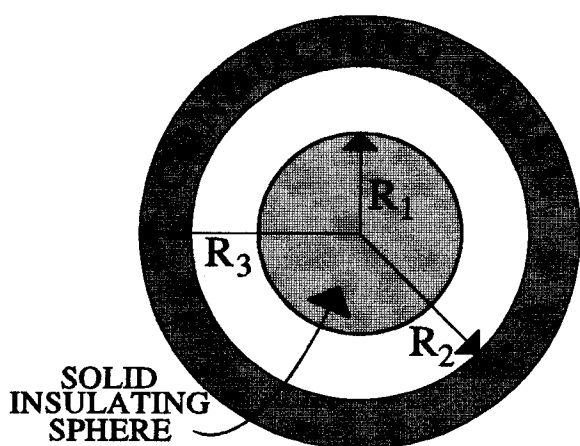
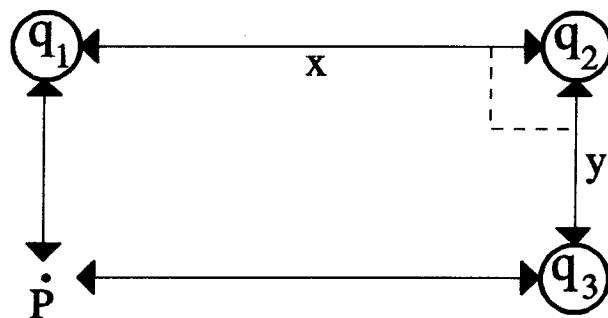


SENIOR PROJECT PHYSICS TEST - CHAPTERS 18-19 - 100 POINTS ELECTROSTATIC FORCES AND FIELDS 1994-95

ANSWER FOUR OF THE FOLLOWING QUESTIONS. SHOW ALL WORK CAREFULLY!

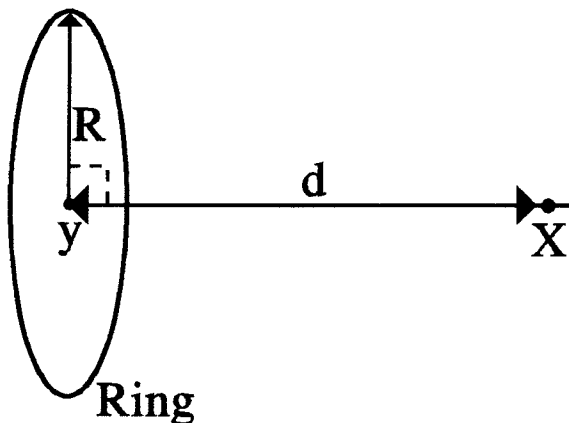
1. Three electric charges are arranged as shown to the right. These charges have values of $q_1 = +4.0 \mu\text{C}$, $q_2 = +9.0 \mu\text{C}$ and $q_3 = -14 \mu\text{C}$ and the distances have values of $x = 12.0 \text{ cm}$ and $y = 5.0 \text{ cm}$.
- What will be the direction and magnitude of the net electrostatic force acting on q_3 ? [10 pts]
 - What will be the direction and magnitude of the electric field strength at point P in the diagram? [10 pts]
 - What will be the magnitude of the electrostatic force acting on a Carbon nucleus [$q = 9.4 \times 10^{-19} \text{ C}$] placed at point P? [5 pts]



2. A solid **insulating** sphere holds a net negative charge density of $\rho = -(3800 + 620r) \mu\text{C}/\text{m}^3$ throughout its interior. The radius of this sphere is $R_1 = 6.0 \text{ cm}$. This sphere, in turn, is surrounded by a **conducting** shell which contains $-4.0 \mu\text{C}$ of charge. The shell has an inner radius of $R_2 = 9.0 \text{ cm}$ and an outer radius of $R_3 = 12.0 \text{ cm}$. All answers must be accompanied by appropriate work!

