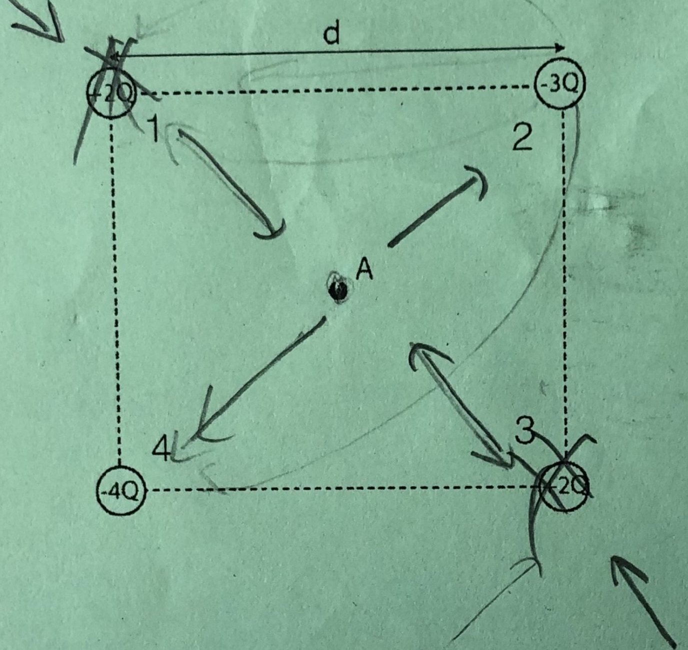
b) [5pts] In which direction does the electric field point ?

$E = \frac{kQ}{d^2}$



(1) to the left

(2) towards charge 4

(3) towards charge 3

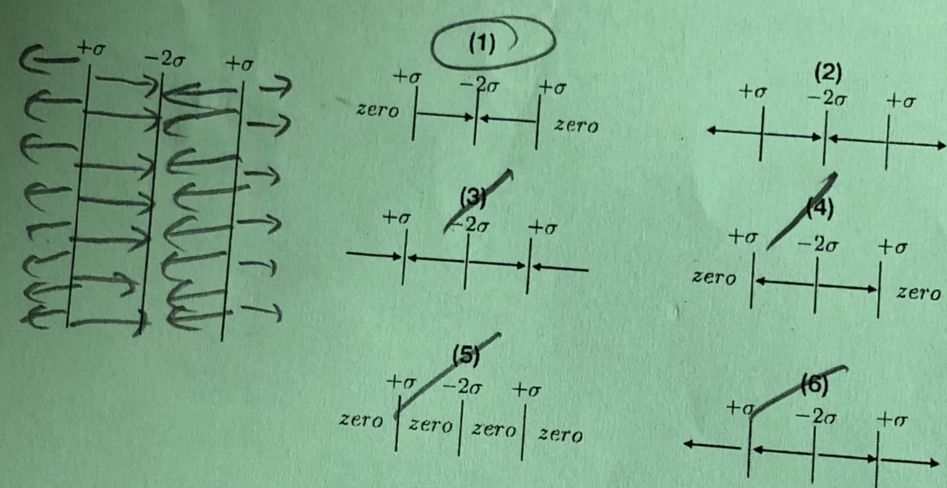
(4) towards charge 2

(5) to the right

(6) the electric field is zero

(7) towards charge 1

c) **[5pts]** There are three parallel infinite sheets with constant charge density $+\sigma$, -2σ and $+\sigma$ (See figure). Which figure best represents the direction of the electric fields ?



