}{r^2}\hat{r}$$

a) (5 points) What is the expression for dq in terms of a variable of integration and constants?
b) (5 points) What is the expression for r^2 in terms of your variable of integration and constants?
c) (5 points) What is the expression for $\hat{r}$ in terms of your variable of integration and constants?
d) (5 points) Set up the integral for $d\vec{E}$ along with the limits of integration.
e) (5 points) Solve the integral for the electric field at point P.
f) (5 points) Suppose that I complete the other half of the ring using a second half-ring with charge -Q. What is the net electric field at the center of the ring?

Problem 3

(20 points) A non-uniform electric field is given by the expression E(x) = (5x + 100) $\hat{x}$ N/C. In other words, the strength of the field increases as you move along the x-axis.

a) (5 points) What is the electric field at (1.0 m, 3.0 m)? Be sure to include both the magnitude / direction or give me the components of the field.
b) (5 points) What is the electric force on a –1.0 mC particle located at the point (2.5 m, 6.8 m)? Be sure to include both the magnitude / direction or give me the components of the force.
c) (5 points) Recall that the kinematics equations that we learned in physics work for a particle undergoing constant acceleration. Explain why the kinematics equations are not valid for motion along the x-axis in this system.
d) (5 points) Suppose I were to place an electric dipole into this electric field with its dipole moment oriented in the +x direction. What is the motion of this particle?

Problem 4

(25 points) An electric field is given by E = 10 $\hat{x}$ + 100 $\hat{z}$ N/C. A circle of radius 1.5 m is traced out in the xy-plane and centered at the origin.

a) (6 points) What is the magnitude of the electric flux passing through the circle?

In this problem, we have put a circular surface in a uniform electric field. Due to the fact that we are dealing with nice, flat surfaces and uniform fields, we do not have to use any calculus to solve for the electric flux. The flux is simply:

$$\phi_E = \vec{E} \cdot \vec{A}$$

The area vector of the circle is pointing in the z direction since the circle itself is in the xy-plane. Thus, only the z-component of the electric field will add to the flux.

$$\phi_E = E_z A = \left(100 \frac{N}{C}\right)(\pi)(1.5 \, m)^2 = 706.9 \frac{Nm^2}{C}$$

b) (6 points) If I were to increase the strength of the electric field, would the electric flux passing through the circle increase, decrease, or stay the same? Why?

The electric flux through the surface is given by $\phi_E = EA \cos\theta$. In this particular setup, the flux through the circle is non-zero since there is a z-component of the electric field. If the electric field were to increase in magnitude, the flux would increase as well.

c) (6 points) If I were to shrink the area of the circle, would the electric flux passing through the circle increase, decrease, or stay the same? Why?

The electric flux through the surface is given by $\phi_E = EA \cos\theta$. In this particular setup, the flux through the circle is non-zero since there is a z-component of the electric field. If the area of the circle were to decrease in magnitude, the flux would decrease as well.

d) (7 points) How might I move or rotate the circle to maximize the electric flux passing through it? Sketch a diagram of the new position of the circle.