- On an appropriate diagram indicate the direction and relative field strength everywhere in the vicinity of this system. [4 pts]
 - What will be the total charge contained within the solid, insulating sphere? [4 pts]
 - What will be the electric field strength 3.0 cm from the center of the solid insulating sphere? [4 pts]
 - What will be the electric field strength 7.0 cm from the center of the solid, insulating sphere? [4 pts]
 - What will be the electric field strength 11.0 cm from the center of the solid, insulating sphere? [4 pts]
 - What will be the electric field strength 22.0 cm from the center of the solid, insulating sphere? [4 pts]
- G. What will be the charge densities on the inside ρ_2 and outside ρ_3 of the conducting shell? [4 pts]

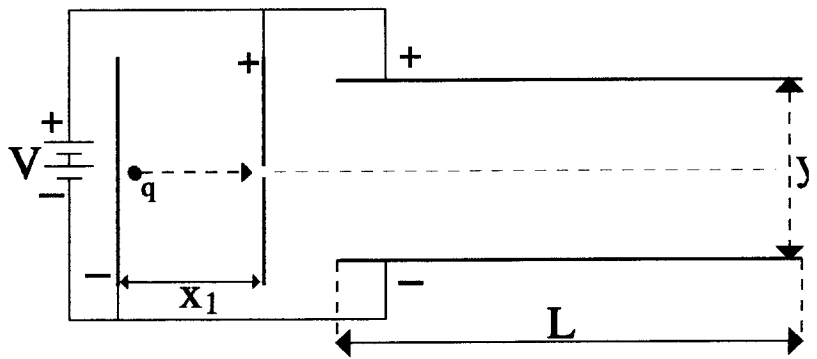
3. A charged ring is shown at the right. The ring has a radius of $R = 12.0 \text{ cm}$ and contains a total of $q = 34.0 \mu\text{C}$ of charge.
- What will be the linear charge density of this ring? [5 pts]
 - What will be the **direction** of the electric field at point X? Explain and justify! [4 pts]
 - What will be the strength of the electric field at point X in the diagram at the right which is located along the principle axis of the ring a distance of $d = 42.0 \text{ cm}$ from the ring? [4 pts]
 - What will be the direction and magnitude of the electrostatic force acting on a proton [$q = +1.6 \times 10^{-19} \text{ C}$] placed at point X? [4 pts]



Suppose that this **ring** is replaced with a **disc** which also contains $34 \mu\text{C}$ and has the same radius of $R = 12.0 \text{ cm}$. The charge is distributed uniformly throughout the disc.

- What will be the direction and magnitude of the resulting electric field at point X? [4 pts]
- What will be the direction and magnitude of the electric field at point y? [4 pts]

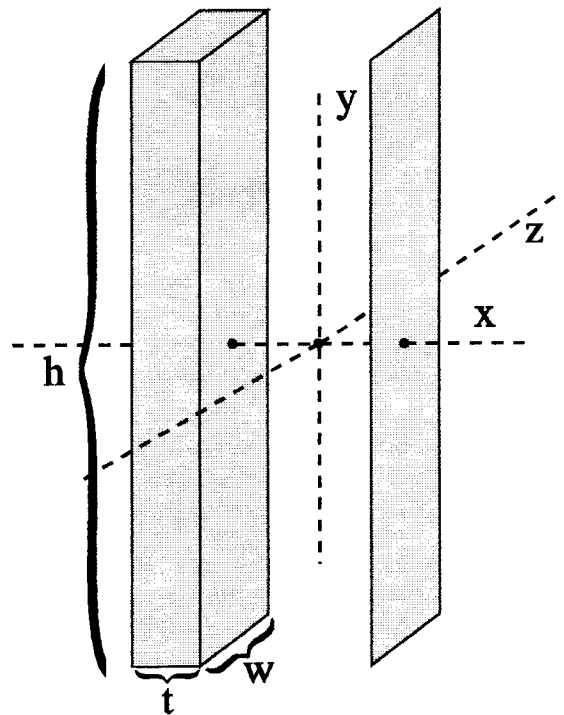
4. Two vertical plates are arranged so as to accelerate a negatively charged particle q , which has a charge of $-0.22 \mu\text{C}$ and a mass of 1.4×10^{-11} grams, to the right as shown. The potential difference between the plates is $V = 5200$ Volts and the plates are spaced $x_1 = 3.8$ centimeters apart. A second pair of plates are arranged horizontally as shown. The two horizontal plates are spaced $y = 6.0$ centimeters apart, are $L = 13.5$ centimeters long and are likewise charged to a potential of 5200 Volts. The charge q begins at the negative plate and then accelerates to the right until it passes through a hole in the center of the positive plate. This charge then passes into the area between the two horizontal plates exactly midway between the two plates.



