Physics 124
Exam 1 Spring 2021

Name: ____

For grading purposes (do not write here):

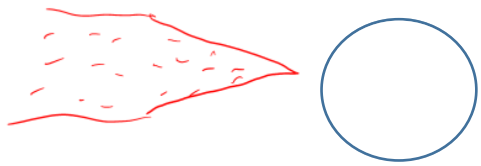
Question	Problem
1.	1.
2.	2.
3.	3.

Include a statement and signature that you have followed the honor code and not cheated on this exam.

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.

For remote students: Write you solutions and answer on a separate piece of paper (unles you print the exam). Be sure to label each question and problem clearly (example – Q1 a) b) etc). Take photos of each page and email to shapiro@wfu.edu within two hours of being sent the exam. Write legibly but conserve space. Clearly mark your final answer (like put a box around it).

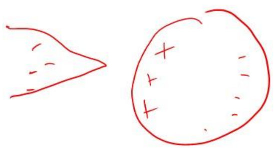
Question 1. (10 points) Consider a negatively charged rod that is brought close to a neutral conducting sphere as shown below.



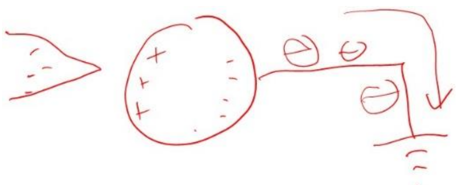
(a) What do the charges in the sphere do? Draw it.
(b) Now, keeping the negatively charged rod in place, you ground the sphere. What happens? Draw the charge distribution
(c) Now you first take the ground away and then take the rod away. What is the net charge (if any) of the sphere (positive or negative or neutral)? Draw it
(d) Say that instead of taking the ground away first and then the rod, you took the rod away first and then the ground. What would be the net charge (if any) of the sphere (positive or negative or neutral) in this case? Draw it

Solutions

(a) The sphere becomes polarized.

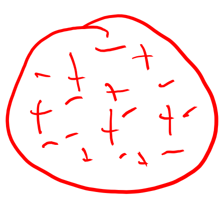


(b) Negative charges flow to the ground



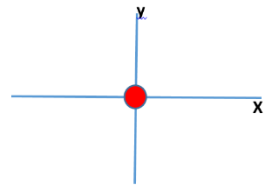
(c) The sphere has a net positive charge equally distributed

(d) If you take the rod away, now you have a sphere that is grounded – so it will become neutral.



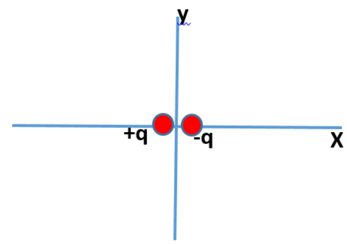
Question 2. (10 points) Let there be a completely neutral sphere at the origin in a space where there are no other objects.

(a) Is there an electric field in this space?



Solution – No. There is no charge so no electric field. If I were to put a test charge somewhere, it would experience no force.

(b) Now say that the sphere splits into two smaller spheres and that one has a net positive charge and the other has a net negative charge and they are equi-distant from the origin along the x-axis. Is there an electric field in the space now?

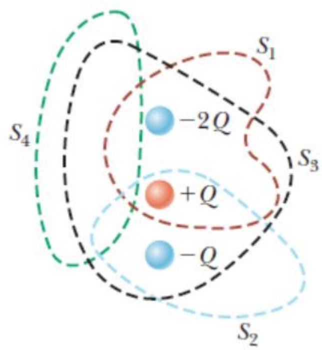


Solution. Yes, This is a dipole and we have a field like we saw in class.

(c) If you answered no, to part b, explain why there is no field and what would need to happen for there to be a field. If you answered yes, describe the direction of the electric field at a point along the positive y axis that is further from the origin than the two spheres are from each other.

Solution. We did this in class, only the negative charge was on the right. The y components of the field cancel and we just have a field pointing to the right parallel to the x-axis.

Question 3. (10 points) Four closed surfaces, S_1 through S_4, together with the charges $-2Q$, Q, and $-Q$ are sketched in the figure below. (The colored lines are the intersections of the surfaces with the page.) Find the electric flux through each surface. (Use the following as necessary: ε_0 and Q.)



(a) S_1
(b) S_2
(c) S_3
(d) S_4
(e) Can we use Gauss' law to find the electric field at the surface of any of the closed surfaces? If so, which one(s)?

