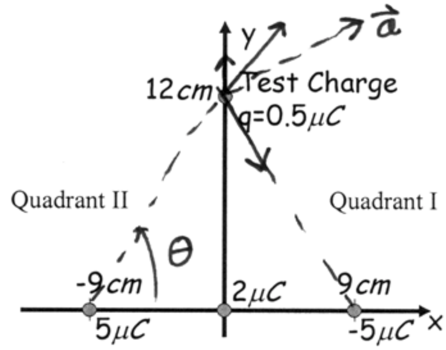
Name *Solutions* Total ____________

(Last, First) Phys 122A

I. [30 Points] Two charges, $5\mu C$ and $-5\mu C$, are placed at $-9cm$ and $+9cm$ along the x-axis, as shown to the right. A third $2\mu C$ charge is fixed at the origin. A test charge is placed at $+12$ cm along the y-axis, with a value of $0.5\mu C$. There is no gravity or friction in this problem. At time t=0, the test charge is released.



1. The direction acceleration of the test charge will be:
   A. In the +x direction. *✗*
   B. In the –x direction. *✗*
   C. In the +y direction. *✗*
   (D.) Between the +x and +y direction (quadrant I).
   E. Between the –x and +y direction (quadrant II).

2. As time marches on, the magnitude of the force felt by the test charge due to the three charges will
   A. Increase.
   (B.) Decrease. *– it will get further away from the charge distribution*
   C. Stay the same.
   D. Not enough information to tell.

3. Calculate the magnitude and direction of the force on the test charge due to the $2\ \mu C$ charge only at t=0.
   A. 6.24×10^{-5} N, -y direction
   (B.) 0.6244 N, +y direction
   C. 1.56 N, +y direction
   D. 1.56 N, 45 degree angle with the x axis
   E. None of the above

   $F = \frac{1}{4\pi\varepsilon_0}\frac{.5 \cdot 2\mu C}{.12\ m} = \frac{1}{4\pi \cdot 8.85\times10^{-12}}\frac{.5\times10^{-6} \cdot 2\times10^{-6}}{(.12)^2}$

   $= .6244$ N

   ↳ repulsive → so away.

4. Calculate the x component of the force, F_x, due to the $+9\mu C$ and $-9\mu C$ charges only at t=0.
   A. -1.6 N
   B. 0 N
   C. 0.6 N
   → (D.) 1.2 N
   E. 1.6 N

   First $|F|$ – then F_x

   $F = \frac{1}{4\pi\varepsilon_0}\frac{(5\mu C)(.5\mu C)}{(.09^2 + .12^2)} = 0.99$N

   $F_x = F\cos\theta = F \cdot \frac{9}{\sqrt{9^2+12^2}} = F \cdot \frac{9}{15} = .599$ N – times two!

page break.

5. Calculate the y component of the force, F_y, due to the $+9\mu C$ and $-9\mu C$ charges only at t=0.
   A. -1.6 N
   (B.) 0 N *– they cancel!*
   C. 0.6 N
   D. 1.2 N
   E. 1.6 N

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6. Where can you move the test charge to such that it experiences zero electric force?
   A. On the y-axis, between zero and +12cm
   B. On the x-axis, between zero and +9cm
   C. On the x-axis, between zero and -9cm
   D. In quadrant I (see figure label)
   E. Not enough information or none of the above

Yes – not on the y axis

↳ but on x – $x > 0$, $x < 9cm$

↳ ~~close~~ to

↳ no – cause there it will feel attraction to –5 & repulsion from 5 & 2.

↳ on x $-9 < x < 0$

Yes – w/out the –5, would find eq between the 2μC & 5μC. Add the –5 and move it slightly to the left

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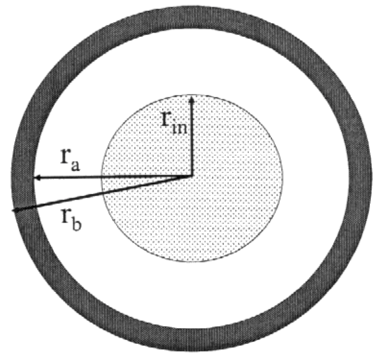
II. [25 Points] Consider the coaxial setup show to the right. The middle is a plastic rod with a charge per unit length of λ_{in}=5μC/m. The outer shield is a conductor with a charge per unit length of λ_{out}=-2μC/m. The coaxial plastic wire is infinitely long.