- What will be the kinetic energy of the the charge q just as it passes through the hole in the positive plate? [5 pts]
- What will be the velocity of the charge as it passes through the hole in the positive plate? [5 pts]
- What will be the direction and magnitude of the force exerted on this charged particle as it passes into the space between the two horizontal plates? [5 pts]
- What will be the velocity of this particle as it exits the area between the two horizontal plates? [5 pts]
- Exactly WHERE will the charged particle exit the electric field between the two horizontal plates? [5 pts]

5. Consider a thick **insulating** slab of charge which is $h = 45.0$ m high by $w = 18.0$ m wide by $t = 2.0$ cm thick as shown. This slab contains a total charge of $+160.0 \mu\text{C}$ which is distributed evenly throughout the slab. The center of this slab is located at $x = -6.0$ cm. Parallel to this slab there is a plane which has the same height and width as the slab, but which has negligible thickness. This plane contains $-80.0 \mu\text{C}$ of charge distributed uniformly across its surface and the center of this plane is located at $x = 4.0$ cm. [Both the slab and the plane are parallel to the y - z plane!]

- What will be the volume charge density ρ throughout the thick slab? [5 pts]
- What will be the direction and magnitude of the electric field at the origin? [4 pts]
- What will be the direction and magnitude of the electric field at $x = 10.0$ cm caused by these charged surfaces? [4 pts]
- What will be the direction and magnitude of the electric field at $x = -10.0$ cm caused by these charged surfaces? [4 pts]
- What will be the direction and magnitude of the electric field within the thick slab as a function of distance from the origin along the x axis? [4 pts]
- Where, along the x axis, will the electric field strength be exactly zero? [4 pts]



SENIOR PROJECT PHYSICS CHAPTERS 18-19 1994-1995 ELECTRIC FIELDS AND FORCES

1. $q_1 := 4.0 \cdot \mu\text{C}$ $q_2 := 9.0 \cdot \mu\text{C}$ $q_3 := -14.0 \cdot \mu\text{C}$ $x := 12.0 \cdot \text{cm}$ $y := 5.0 \cdot \text{cm}$ $k := 9.0 \cdot 10^9 \cdot \text{N} \cdot \frac{\text{m}^2}{\text{C}^2}$

a.

$$F_{31} := \frac{k \cdot q_1 \cdot q_3}{x^2 + y^2} \quad F_{31} = -29.822 \cdot \text{N} \quad F_{32y} := \frac{-k \cdot q_2 \cdot q_3}{y^2} \quad F_{32y} = 453.6 \cdot \text{N} \cdot \mathbf{j}$$

$$F_{31x} := F_{31} \cdot \frac{x}{\sqrt{x^2 + y^2}} \quad F_{31x} = -27.528 \cdot \text{N}$$

$$F_{31y} := -F_{31} \cdot \frac{y}{\sqrt{x^2 + y^2}} \quad F_{31y} = 11.47 \cdot \text{N}$$

$$F_{3y} := F_{31y} + F_{32y} \quad F_{3y} = 465.07 \cdot \text{N} \quad F_{3x} := F_{31x} \quad F_{3x} = -27.528 \cdot \text{N}$$

$$F_3 := \sqrt{F_{3y}^2 + F_{3x}^2} \quad F_3 = 465.884 \cdot \text{N} \quad \alpha := \text{atan}\left(\left|\frac{F_{3y}}{F_{3x}}\right|\right) \quad \alpha = 86.612 \cdot \text{deg} \quad \mathbf{NW}$$

