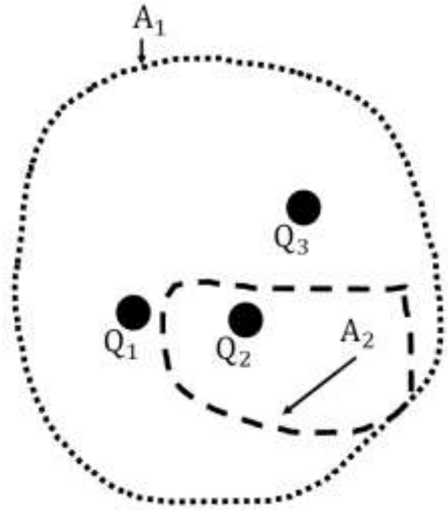
PH 221 Homework Assignment Chapter on Gauss's Law – 22 Problems Total

1. An approximate measurement of the Earth's electric field indicates a magnitude of $150.\, {}^{N}/_{C}$ and it is directed radially inward towards the center of the Earth. Determine the net electric flux outward through a spherical surface surrounding and just beyond the surface of the Earth.

Solution for Problem 1

2. Shown below you find three charges: $Q_1 = -8.94\ \mu C$, $Q_2 = +4.47\ \mu C$, and $Q_3 = -2.32\ \mu C$.



(a) Determine the net electric flux through surface A_1.

(b) Determine the net electric flux through surface A_2.

Solution for Problem 2

3. A point charge Q is placed at the center of a cube which has side lengths of L.

(a) Determine the net electric flux through the entire surface area of the cube.

(b) Determine the net electric flux through one face of the entire surface area of the cube.

Solution for Problem 3

4. A nonconducting sphere of radius $2.56 \text{ x } 10^{-2}$ m has a charge uniformly distributed on the surface of the sphere. The sphere is encased in a container. A measurement of the electric flux passing through the container is found to be $-9.56 \text{ x } 10^{5} \, ^{\text{Nm}^2}/_{\text{C}}$. What is the surface charge density found on the sphere?

Solution for Problem 4

5. The electric field just outside the surface of a metallic hollow sphere is found to be $3.04 \text{ x } 10^{4} \, ^{\text{N}}/_{\text{C}} \, \widehat{(+\text{r})}$. If the sphere has a radius of $4.60 \text{ x } 10^{-2}$ m, what is the net charge on the surface of the sphere?

Solution for Problem 5

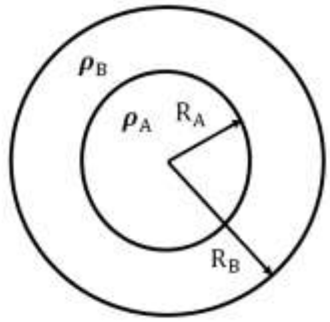
6. An infinitely long wire has a negative charge uniformly distributed along its length with a linear charge density of $\lambda = -8.13 \, ^{\text{mC}}/_{\text{m}}$ as shown below

(a) Determine the net electric field at a radial distance of $r_a = 11.0$ m.

(b) Determine the net electric field at a radial distance of $r_b = 1.10$ m.

Solution for Problem 6

7. An object is made of non-conducting materials in such a way that you have two concentric solid spheres. The inner sphere has a radius $(R_A = 2.50 \text{ x } 10^{-1} \text{ m})$, and has a charge uniformly distributed over its volume with a charge density of $\left(\rho_A = +9.03 \text{ C}/_{\text{m}^3}\right)$. The outer sphere has a radius $(R_B = 5.30 \text{ x } 10^{-1} \text{ m})$, and has a charge uniformly distributed over its volume with a charge density of $\left(\rho_B = -6.33 \text{ C}/_{\text{m}^3}\right)$.



(a) Determine an expression for the electric field for locations $0 \leq r \leq R_A$.

(b) Determine an expression for the electric field for locations $R_A \leq r \leq R_B$.

(c) Determine an expression for the electric field for locations $R_B \leq r \leq \infty$.

(d) Plot the electric field vs distance from the center of this object.

Solution for Problem 7

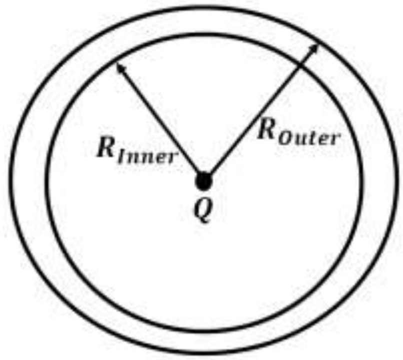
8. A square piece of copper plate has side length $(L = 1.50 \text{ x } 10^{-1} \text{ m})$. There is a net charge $(Q = -4.12 \text{ mC})$ uniformly distributed on the copper plate.

