Physics 1B-2 Quiz B Quiz 3

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TOTAL POINTS

34 / 35

QUESTION 1

sheet 12 pts

1.1 lines **4 / 4**

✓ **- 0 pts** Correct

- 1 pts equipotential surface wrong or missing

1.2 q? **4 / 4**

✓ **- 0 pts** Correct

- 1 pts calculation error

- 4 pts no answer

- 2 pts wrong approach

1.3 dust **4 / 4**

✓ **- 0 pts** Correct

- 1.5 pts no force equilibrium

- 1 pts calculation error

- 1 pts no numerical answer

- 4 pts no answer

- 2 pts wrong setup

QUESTION 2

Gauss 14 pts

2.1 charge **5 / 5**

✓ **- 0 pts** Correct

- 1 pts Outer charge wrong, missing, or not consistent

- 1 pts Inner charge wrong, missing, or not consistent

2.2 E **6 / 6**

✓ **- 0 pts** Correct

- 1 pts 0-R1 wrong

- 1 pts R1-R2 wrong

- 1 pts R2-R3 wrong

- 1 pts outside R3 wrong

- 0 pts outside R3 wrong scaling

- 6 pts no answer

2.3 point charge **2 / 3**

- 0 pts Correct

✓ **- 1 pts wrong or missing**

- 0 pts wrong explanation

- 1 pts numerical error or missing

- 3 pts no answer

QUESTION 3

rho 9 pts

3.1 e-field **5 / 5**

✓ **- 0 pts** Correct

- 1 pts calculation error

- 2 pts volume integral wrong or missing

- 5 pts no answer

- 1 pts E not everywhere

3.2 charge **4 / 4**

✓ **- 0 pts** Correct or consistent

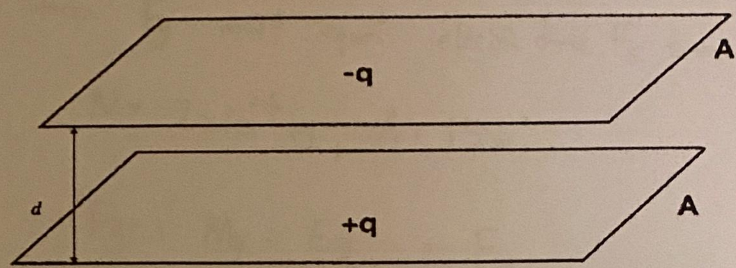
- 1 pts calculation error or wrong approach

- 4 pts no answer

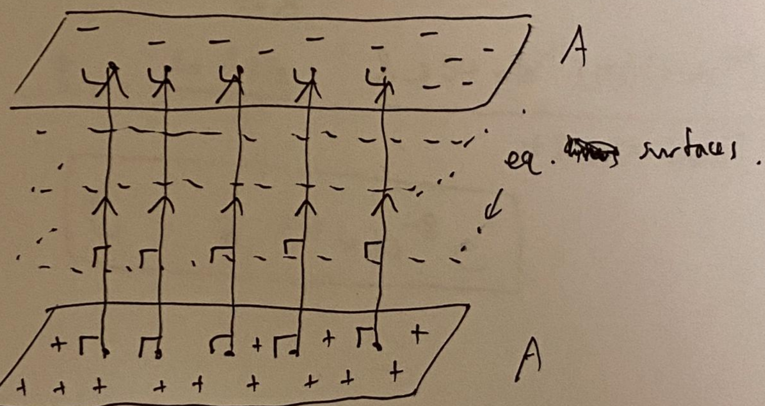
- 3 pts wrong

1B Winter 2021: Quiz 3B

1. Two parallel sheets have an area of 15 m^2 and are separated by a distance of 1.5 cm. The charge on the top plate is +q uniformly distributed and the bottom charge is -q uniformly distributed. You can model the electric field between the sheets as if the sheets were infinite.



a) For positive q sketch the field lines and the equipotential surfaces between the sheets. *(4 points)*



b) You measure a potential difference between the top and bottom sheet of $V_{top} - V_{bottom} = -10\ V$. What is q? *(4 points)*