1a. The net force acting on $q_3 = F_3 = 465.884 \cdot \text{N}$ at $\alpha = 86.612 \cdot \text{deg}$. [10 pts]

b.

$$E_{p1} := \frac{-k \cdot q_1}{y^2} \quad E_{p1} = -1.44 \cdot 10^7 \cdot \frac{\text{N}}{\text{C}} \cdot \mathbf{j} \quad E_{p3} := \frac{-k \cdot q_3}{x^2} \quad E_{p3} = 8.75 \cdot 10^6 \cdot \frac{\text{N}}{\text{C}} \cdot \mathbf{i}$$

$$E_{p2} := \frac{k \cdot q_2}{x^2 + y^2} \quad E_{p2} = 4.793 \cdot 10^6 \cdot \frac{\text{N}}{\text{C}} \quad E_{p2x} := -E_{p2} \cdot \frac{x}{\sqrt{x^2 + y^2}} \quad E_{p2x} = -4.424 \cdot 10^6 \cdot \frac{\text{N}}{\text{C}} \cdot \mathbf{i}$$

$$E_{p2y} := -E_{p2} \cdot \frac{y}{\sqrt{x^2 + y^2}} \quad E_{p2y} = -1.843 \cdot 10^6 \cdot \frac{\text{N}}{\text{C}} \cdot \mathbf{j}$$

$$E_{px} := E_{p3} + E_{p2x} \quad E_{px} = 4.326 \cdot 10^6 \cdot \frac{\text{N}}{\text{C}} \cdot \mathbf{i}$$

$$E_{py} := E_{p1} + E_{p2y} \quad E_{py} = -1.624 \cdot 10^7 \cdot \frac{\text{N}}{\text{C}} \cdot \mathbf{j}$$

$$E_p := \sqrt{E_{py}^2 + E_{px}^2} \quad E_p = 1.681 \cdot 10^7 \cdot \frac{\text{N}}{\text{C}} \quad \beta := \text{atan}\left(\left|\frac{E_{py}}{E_{px}}\right|\right) \quad \beta = 75.088 \cdot \text{deg} \quad \mathbf{SE}$$

1b. The electric field at point P = $E_p = 1.681 \cdot 10^7 \cdot \frac{\text{N}}{\text{C}}$ at $\beta = 75.088 \cdot \text{deg}$. [10 pts]

c.

$$q_{\text{carbon}} := 9.3 \cdot 10^{-19} \cdot \text{C} \quad F_{C12} := E_p \cdot q_{\text{carbon}} \quad F_{C12} = 1.563 \cdot 10^{-11} \cdot \text{N}$$

1c. The electrostatic force acting on a carbon nucleus placed at P = $F_{C12} = 1.563 \cdot 10^{-11} \cdot \text{N}$ [5 pts]

2. $r := 1 \cdot \text{m}$ $\mu\text{C} := 10^{-6} \cdot \text{coul}$ $R_1 := 6.0 \cdot \text{cm}$ $C := \text{coul}$ $N := \text{newton}$ $Q_{\text{shell}} := -4 \cdot \mu\text{C}$

$$\rho := - \left(3800 \cdot \frac{\mu\text{C}}{\text{m}^3} + 620 \cdot \frac{\mu\text{C}}{\text{m}^4} \cdot r \right) \quad k := 9 \cdot 10^9 \cdot \text{N} \cdot \frac{\text{m}^2}{\text{C}^2} \quad R_2 := 9.0 \cdot \text{cm} \quad R_3 := 12.0 \cdot \text{cm}$$