(1)

(2)

(3)

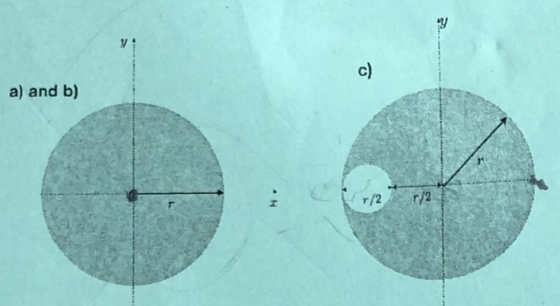
(4)

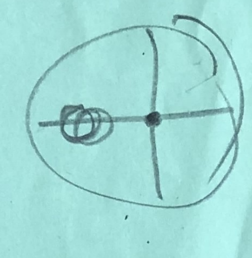
(5)

(6)

16

Problem 2: [30pts]
A spherical insulator has a constant charge density $\rho = -1.7 \times 10^{-4} C/m^3$. The sphere is centered at the origin and has a radius $r = 20cm$. [The figure depicts a cross section of the sphere in the x-y plane].





a) [10pts] Find the magnitude and direction of the electric field at $x = y = z = 0$ and at $x = 10cm, y = 0, z = 0$.

b) [10pts] Find the potential at $x = 40cm, y = 0, z = 0$ assuming that V is zero at infinity.

c) [10pts] Out of the spherical insulator you remove a sphere of radius $\frac{r}{4}$ centered at $x = -\frac{3}{4}r, y = 0, z = 0$ [see the 2nd figure]. What is the magnitude and direction of the electric field at $x = y = z = 0$?

A) $EA = \frac{q_{enc}}{\varepsilon_0}$

$E(4\pi r^2) = \frac{q_{enc}}{\varepsilon_0}$

$E 4\pi r^2 = \frac{\rho(\frac{4}{3}\pi r^3)}{\varepsilon_0}$

$E = \frac{\rho \frac{1}{3} r}{\varepsilon_0} \hat{r}$

$E = \frac{-1.7\times10^{-4}(\frac{1}{3})(r)}{8.85\times10^{-12}}$

at $x=0=y=z$, $r=0$

$E = 0$

$q_{enc} = (\rho)$ volume

$\rho(\frac{4}{3}\pi r^3)$

at $x=0, y=0, z=10$

$r = .1m$

$E = \frac{(1.7\times10^{-4})(\frac{1}{3})(.1)}{8.55\times10^{-12}}$

$E = -640301.3183$ 10

(B) $V = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{r}$

$\frac{1}{4\pi\varepsilon_0} \cdot \frac{\rho(v)}{r}$

$V = \frac{1}{4\pi\varepsilon_0} \cdot \frac{-1.7\times10^{-4}(\frac{4}{3}\pi r^3)}{r}$

$r = .4$

$V = 8.99\times10^9 \cdot (-1.7\times10^{-4}(\frac{4}{3}\pi(.4)^2))$

$V = -1024276.49$ Joules

+5

C. $\Phi = \vec{A}\vec{E}$

$\Phi = \frac{q_{enc}}{\varepsilon_0}$

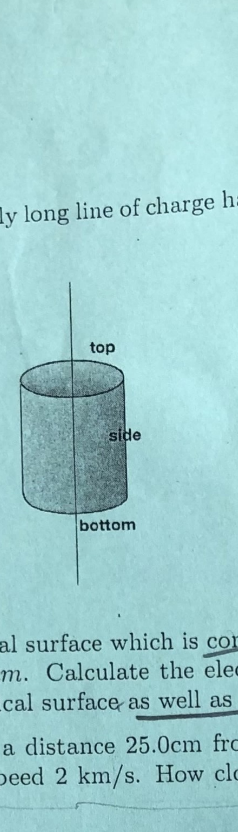
$\vec{A}\vec{E} = \frac{q_{enc}}{\varepsilon_0}$ $\rho(v)$

$\vec{E}$ = Direction of electric field is to the right b/c there is more negative charge on right hand side

$E = 0$ +4

6

Problem 3: [20pts] An infinitely long line of charge has a linear charge density of $\mu = 5.5 \times 10^{-12} C/m$.



a) [10pts] Consider a cylindrical surface which is concentric to line line charge and height $20cm$ and radius $3cm$. Calculate the electric flux through the top and bottom base of the cylindrical surface as well as curved side.

b) [10pts] A proton starts at a distance 25.0cm from the line and is moving directly toward the line with speed 2 km/s. How close does the proton get to the line of charge?