7. *4* To calculate the electric field E(r) using Gauss' law, what Gaussian surface would you use?
   A. A Sphere, centered at the origin, or radius r.
   B. A pill-box (a brick shaped box) centered at the origin with long dimension L, and short dimension r.
   C. A pill-box centered at the origin with long dimension infinite, and short dimension r. *← use same symmetry of problem!*
   (D) A cylinder centered at the origin (in/out of the page) of length L, radius r.
   E. A cylinder centered at the origin (in/out of the page) of infinite length, radius r.

4

8. What can you say about the ~~magnitude~~ *abs value* of the charge per unit length on the surface of the inner plastic rod (r_{in})? *– will be very little – it is a non-conductor!*
   A. It is greater than the magnitude of the charge per unit length contained in the vertical cylinder $r<r_{in}/2$. *No!*
   B. It is greater than the magnitude of the charge per unit length on the outer surface (r_b). *No – that has $\lambda_{out} + \lambda_{in}$ (induced)*
   → (C.) It is less than the charge per unit length on the inner surface of the shell (r_a). *Yes – that has $|-\lambda_{in}|$ on it.*
   ~~(D.)~~ It is less than the magnitude of the charge inside the conducting shell (the charge contained between r_a and r_b).
   E. None of the above.

5

9. What is the charge per unit length on the inner surface of the outer metal shield (at $r=r_a$)?
   (A.) -5 μC/m. *E = 0 inside conductor – so $-\lambda_{in}$.*
   B. -2 μC/m.
   C. 0.0 μC/m.
   D. 2 μC/m.
   E. 5 μC/m.

For each of the following questions, $r_{in} = 1cm$, r_a=2cm, and r_b=2.5cm.

10. *4* What is the magnitude E field at r=3cm? *G's law $\varepsilon_0 \oint \vec{E}\cdot d\vec{A} = Q_{enc} = L\lambda$*
   A. 0.0 N/C
   (B.) 1.8 x 10^6 N/C
   C. 4.2 x 10^6 N/C
   D. 1.6 x 10^7 N/C
   E. 6.0 x 10^7 N/C

$\varepsilon_0 E \oint dA = \varepsilon_0 E\, 2\pi r L$

$\Rightarrow E = \frac{\lambda}{2\pi\varepsilon_0}\frac{1}{r}$

at 3cm, $\lambda = \lambda_{in} + \lambda_{out}$

$E = \frac{3\times10^{-6}C}{2\pi(8.85\times10^{-12})}\frac{1}{(.03)} = 1.79\times10^6$ N/C

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11. What is the magnitude E field at r=2.25*cm*?

    A. 0.0 N/C
    B. 2.4 x 10^6 N/C
    C. 4.0 x 10^6 N/C
    D. 1.1 x 10^8 N/C
    E. 1.8 x 10^8 N/C

Inside the conductor!

12. What is the magnitude E field at r=1.5*cm*?

    A. 0 N/C
    B. 3.6 x 10^6 N/C
    C. 6.0 x 10^6 N/C
    D. 1.4 x 10^7 N/C
    E. 4.0 x 10^8 N/C

$\lambda = \lambda_{in}$

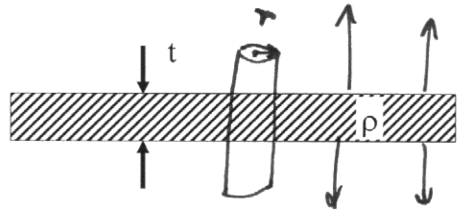
$$E = \frac{5\times10^{-6}}{2\pi(8.85\times10^{-12})} \cdot \frac{1}{(0.015)}$$

$= 5.99\times10^{6}$ N/C

Name Solutions (Last, First) Total ___________

Phys 122A

III. [Points] An infinite plastic sheet of thickness t is shown to the right. It has charge evenly distributed throughout its volume; the charge density is ρ (C/m^3).