2a. Field in and in. [4 pts]

b. $Q := \int_{0 \cdot \text{m}}^{R_1} - \left(3800 \cdot \frac{\mu\text{C}}{\text{m}^3} + 620 \cdot \frac{\mu\text{C}}{\text{m}^4} \cdot r \right) \cdot 4 \cdot \pi \cdot r^2 \, dr \quad Q = -3.4634 \cdot \mu\text{C}$ **2b. Total charge contained in the insulating sphere. [4 pts]**

c. $r := .03 \cdot \text{m}$ $Q_{\text{enclosed}} := \int_{0 \cdot \text{m}}^r - \left(3800 \cdot \frac{\mu\text{C}}{\text{m}^3} + 620 \cdot \frac{\mu\text{C}}{\text{m}^4} \cdot r \right) \cdot 4 \cdot \pi \cdot r^2 \, dr \quad Q_{\text{enclosed}} = -0.431 \cdot \mu\text{C}$

$$\int E \, dA = 4 \cdot \pi \cdot k \cdot Q_{\text{enclosed}}$$

$$E \cdot 4 \cdot \pi \cdot r^2 = 4 \cdot \pi \cdot k \cdot Q_{\text{enclosed}}$$

d. $E := k \cdot \frac{Q_{\text{enclosed}}}{r^2} \quad E = -4.313 \cdot 10^6 \cdot \frac{\text{N}}{\text{C}}$ **2c. Electric field 3.0 cm from center. [4 pts]**

d. $r := .07 \cdot \text{m}$ $\int E \, dA = 4 \cdot \pi \cdot k \cdot Q_{\text{enclosed}}$

$E \cdot 4 \cdot \pi \cdot r^2 = 4 \cdot \pi \cdot k \cdot Q$ $E := k \cdot \frac{Q}{r^2} \quad E = -6.361 \cdot 10^6 \cdot \frac{\text{N}}{\text{C}}$ **2d. Electric field 7.0 cm from center. [4 pts]**

e. $\int E \, dA = 4 \cdot \pi \cdot k \cdot Q_{\text{enclosed}} \quad E \cdot 4 \cdot \pi \cdot r^2 = 4 \cdot \pi \cdot k \cdot (0 \cdot \text{C}) \quad E := 0 \cdot \frac{\text{N}}{\text{C}}$ **2e. Electric field inside conductor. [4 pts]**

f. $r := 22.0 \cdot \text{cm}$ $\int E \, dA = 4 \cdot \pi \cdot k \cdot Q_{\text{enclosed}} \quad E \cdot 4 \cdot \pi \cdot r^2 = 4 \cdot \pi \cdot k \cdot (Q + Q_{\text{shell}})$

$$Q + Q_{\text{shell}} = -7.463 \cdot \mu\text{C}$$

$E := k \cdot \frac{(Q + Q_{\text{shell}})}{r^2} \quad E = -1.388 \cdot 10^6 \cdot \frac{\text{N}}{\text{C}}$ **2f. The electric field 22.0 cm from the center. [4 pts]**

g. **The total charge contained within the solid sphere = - 3.46 μC . Since a Gaussian surface within the conducting shell must have zero net flux passing through it and so the Gaussian surface must contain zero net charge. Therefore the charge on the inside of the shell $q_2 = +3.46 \mu\text{C}$. Since the net charge on the conducting shell is -4 μC , and since the charge on the inside of the shell is +4.0 μC as above the outside of the shell must contain $q_3 = -7.46 \mu\text{C}$.**

$$\rho_2 := \frac{-Q}{4 \cdot \pi \cdot R_2^2} \quad \rho_2 = 3.403 \cdot 10^{-5} \cdot \frac{\text{C}}{\text{m}^2} \quad Q = -3.463 \cdot 10^{-6} \cdot \text{coul}$$

$$\rho_3 := \frac{Q + Q_{\text{shell}}}{4 \cdot \pi \cdot R_3^2} \quad \rho_3 = -4.124 \cdot 10^{-5} \cdot \frac{\text{C}}{\text{m}^2} \quad Q_{\text{shell}} = -4 \cdot 10^{-6} \cdot \text{coul}$$