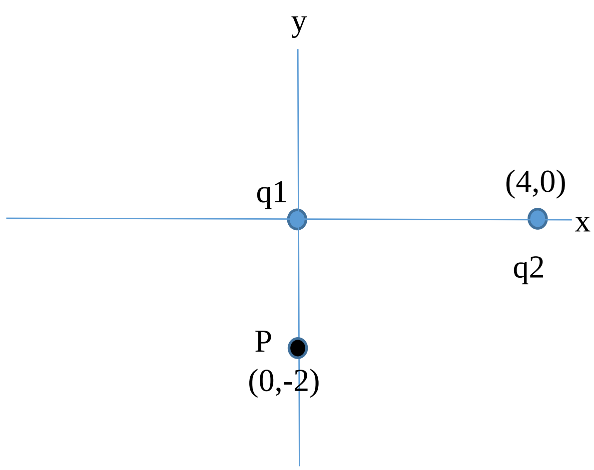
Solutions

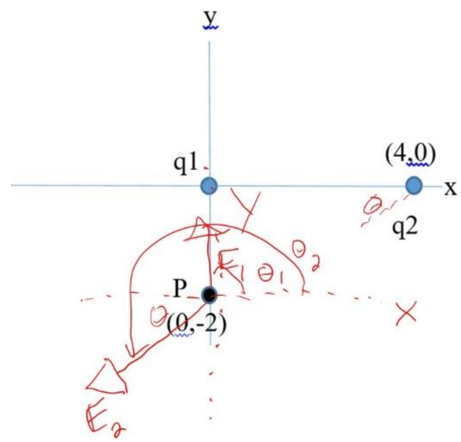
Only the charges inside the surface contribute to the flux.

(a) $\Phi = (Q\text{-}2Q)/\varepsilon_0 = \text{-}Q/\varepsilon_0$
(b) $\Phi = (Q\text{-}2\text{=}Q)/\varepsilon_0 = 0$
(c) $\Phi = (Q\text{-}2Q\text{-}Q)/\varepsilon_0 = \text{-}2Q/\varepsilon_0$
(d) $\Phi = 0$
(e) No, there is no symmetry here. The dot product of **E** and **dA** is not constant over parts of the surfaces.

Problem 1. (15 points) Two point charges q_1 = - 5 μC and q2 = 10 μC are located on the x-y plane at the origin and (4,0) m respectively. (a) Calculate the electric field at point P which is at (0,-2). (b) If a 5 nC charge were placed at point P, what would the force be on that charge due to the electric field?

Solutions





(a) The electric field is the vector sum of that due to charges 1 and 2. To find the direction of these fields we ask what the direction of the force would be for a positive test charge. $\mathbf{E}_1$ is upward as q1 would attract a positive charge. $\mathbf{E}_2$ is downward to the left as q2 would repel a positive test charge at P. Thus, θ1 is 90 degrees and θ2 is 180 degrees plus the arctan(2/4) = 180 + 26.56 = 206.56 degrees.

$\mathbf{E} = \mathbf{E}_1 + \mathbf{E}_2 =$

$$E_{1x}\hat{i} + E_{1y}\hat{j} + E_{2x}\hat{i} + E_{2y}\hat{j} = (E_1\cos(\theta_1) + E_2\cos(\theta_2))\hat{i} + (E_1\sin(\theta_1) + E_2\sin(\theta_2))\hat{j}$$

=

$$(0 + \frac{(9\times10^9)(10\times10^{-6})}{20}\cos(206.56))\hat{i} + (\frac{(9\times10^9)(5\times10^{-6})}{4}\sin(90) + \frac{(9\times10^9)(10\times10^{-6})}{20}\sin(206.56))\hat{j}$$

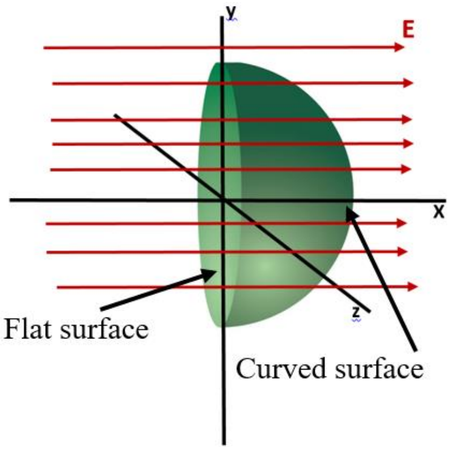
= (4500)(-.894) $\hat{i}$ + [11,250+(4500)(-.447)] $\hat{j}$

=-4025 $\hat{i}$ +9238 $\hat{j}$ N/C.