Potential difference $V = Ed$ $\quad d = 1.5cm = 0.015m$

The electric field between a parallel plate capacitor is $E = \frac{q}{\varepsilon_0 A}$ $\quad A = \text{area} = 15m^2$

So $V = \frac{qd}{\varepsilon_0 A} \rightarrow q = \frac{\varepsilon_0 A V}{d}$

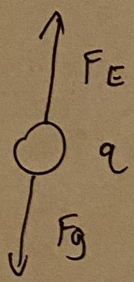
$= \frac{8.854\times10^{-12}(15)(-10)}{0.015}$

$= \boxed{-8.854\times10^{-8}\ C}$

$8.854\times10^{-8}\ C \rightarrow$ if positive q

A tiny dust particle of mass 2.0 milligram is charged with charge q_1 and placed between the two charged sheets. You observe that it is stationary and floating between th charged sheets. What is q_1? (if you could not do part b) then assume $q = 2.12 \cdot 10^{-8}$ C. *(4 points)*

Since the dust particle is stationary, $F_{net} = 0$. So gravitational force F_g must equal electric force F_E from the parallel plates



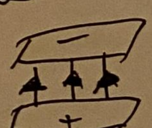
$M = 2\times10^{-6}$ kg, $A = 15\ m^2$

$F_g = Mg = Eq_1 = F_E$

The electric force between a parallel plate capacitor is $E = \frac{q}{\varepsilon_0 A}$

So $Mg = \frac{q q_1}{\varepsilon_0 A}$

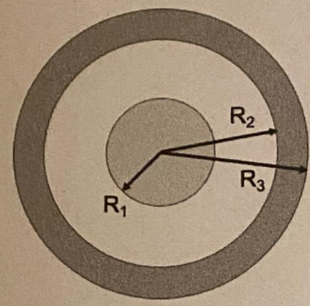
Assuming positive q so



$q_1 = \frac{\varepsilon_0 A M g}{q} = \frac{8.854\times10^{-12}(15)(2\times10^{-6})(9.8)}{+8.854\times10^{-8}}$

$\boxed{q_1 = 2.94\times10^{-8}\ C}$

2. Consider the spherically symmetric charge configuration shown below. An insulating sphere of radius R_1 and charge -4Q homogeneously distributed throughout is surrounded by air, which is surrounded by a conducting shell of inner radius R_2, outer radius R_3



a) If the field outside the outer shell ($r > R_3$) varies as $E = \frac{Q}{\pi \epsilon_0 r^2}$ what is the charge on the inner surface of the outer conductor (R_3) and what is the charge on the outer suface of the outer conductor (R_4)?
[5 points]

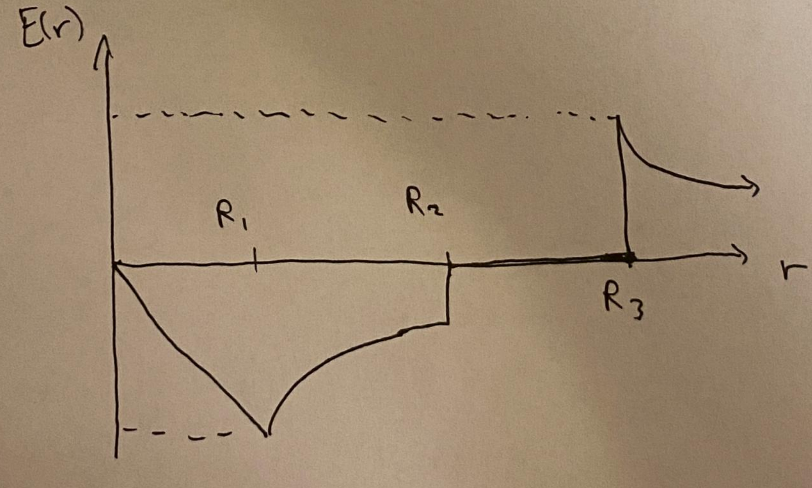
If we compare this field equation to the electric field for a standard sphere we see $E = \frac{Q_{encl}}{4\pi \epsilon_0 r^2} = \frac{Q}{\pi \epsilon_0 r^2} \rightarrow Q_{encl} = +4Q$.