3.

a. $R := 12.0 \cdot \text{cm}$ $q := 34.0 \cdot \mu\text{C}$ $\lambda := \frac{q}{2 \cdot \pi \cdot R}$ $\lambda = 4.509 \cdot 10^{-5} \cdot \frac{\text{C}}{\text{m}}$ **3a. The linear charge density. [4 pts]**

b. Parallel to the x axis - because of symmetry arguments.

c. $x := 42.0 \cdot \text{cm}$ $y := R$ $q_{\text{proton}} := 1.6 \cdot 10^{-19} \cdot \text{C}$

$E := \frac{k \cdot q}{x^2 + y^2} \cdot \frac{x}{\sqrt{x^2 + y^2}}$ $E = 1.542 \cdot 10^6 \cdot \frac{\text{N}}{\text{C}}$ **3c. The electric field at point X. [4 pts]**

d. $F := E \cdot q_{\text{proton}}$ $F = 2.467 \cdot 10^{-13} \cdot \text{N}$ **3d. The force on a proton placed at X. [4 pts]**

e. $\sigma := \frac{q}{\pi R^2}$ $\sigma = 751.565 \cdot \frac{\mu\text{C}}{\text{m}^2}$ $dq = \sigma dA = \sigma \cdot 2 \cdot \pi \cdot r \cdot dr$

$E := \int_{0 \cdot \text{m}}^R \frac{k \cdot \sigma \cdot 2 \cdot \pi \cdot y}{x^2 + y^2} \cdot \frac{x}{\sqrt{x^2 + y^2}} dy$ $E = 1.635 \cdot 10^6 \cdot \frac{\text{N}}{\text{C}}$ **3e. The electric field at point X if the source is a disk. [4 pts]**

f. Zero - infinity? symmetry. [4 pts]

4.

$q := -0.22 \cdot \mu\text{C}$ $m_1 := 1.4 \cdot 10^{-11} \cdot \text{gm}$ $V := 5200 \cdot \text{volt}$ $x_1 := 3.80 \cdot \text{cm}$ $y := 6.0 \cdot \text{cm}$ $L := 13.5 \cdot \text{cm}$ $v_1 := 1 \cdot \frac{\text{m}}{\text{sec}}$

a. $KE := V \cdot |q|$ $KE = 0.00114 \cdot \text{J}$ **4a. The kinetic energy of the particle. [5 pts]**

b. $KE = \frac{1}{2} \cdot m_1 \cdot v_1^2$ $v_1 := \frac{1}{\sqrt{m_1}} \cdot \sqrt{2 \cdot \sqrt{KE}}$ $v_1 = 4.043 \cdot 10^5 \cdot \frac{\text{m}}{\text{sec}}$ **4b. The velocity of the particle. [5 pts]**

c. $E_y := \frac{V}{y}$ $E_y = 8.667 \cdot 10^4 \cdot \frac{\text{N}}{\text{C}}$ $F := E_y \cdot |q|$ $F = 0.0191 \cdot \text{N}$ **4c. The electrostatic force acting on the charged particle. [5 pts]**

$a_y := \frac{F}{m_1}$ $a_y = 1.362 \cdot 10^{12} \cdot \frac{\text{m}}{\text{sec}^2}$

d. $t_h := \frac{L}{v_1}$ $t_h = 3.339 \cdot 10^{-7} \cdot \text{sec}$ $t_v := \sqrt{\frac{2 \cdot \left(\frac{y}{2}\right)}{a_y}}$ $t_v = 2.099 \cdot 10^{-7} \cdot \text{sec}$

$t := t_v$ $t = 2.099 \cdot 10^{-7} \cdot \text{sec}$ **Particle strikes plate!**