(a) Determine the magnitude and direction for the electric field at point directly above the center of the plate a distance $(z = 5.00 \text{ x } 10^{-2} \text{ m})$.

(b) Determine the magnitude and direction for the electric field at point directly above the center of the plate a distance $(z = 5.00 \text{ x } 10^{1} \text{ m})$.

Solution for Problem 8

9. A positive point charge Q is at rest at the center of a thin spherical shell made of conductive material. This is pictured below.



(a) Determine an expression for the electric field as a function of radial distance for the region $0 \leq r \leq R_{\text{Inner}}$.

(b) Determine an expression for the electric field as a function of radial distance for the region $R_{\text{Inner}} \leq r \leq R_{\text{Outer}}$.

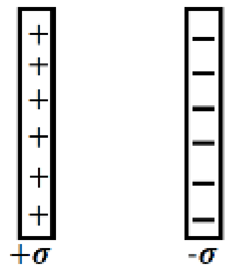
(c) Determine an expression for the electric field as a function of radial distance for the region $R_{\text{Outer}} \leq r \leq \infty$.

(d) How does the presence of the shell affect the electric field created by the charge?

(e) How does the presence of the charge affect the shell?

<u>Solution for Problem 9</u>

10. Two large flat conducting plates are separated by a distance which is small compared the height and width of the plates. As shown below the left plate has a positive charge uniformly distributed across the area of the plate. $\sigma = \frac{Q}{A}$. The right plate has a similar charge density but it is negative instead of positive.



(a) Use Gauss's Law to determine the electric field resulting from the two plates in the region between the two plates.

(b) Use Gauss's Law to determine the electric field resulting from the two plates in the region on the left side of the two plates.

(c) Use Gauss's Law to determine the electric field resulting from the two plates in the region on the right side of the two plates.

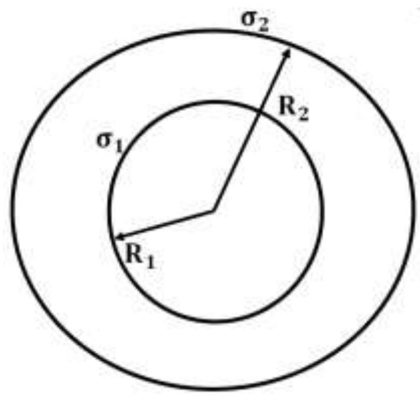
(d) How would these answers change if the plates were not conducting?

<u>Solution for Problem 10</u>

11. Consider two metal plates which are square $(\mathrm{L = 2.00\ m})$ and separated by a distance $(\mathrm{d = 1.75 \times 10^{-2}\ m})$. Each plate has the same magnitude of charge distributed on it, but one is positive charge and one is negative. If the electric field at the center point between the two plates and also the center of the squares is found to be $385.\ \mathrm{N/C}$, what is the magnitude of the charge on each plate? Ignore any edge or fringing effects.

<u>Solution for Problem 11</u>

12. Two thin conducting spherical shells have a common center. They have radii $R_1 < R_2$. Each shell has uniformly distributed charge with surface charge densities of σ_1 and σ_2 respectively. Neglect any thickness of the shells.



(a) Use Gauss's Law to determine the electric field resulting from the two charged spherical shells for distances in the range $0 \leq r < R_1$.

(b) Use Gauss's Law to determine the electric field resulting from the two charged spherical shells for distances in the range $R_1 \leq r < R_2$.

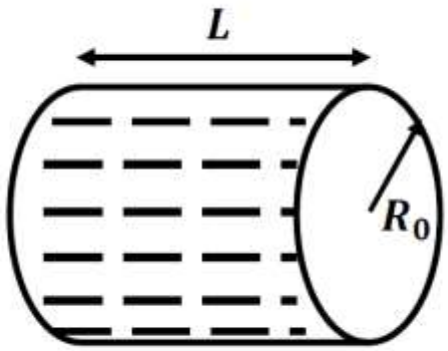
(c) Use Gauss's Law to determine the electric field resulting from the two charged spherical shells for distances in the range $R_2 \leq r < \infty$.

(d) Under what conditions will the electric field go to zero for the range $R_2 \leq r < \infty$?