$Q = 1.1 \times 10^{-12}$

A) $\mu = 5.5 \times 10^{-12}$ c/m

Electric Field is orthogonal to top and bottom of cylinder, so $E = 0$ at top and bottom of cylinder

$EA = \frac{q_{enc}}{\varepsilon_0}$

$A = 2\pi r h$ ← of curved part around cylinder

$E = \frac{1.1 \times 10^{-12}}{(2\pi r h)(\varepsilon_0)} =$

$r = .03$

$h = .2$

$q_{enc} = \mu (h)$

$q_{enc} = \mu (.2)$

$q_{enc} = 5.5 \times 10^{-12} \cdot .2$

$q_{enc} = 1.1 \times 10^{-12}$

$E = \frac{1.1 \times 10^{-12}}{(2\pi)(.03)(.2)(8.85 \times 10^{-12})}$

$E = 32.54$

We want Φ not E! -3

B. $V = \frac{U}{q}$ ✗ $\frac{2}{10}$

Potential of Line charge

$V = \frac{1}{4\pi\varepsilon_0} \int_{-a}^{a} \frac{Q}{2a} \frac{dy}{\sqrt{x^2+y^2}}$ $a = .1$ m, $y = .25$

$V = \frac{1}{4\pi\varepsilon_0} \cdot \frac{Q}{2a} \ln \left(\frac{\sqrt{a^2+y^2}+a}{\sqrt{a^2+y^2}-a} \right)$

$\frac{1}{4\pi\varepsilon_0} \cdot \frac{1.1 \times 10^{-12}}{.2} \ln \left(\frac{\sqrt{.1^2+(.25)^2}+.1}{\sqrt{.1^2+(.25)^2}-.1} \right)$

$(8.99 \times 10^{-4})(5.5 \times 10^{-12}) \ln \left(\frac{.36926}{.16925} \right)$

3.0056×10^{-20} Joules $= V$

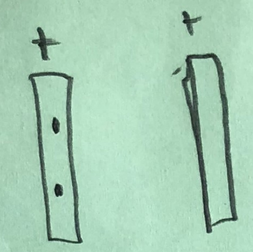
$V = \frac{U}{q}$ ← proton

$(3.8856 \times 10^{-20})(1.602 \times 10^{-19})$ to $= \frac{1}{2}mv^2$

$\Delta U = 6.17802 \times 10^{-39} = \frac{1}{2}mv^2 + mgh$? ?

6.178×10^{-39} 8 $\frac{1}{2}(.002)^2(1.67 \times 10^{-27})$ + mgh

$U = -3.34 \times 10^{-33}$ ← Use this to find distance

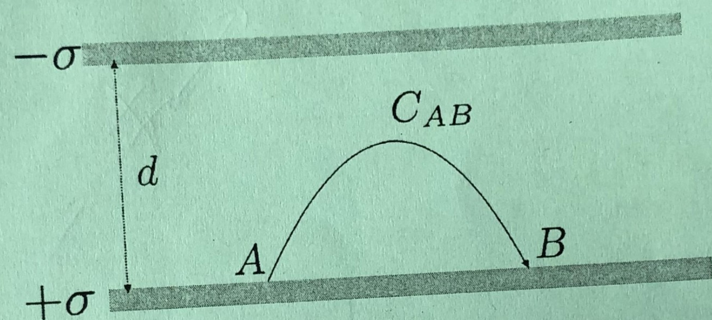


Problem 1: [15pts] Concept questions

a) **[5pts]** Two thin infinite conducting plates are charged with charge density σ and are a distance d apart. Consider a path C_{AB} from two points on the surface of one of the conductors. Consider the following quantity

$$\int_{C_{AB}} \vec{E} \cdot d\vec{x} \quad (1)$$

How does the result depend on σ, C_{AB} and d ?



(1) On none of them

(2) Only on σ and the length of the path C_{AB}

(3) On σ, d and the length of the path C_{AB}

(4) Only on the length of the path C_{AB}

(5) Only on σ and d

$E = \frac{\sigma}{\varepsilon_0}$

σ ✓

d ✓