$v_y := a_y \cdot t$ $v_y = 2.859 \cdot 10^5 \cdot \frac{\text{m}}{\text{sec}}$ $v_x := v_1$ $v_x = 4.043 \cdot 10^5 \cdot \frac{\text{m}}{\text{sec}}$

$v := \sqrt{v_x^2 + v_y^2}$ $v = 4.951 \cdot 10^5 \cdot \frac{\text{m}}{\text{sec}}$

$\alpha := \text{atan}\left(\frac{v_y}{v_x}\right)$ $\alpha = 35.264 \cdot \text{deg}$

4d. The particle strikes the upper plate with a velocity. [5 pts]

e. $D_h := v_1 \cdot t$ $D_h = 0.085 \cdot \text{m}$ **4e. The charge strikes the upper plate. [5 pts]**

5. $h := 45.0 \cdot \text{m}$ $w := 18.0 \cdot \text{m}$ $t := 2.0 \cdot \text{cm}$ $q_{\text{slab}} := 160 \cdot \mu\text{C}$ $x_{\text{slab}} := -6.0 \cdot \text{cm}$ $q_{\text{plane}} := -80.0 \cdot \mu\text{C}$ $x_{\text{plane}} := 4.0 \cdot \text{cm}$

a. $\rho := \frac{q_{\text{slab}}}{(h \cdot w \cdot t)}$ $\rho = 9.877 \cdot 10^{-6} \cdot \frac{\text{C}}{\text{m}^3}$ **5a. The volume charge density. [5 pts]**

b. $\sigma_{\text{slab}} := \frac{q_{\text{slab}}}{(h \cdot w)}$ $\sigma_{\text{slab}} = 1.975 \cdot 10^{-7} \cdot \frac{\text{C}}{\text{m}^2}$ $\sigma_{\text{plane}} := \frac{q_{\text{plane}}}{(h \cdot w)}$ $\sigma_{\text{plane}} = -9.877 \cdot 10^{-8} \cdot \frac{\text{C}}{\text{m}^2}$

$E_{\text{oslab}} := 2 \cdot k \cdot \pi \cdot \sigma_{\text{slab}}$ $E_{\text{oslab}} = 1.117 \cdot 10^4 \cdot \frac{\text{N}}{\text{C}} \mathbf{i}$

$E_{\text{oplane}} := |2 \cdot k \cdot \pi \cdot \sigma_{\text{plane}}|$ $E_{\text{oplane}} = 5.585 \cdot 10^3 \cdot \frac{\text{N}}{\text{C}} \mathbf{i}$

$E_{\text{origin}} := E_{\text{oslab}} + E_{\text{oplane}}$ $E_{\text{origin}} = 1.676 \cdot 10^4 \cdot \frac{\text{N}}{\text{C}} \mathbf{i}$ **5b. The electric field at the origin. [4 pts]**

c. $E_{x10} := E_{\text{oslab}} - E_{\text{oplane}}$ $E_{x10} = 5.585 \cdot 10^3 \cdot \frac{\text{N}}{\text{C}} \mathbf{i}$ **5c. The electric field at $x = 10 \text{ cm}$. [4 pts]**

d. $E_{x\text{left}} := -E_{\text{oslab}} + E_{\text{oplane}}$ $E_{x\text{left}} = -5.585 \cdot 10^3 \cdot \frac{\text{N}}{\text{C}} \mathbf{i}$ **5d. The electric field at $x = -10 \text{ cm}$. [4 pts]**

e. $E_{\text{within}} := -E_{\text{oplane}} - 4 \cdot \pi \cdot k \cdot \rho \cdot (x - .05 \cdot \text{m})$

f. GIVEN $0 \cdot \frac{\text{N}}{\text{C}} = E_{\text{oplane}} - 4 \cdot \pi \cdot k \cdot \rho \cdot (x - .05 \cdot \text{m})$

$x := \text{FIND}(x)$ $x = 5.5 \cdot \text{cm}$ **5f. Position within the slab where the electric field will be zero.**