(e) Under what conditions will the electric field go to zero for the range $R_1 \leq r < R_2$?

Solution for Problem 12

13. A thin walled cylindrical shell has a radius R_0 and a length L. The radius is much smaller than the length i.e. $R_0 \ll L$. As shown in the diagram below there is a uniformly distributed negative surface charge density σ. Assume the $L \to \infty$. Also assume the thickness of the shell is negligible.



(a) Use Gauss's Law to determine the electric field resulting from the charged cylindrical shells for radial distances in the range $0 \leq r < R_0$.

(b) Use Gauss's Law to determine the electric field resulting from the charged cylindrical shells for radial distances in the range $R_0 \leq r < \infty$.

(c) How does the result of part (b) compare with the electric field of a long line of negative charge which can be expressed as

$$\overrightarrow{E_{Line}} = \frac{\lambda}{2\pi\varepsilon_0 r}\,\widehat{(-r)}$$

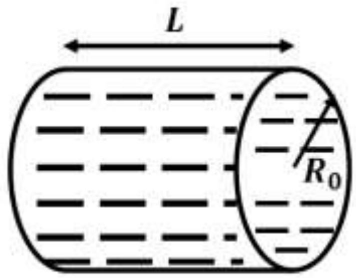
where

$$\lambda = {}^{Q}/_{L}$$

Is linear charge density.

<u>**Solution for Problem 13**</u>

14. A non-conducting solid cylinder $(\text{Radius } R_0,\ \text{Length } L, \text{with } R_0 \ll L \text{ and } L \to \infty)$ has a uniform volume charge density $\rho_0 \left(\text{units of } {}^{C}/_{m^3}\right)$ of negative charges as indicated in the diagram below. Assume the radial distances r are measured from the central axis and far away from the ends of the cylinder.

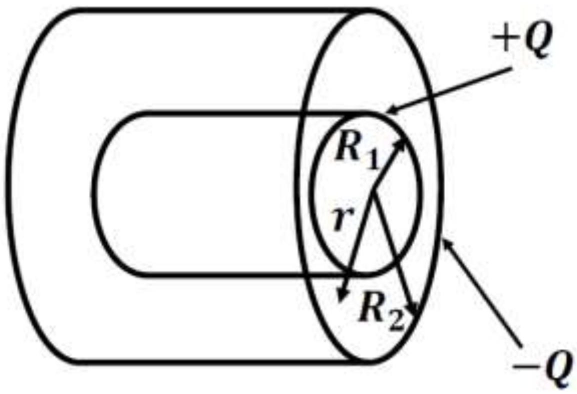


(a) Use Gauss's Law to determine the electric field resulting from the charged cylinder for radial distances in the range $0 \leq r < R_0$.

(b) Use Gauss's Law to determine the electric field resulting from the charged cylinder for radial distances in the range $R_0 \leq r < \infty$.

Solution for Problem 14

15. Two concentric thin walled cylindrical conducting shells have radii R_1 for the inner one and R_2 for the outer one. The length of the cylinders is L and it is the case that $L \gg R_2 > R_1$. The outer shell has a total charge of $-Q$, while the inner shell has a total charge of $+Q$. Assume the charges are uniformly distributed over the surface of the shells. Ignore the thickness of the shells.



(a) Use Gauss's Law to determine the electric field resulting from the charged cylindrical shells for radial distances in the range $0 \le r < R_1$.

(b) Use Gauss's Law to determine the electric field resulting from the charged cylindrical shells for radial distances in the range $R_1 \le r < R_2$.

(c) Use Gauss's Law to determine the electric field resulting from the charged cylindrical shells for radial distances in the range $R_2 \le r < \infty$.

(d) What is the kinetic energy of an electron if it moves between the shells and concentric to them with a circular orbit of radius $r = R = \frac{R_1+R_2}{2}$?

Solution for Problem 15

16. There are two thin flat conducting metal plates which both have dimensions $(\mathrm{L \times L} = 5.00 \text{ m} \times 5.00 \text{ m})$. The thicknesses of the plates are negligible. The plates are separated by a distance $(d_0 = 5.00 \times 10^{-3} \text{ m})$ The lower plate has a charge $(Q_{Lower} = -75.0 \times 10^{-6} \text{ C})$ uniformly spread over its area. The upper plate has a charge $(Q_{Upper} = +75.0 \times 10^{-6} \text{ C})$ uniformly spread over its area. Ignore any edge effects as you work this problem.

