Physics 114
Exam 1 Fall 2019

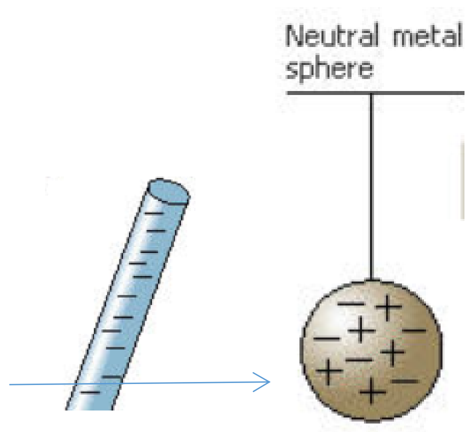
Name: ____

For grading purposes (do not write here):

Question	Problem
1.	1.
2.	2.
3.	3.

Answer each of the following questions and each of the problems. Points for each question and problem are indicated in red with the amount being spread equally among parts (a,b,c etc). Be sure to show all your work.
Use the back of the pages if necessary.

Question 1. (10 points) A negatively charged rod is brought close to a small metal ball suspended by a thin thread, but doesn't touch it. (a) What do the charges in sphere do?
(b) What does the sphere do, if anything.
Now, still without the rod touching the sphere, but while holding the rod close to the sphere, you ground the sphere by touching it. (c) What do charges in the sphere or elsewhere (like from the ground) do at this point.
You take away your hand (the connection to ground). (d) What is the net charge of the sphere now (positive, negative, or neutral)?



Solution

(a) They polarize; the negative charges move away from the rod so that the left side is positive and right side is negative.
(b) The sphere is attracted to the rod and moves towards it
(c) Negative charges in the sphere flow into the ground.
(d) The charge on the sphere is positive.

Question 2. (10 points) . A test charge of + 3 nC is placed in a constant external field directed along the positive x-axis with a magnitude of 4×10^6 N/C.

(a) What is the direction of the force on this charge?

$$\boldsymbol{F} = q\boldsymbol{E} = (+)(+\hat{\boldsymbol{x}})$$

Positive x-direction

(b) If the test charge is replaced by a negative test charge with q = - 3 nC, what is the direction of the force on this negative charge?

$$\boldsymbol{F} = q\boldsymbol{E} = (-)(+\hat{\boldsymbol{x}}) = (-\hat{\boldsymbol{x}})$$

Negative x-direction

(c) When the positive test charge is replaced by the negative one, what happens to the external electric field, does it increase significantly, decrease significantly, or essentially stay the same?

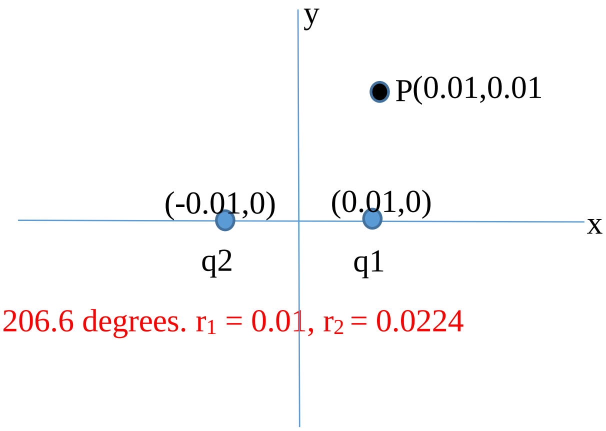
Essentially stay the same, the electric field is not dependent on the test charge, unlike the electric field.

Question 3. (10 points) Suppose that a point charge = 10 C is located at the center of a sphere of radius 10 m. The electric field at the surface of the sphere and the total flux through the sphere are determined.

(a) If the radius of the sphere is cut in half, what happened to the electric field at the surface of the sphere? Does it increase, decrease or stay the same?
(b) If the radius of the sphere is cut in half, what happened to the total electric flux through the sphere"
(c) If the sphere (now of radius 5 m) is replaced by cube with each side 10 m, what happens to the total flux through the surface (compared to the sphere, is there more or less flux or is it the same?

(a) It increases. The electric field of a point charge goes as $1/r^2$ so it actually goes up by a factor of 4.
(b) It stays the same. Gauss's law says that the flux is independent of the size and shape of a closed surface. The number of field lines through the sphere stay the same.
(c) It is the same. Gauss's law says that the flux is independent of the size and shape of a closed surface. The number of field lines through the surface stay the same.