So the total net charge must be +4Q, and $\boxed{Q_{outer} = +4Q}$

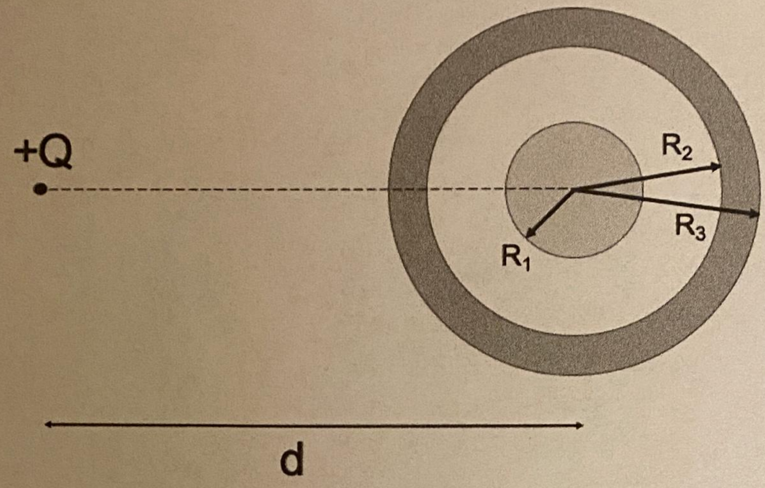
Between R_2 & R_3, E inside shell must be 0 (b/c conductor) so enclosed charge must be zero. So $-4Q + Q_{inner} = 0 \rightarrow \boxed{Q_{inner} = +4Q}$

(Gauss's Law)

b) Qualitatively sketch $E(r)$ as a function of r everwhere. *[6 points]*



c) If you now introduce a point charge +Q at point P shown in the figure, a distance of d=2.5 m from the center of the spherical charge configuration, what will be the total E-field inside the center of that spherical charge? *[3 points]*



By symmetry, the E-field at the center of the sphere = 0.

$E_{total} = E_Q + E_{sphere} = E_Q$ → so e-field based on field produced by +Q only.

So we can use Coulomb's Law!

$E = \frac{F}{q} = \frac{\left(\frac{1}{4\pi\varepsilon_0} \cdot \frac{+Qq}{r^2}\right)}{q} = \frac{Q}{4\pi\varepsilon_0 r^2}$ $r = d = 2.5\,m$

So $E = \frac{Q}{4\pi\varepsilon_0 (2.5)^2} = \boxed{\frac{Q}{25\pi\varepsilon_0}}$

3. Consider an insulating sphere of radius $R = 0.1\ m$ with a volume charge density given as

$$\rho_V = 2.5 \cdot r\ \frac{\mu C}{m^4}$$

a) Find the electric field anywhere inside the sphere? *(5 points)*

We can use Gauss's Law. Consider a spherical surface with $r < R$.

$$\oint \vec{E} \cdot d\vec{A} = E \cdot 4\pi r^2 = \frac{Q_{encl}}{\varepsilon_0} \quad \text{(spherical symmetry)}$$

$$Q_{encl} = \int \rho_v\, dV = \iiint_0^r 2.5r\,(r^2 \sin\theta)\, dr\, d\phi\, d\theta$$

$$= 4\pi (2.5) \int_0^r r^3\, dr = 10\pi \left(\frac{1}{4} r^4\right) = Q_{encl}.$$

$$E = \frac{1}{4\pi r^2}\left(\frac{\left(\frac{5\pi r^4}{2}\right)}{\varepsilon_0}\right) = \boxed{\frac{5r^2}{8\varepsilon_0}}$$

b) What is the total charge on the sphere? *(4 points)*

To find the total charge, integrate charge density over whole sphere (when $r = R = 0.1m$)

So $$Q = \int \rho_v\, dV = \iiint_0^R 2.5r\,(r^2 \sin\theta)\, dr\, d\phi\, d\theta$$

$$= 10\pi \int_0^R r^3\, dr$$

$$= 10\pi\, \frac{1}{4} R^4$$

$$= \frac{10\pi}{4}\left(\frac{1}{10}\right)^4 = \boxed{\frac{\pi}{4000}\ \mu C}$$