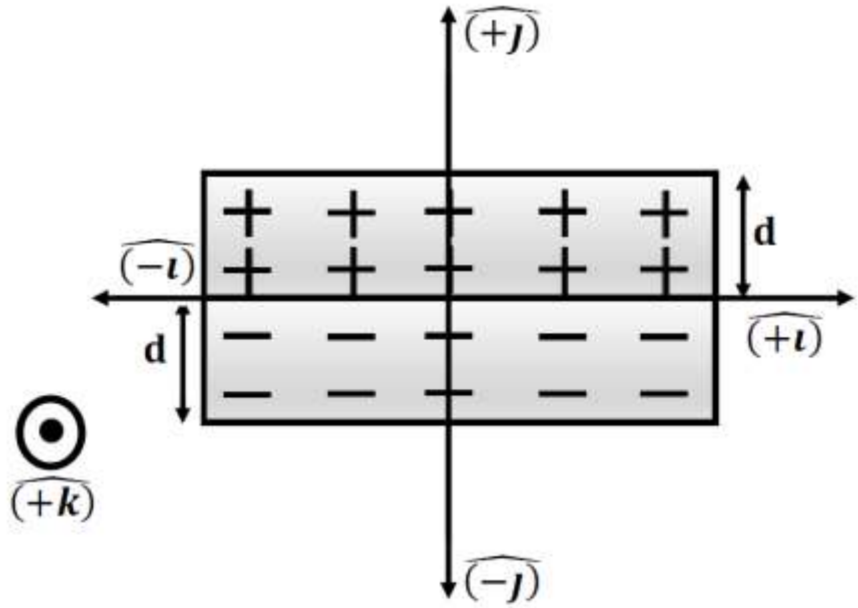
(a) Calculate the force either plate exerts on the other.

(b) Is this force attractive or repulsive?

(c) Determine the work done by the electric field to change the separation of the plates from the original separation (d_0) to a final separation of $(d_f = 5.00 \times 10^{-2} \text{ m})$.

Solution for Problem 16

17. Shown below is two very large slabs of nonconducting material. Each has a thickness of d in the y or $\widehat{(+\jmath)}$ direction and assume the other two directions x or $\widehat{(+\imath)}$ and z or $\widehat{(+\mathrm{k})}$ directions, the dimensions approach infinity. As you can see the origin of the coordinates is at the center of the two slabs joined. The upper slab $(0 \leq \mathrm{y} \leq +\mathrm{d})$ has a volume charge density $\rho_{\text{Upper}} = +\rho_0$, while the lower slab $(-\mathrm{d} \leq \mathrm{y} \leq 0)$ has a volume charge density $\rho_{\text{Lower}} = -\rho_0$. ρ_0 is a positive constant value.



(a) Find the magnitude and direction of the Electric field as a function of y for the region $-\infty \leq \mathrm{y} < -\mathrm{d}$.

(b) Find the magnitude and direction of the Electric field as a function of y for the region $-\mathrm{d} \leq \mathrm{y} < 0$.

(c) Find the magnitude and direction of the Electric field as a function of y for the region $0 \leq \mathrm{y} < +\mathrm{d}$.

(d) Find the magnitude and direction of the Electric field as a function of y for the region $+\mathrm{d} \leq \mathrm{y} < +\infty$.

Solution for Problem 17

18. A solid nonconducting sphere of radius R_0 has a total charge of Q_0 which is not uniformly distributed. Instead the volume charge density has a functional form of $\rho_s = ar$, where a is a constant that ensures the units for the volume charge density are $\left(\mathrm{C}/_{\mathrm{m}^3}\right)$.

(a) Find the expression for a in terms of Q_0 and R_0.

(b) Determine expressions for the electric field for radial distances in the region $R_0 \leq r < \infty$.

(c) Determine expressions for the electric field for radial distances in the region $0 \leq r < R_0$.

<u>Solution for Problem 18</u>

19. A point charge produces an electric flux of $-335. \, \mathrm{N\,m^2}/_{\mathrm{C}}$ through a Gaussian sphere with a radius of 2.50×10^{-1} m.