(assume ρ>0)

15 pts 1. Calculate the electric field at distance y above the upper surface of the sheet. Please make sure to clearly box your answer. Is the electric field below the lower surface the same? Explain.

Use G's law to calculate this – ~~cyln~~ cylinder (or pill box).

$$\varepsilon_0 \oint E\cdot dA = Q_{enc}$$

$$Q_{enc} = \underbrace{\pi r^2 t}_{\text{volume}}\rho$$

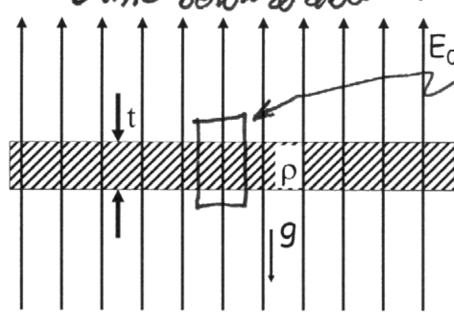
$$\int_{top} E\cdot dA = E\cdot\pi r^2 \qquad \int_{bot} E\cdot dA = E\cdot\pi r^2$$

$$\varepsilon_0 2E\pi r^2 = \pi r^2 t\rho \Rightarrow \boxed{E = \frac{t\rho}{2\varepsilon_0}}$$

$$\oint E\cdot dA = \int_{top} E\cdot dA + \int_{bot} E\cdot dA + \int_{side} E\cdot dA$$ (side ↑ zero!)

- could be done w/ pill box
- could be done by 'calcing' σ from ρ and using E for ∞ surface.
- same below & above the surface

10 pts 2. The same infinite plastic sheet is now placed in a room with a uniform electric field E_0, pointing in the positive y direction (as shown). The sheet has a mass density d (kg/m^3). Gravity points down ($-y$ direction). Calculate the value of E_0 in terms of values given such that the total force on the plastic sheet is zero (i.e. it floats!).



look at a box of size l (>t)

The key to this problem is scaling → must assume some area to calc the force.

Since $F_T = 0$, $F_g + F_c = 0$ on the sheet.

$$F_g = mg = \underbrace{(l^2 t d)}_{\text{mass of this cube}} g$$ – look at a small bit of the plane – a 'box' (cube) of size $l \times l \times t$.

↳ if $F_T = 0$ on this cube & every cube like it, we have it! → (5 pts)

(4 pts)

$$F_c = qE = l^2 t\rho E_0$$

$$F_T = 0 = l^2 t\rho E_0 + l^2 t d g$$

$$\Rightarrow \boxed{E_0 = -\frac{dg}{\rho}}$$

"–" ⇒ points opposite to gravity. ← (1 point)

Name ____________________________________**Student ID** ____________ **Score**______

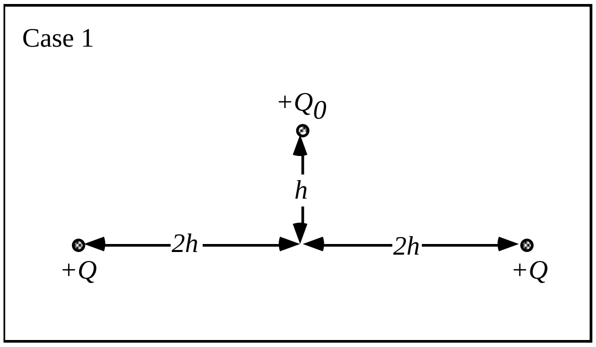
last *first*

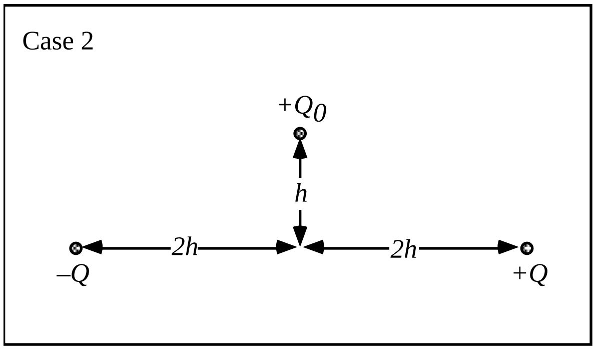
IV. [20 points]