Problem 1. (15 points) Two point charges lie along x-axis. The charge q1 = 2 C at x = 0.01 m and the charge q2 = - 4 C is at x = -0.01 m. (a) Find the resultant electric field at the point P which is at (0.01, 0.01). (b) Calculate the force on a 2 nC charge if it were placed at point P.



(a) $\mathbf{E}_{total} = \mathbf{E}_1 + \mathbf{E}_2$

The magnitude of the electric field is $k_e q/r^2$. We need to add vector components. $\mathbf{E}_1$ is in the positive y direction. $\mathbf{E}_2$ is at 270 degrees minus invtan(2/1) = 206.6 degrees. $r_1 = 0.01$, $r_2 = 0.0224$

$$\vec{E} = \frac{kq_1}{r_1^2}\hat{j} + \frac{kq_2}{r_2^2}\left(\cos(206.6)\hat{i} + \sin(206.6)\hat{j}\right) = \frac{(9\times10^9)(2)}{0.0001}\hat{j} + \frac{(9\times10^9)(4)}{0.0005}\left(-.894\hat{i} - 0.448\hat{j}\right)$$

$$= 1.8\times10^{14}\hat{j} - 6.4\times10^{13}\hat{i} - 3.2\times10^{13}\hat{j} = -6.4\times10^{13}\hat{i} + 1.48\times10^{14}\hat{j} \text{ N/C}$$

(***b***) $\boldsymbol{F} = q\boldsymbol{E}$ **.** Just multiply the answer from part a by 2 nC

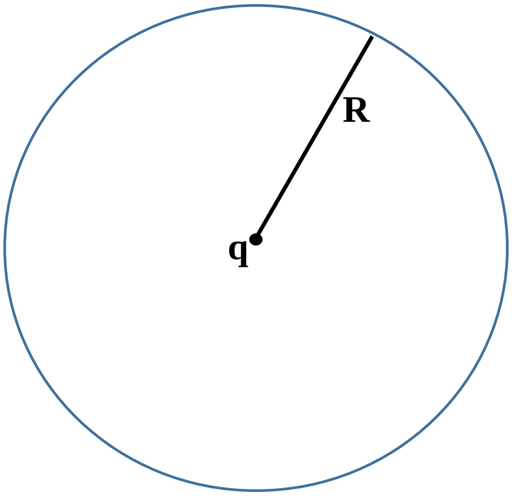
$$\vec{F} = -1.28\times10^5\hat{i} + 2.96\times10^5\hat{j} \text{ N}$$

Problem 2. (15 points). A 40 cm diameter loop is rotated in a uniform electric field until the position of maximum electric flux (through the loop) is found.
The flux in this position is 5.20×10^5 Nm^2/C. (a) What is the electric field strength? (b) The loop is now rotated until the flux through it is a minimum. What is the value of the flux in the new orientation? (c) The loop is once again rotated until now the flux through it is 2.6×10^5 Nm^2/C. What is the angle between the loop and the electric field (describe this clearly in terms of either the normal to the loop or the plane of the loop).

(a) At the max position the normal is parallel to the field and the flux $\Phi = EA$. $A = \pi r^2 = 0.126\ m^2$. $E = \Phi/A = 4.14 \times 10^6$ N/C
(b) It's zero.
(c) $\Phi = EA\cos(\theta)$. $\cos(\theta) = \Phi/EA = 0.498$. $\theta = 60$ degrees. This is the angle the normal to the loop makes with the field.

Problem 3. (15 points). A point charge $q = 5$ mC is placed at the center of a spherical shell (like a hollow ball) of radius R= 2 m that has 10 mC evenly distributed over its surface. Find the electric field at a radial distance from the point charge at

a) $r = 1$ m
b) $r = 5$ m.



(a) Draw a Gaussian sphere are $r = 1$ m. We have $EA = E4\pi r^2$. Q inside is just $q = 5$mC. We get $E4\pi r^2 = q/\varepsilon_0$. So $E = k_e q/r^2 = (9 \times 10^9)(5 \times 10^{-3})/1 = 4.5 \times 10^7$ N/C radially outward.

(b) Draw a Gaussian sphere are $r = 5$ m. Everything is like part a except Q inside is now 15 mC and $r = 5$ m. $E = k_e q/r^2 = (9 \times 10^9)(15 \times 10^{-3})/25 = 5.4 \times 10^6$ N/C radially outward.