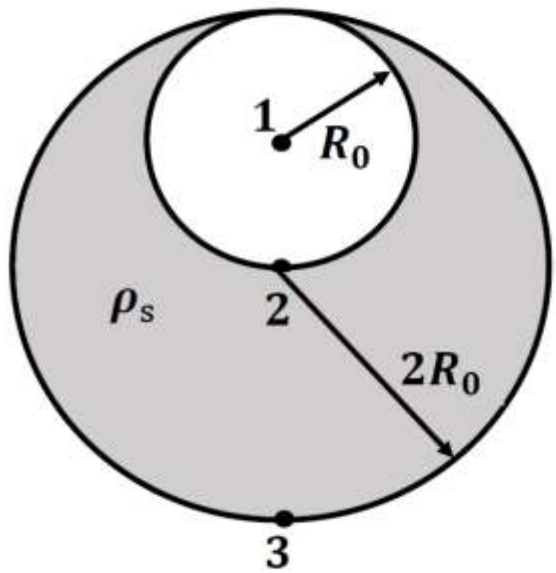
(a) Does the amount of flux depend on whether the charge is located at the center of the Gaussian sphere or not?

(b) What is the electric flux if the Gaussian sphere had a radius of 7.90×10^{-1} m instead?

(c) What is the magnitude and sign of the charge?

<u>Solution for Problem 19</u>

20. A nonconducting sphere has a radius $2R_0$ and has a uniform volume charge density of ρ_s. A spherical cavity exists within the sphere as shown below. This cavity has a radius of R_0 and this cavity is centered on the point labeled 1. The center of the larger sphere is centered on the point labeled 2.

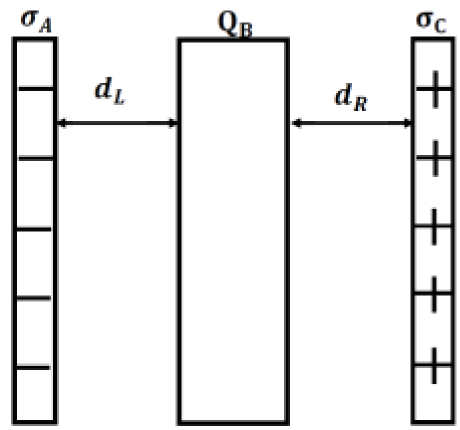


(a) Determine the magnitude and direction of the electric field at Point 2.

(b) Determine the magnitude and direction of the electric field at Point 3.

<u>**Solution for Problem 20**</u>

21. Shown below are three large plates. Plates A and C are nonconducting and have surface charge densities $\sigma_A = -25.0\ {}^{\mu C}/_{m^2}$ and $\sigma_C = +25.0\ {}^{\mu C}/_{m^2}$. The center plate B is conducting and has a net charge $Q_B = 0.00\ C$. The distance between Plate A and B is $d_L = 1.20 \times 10^{-1}\ m$. The distance between Plate B and C is $d_R = 1.20 \times 10^{-1}\ m$.



(a) What is the magnitude and direction of the electric field inside Plate B?

(b) What is the magnitude and direction of the electric field between Plate A and Plate B?

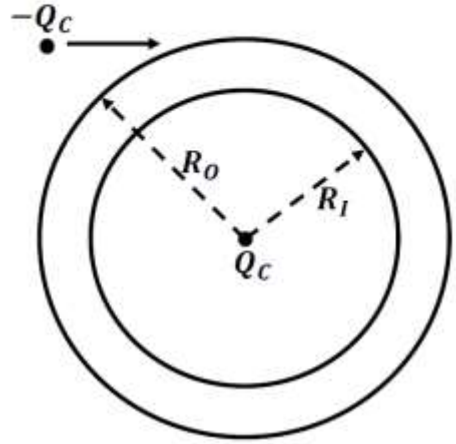
(c) What is the magnitude and direction of the electric field between Plate B and Plate C?

(d) What is the induced surface charge density on the left side of Plate B?

(e) What is the induced surface charge density on the right side of Plate B?

<u>**Solution for Problem 21**</u>

22. A conducting spherical shell has inner radius $R_I = 2.50 \times 10^{-1}$ m, and an outer radius of $R_O = 4.00 \times 10^{-1}$ m. A point charge $Q_C = +50.0\ \mu C$ is placed at the center of the spherical shell, while an equivalent but negative amount of charge is placed on the spherical shell. This is illustrated below.



(a) Where does the charge migrate to on the spherical conducting shell?

(b) What is the magnitude and direction of the Electric Field as a function of radial distance in the region $0 \leq r < R_I$?

(c) What is the magnitude and direction of the Electric Field as a function of radial distance in the region $R_I \leq r < R_O$?

(d) What is the magnitude and direction of the Electric Field as a function of radial distance in the region $R_O \leq r < +\infty$?

Solution for Problem 22

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