A.

15. [4 pts] In the two cases shown, draw an arrow to indicate the direction of the net electrical force on the point charge labeled $+Q_0$. Explain.

    In both cases I can draw the force vector for each charge separately, and the net electrical force is the vector sum of the two.

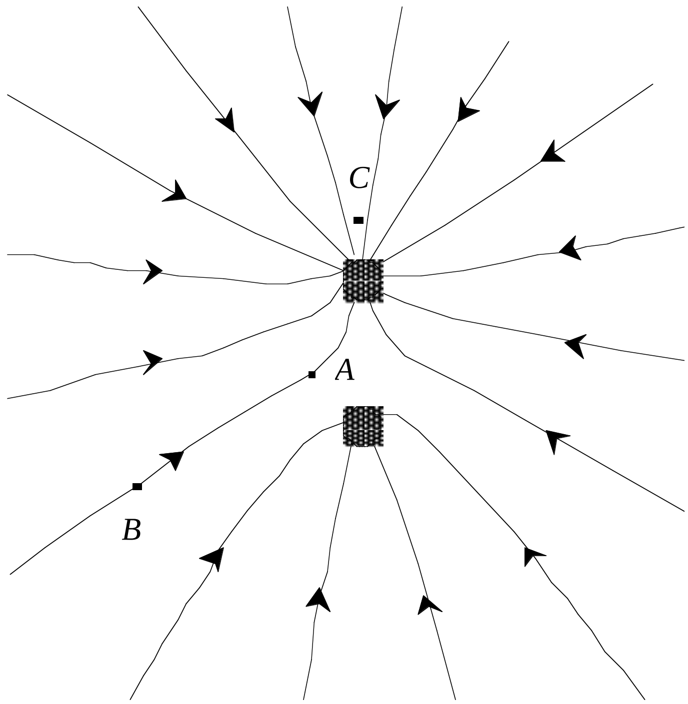




16. [4 pts] State whether the magnitude of the net force on the point charge labeled $+Q_0$ in case 1 is *greater than, less than,* or *equal to* the magnitude of the net force on the charge labeled $+Q_0$ in case 2. Explain.

    The net force in case 1 is less than the net force in case two. In case 1, the horizontal components of the two forces cancel, and in case 2 the vertical components of the forces cancel. Since, in both cases, the horizontal components of the forces are larger, this means that the sum of the horizontal components in case 2 is larger than the sum of the vertical components in case 1.

B. An electric field line diagram of the electric field in a certain region of space is shown below at right.



17. [6pts] On the diagram, draw an arrow to indicate the direction of the *electrical force* that would be exerted on a small positive test charge at points *A*, *B*, and *C*. If the electrical force is zero at any point, state so explicitly. Explain.

    The electric force vector on a positive test charge will be tangent to the field line at that point, or the line that would go through that point, and will be pointed in the direction of the arrow on that field line.

18. [6pts] Compare the magnitudes of the *electrical force* on the small positive test charge at the following pairs of points:

    i. Points *A* and *B*. Explain.

    The force at A will be greater than the force at B, because the electric field, given by the ratio of the force on a test charge to the size of the test charge, is larger at A than B as seen by the field lines being closer together. So for a given charge, it must experience more force at A than at B.

    ii. Points *A* and *C*. Explain.

    At point C The field lines look even closer together, indicating an even larger electric field, so the electric force experienced by the test charge must be larger at C than at A.