(b) Just use $\mathbf{F} = q\mathbf{E}$ with $q = 5 \times 10^{-9}$ C. Thus

$\mathbf{F} = -2.0 \times 10^{-5}\hat{i} + 4.6 \times 10^{-5}\hat{j}$ N

Problem 2. (15 points). A solid, closed hemisphere with a radius of 2 m is in a constant electric field of magnitude 5 N/C pointing in the positive x-direction. So $\vec{E} = 5\hat{i}$ N/C. The flat face of the hemisphere is parallel to the y-z plane facing toward the negative x-direction as shown below.



(a) What is the flux through the flat surface?

(b) What is the flux through the curved surface?

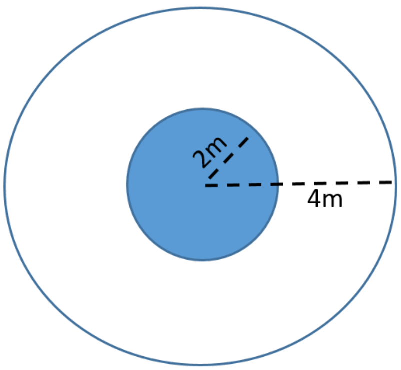
(c) What is the total flux through the whole surface?

(d) The sphere is now rotated 30 degrees around the y-axis so that the normal to the flat surface makes an acute angle of 60 degrees with the positive z-axis. What is the flux through the flat surface now?

Solutions

(a) We have a flat surface with the normal in the minus x direction. We have the flux is EAcos(θ) = (5)($\pi 2^2$)cos(180) = -20 π = -62.8 Nm^2/C
(b) The flux for the whole surface is zero (part c) so here it must be + 62.8 N/C
(c) 0. It is a closed surface with no charge inside
(d) The angle between the normal and field is now 150 degrees. We have EAcos(θ) = (5)($\pi 2^2$)cos(150) = -54.4 Nm^2/C

Problem 3. (15 points). A solid insulating sphere with a radius of 2 m has a charge of 5 C distributed evenly throughout its volume (uniform volume charge density). A thin spherical shell of insulating material is concentric with the solid sphere and has a radius of 4 m and it has a charge of 3 C evenly distributed throughout (uniform surface charge density).



Use Gauss' law to find the electric field at (a) 1 m, (b) 3 m, (c) 6 m from the center of the sold sphere. For each case, clearly state what the charge enclosed in your Gaussian surface is.

Solutions

(a) Draw a Gaussian surface which is a sphere of radius r = 1 m. The charge enclosed a portion of 5 C on the sphere given by the ratio of the enclosed volume to the total volume.
$Q_{encl} = (r/a)^3 Q_{tot} = (1/2)^3 5C =$ **0.625 C**

$$\varepsilon_0 \Phi = \varepsilon_0 \oint \vec{E}.d\vec{A} = q_{enc}$$

$E4\pi r^2 = Q_{encl}/\varepsilon_0$. $E = k\, Q_{encl}/r^2 = (9 \times 10^9)\,(0.625\ C)/1^2 =$ **5.63×10^9 N/C, directly radially outward**

(b) Draw a Gaussian surface which is a sphere of radius r = 3 m. The charge enclosed is the full **5 C** on the sphere.
$E4\pi r^2 = Q_{encl}/\varepsilon_0$. $E = k\, Q_{encl}/r^2 = (9 \times 10^9)\,(5\ C)/3^2 =$ **5.00×10^9 N/C, directly radially outward**

(c) Draw a Gaussian surface which is a sphere of radius r = 6 m. Now the charge enclosed is the total charge here which is 5 + 3 = **8 C**
$E4\pi r^2 = Q_{encl}/\varepsilon_0$. $E = k\, Q_{encl}/r^2 = (9 \times 10^9)\,(8\ C)/6^2 =$ **2.00×10^9 N/C, directly radially outward**

Possibly Useful Information

$$F = \frac{1}{4\pi\varepsilon_0}\frac{|q_1||q_2|}{r^2}$$

$$\varepsilon_0 = 8.85 \text{ X } 10^{-12} (C^2 / N - m^2)$$

$$e = 1.6 \text{ X } 10^{-19} \text{ C}$$

$$\vec{E} = \vec{F}/q_0$$

$$E = \frac{|q|}{4\pi\varepsilon_0 r^2}$$

$$\varepsilon_0 \Phi = \varepsilon_0 \oint \vec{E}.d\vec{A} = q_{enc}$$

$$k_e = \frac{1}{4\pi\varepsilon_0} = 9\times10^9 \text{ N}\bullet\text{m}^2/\text{C}^2$$

$$\vec{r} = x\hat{i} + y\hat{j} + z\hat{k}$$