Electricity and Magnetism

- Physics 259 – L02
- Lecture 18

UNIVERSITY OF CALGARY

Chapter 23

Last time

- Chapter 23.2 and 23.3 

This time

- Chapter 23.5 and 23.5 

today → Finish chapter. 23

Midterm exam =>

Tuesday 14 Feb.

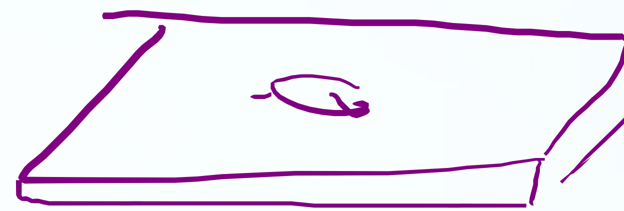
7-9 pm

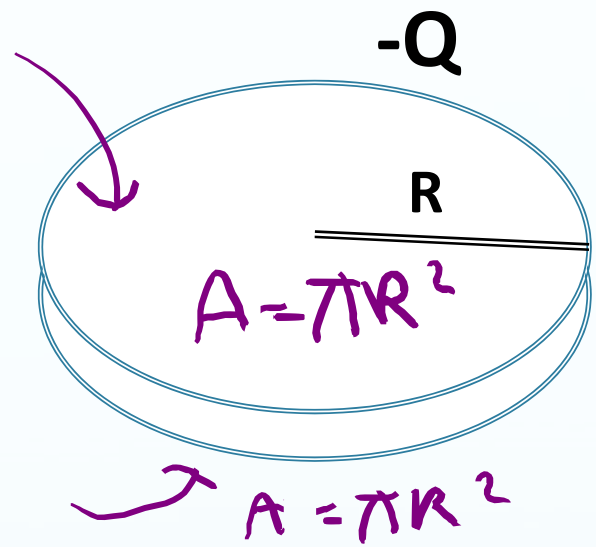
Multiple choice questions

Bring calculator

Chapters 21, 22 and 23

TopHat Question:
Metal plate→





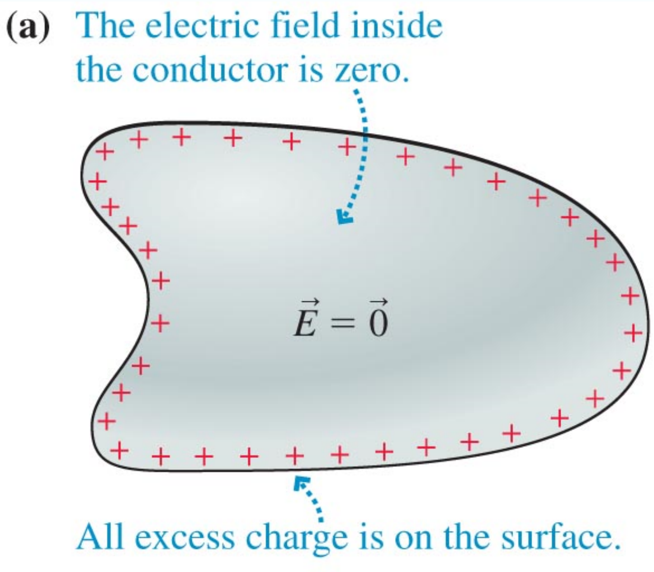
$\sigma = ?$

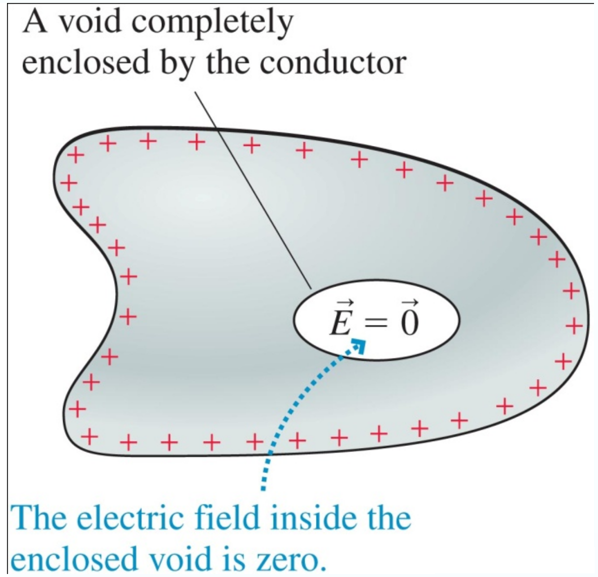
$\sigma = \frac{q}{A} = \frac{-Q}{2\pi R^2}$

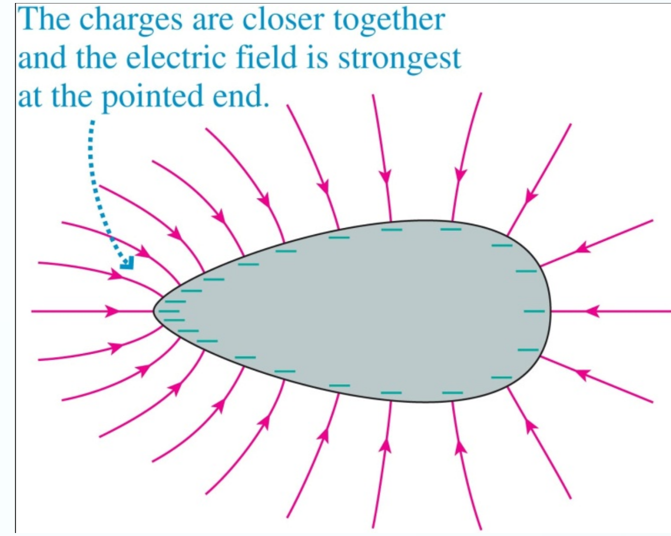
What is surface charge density of the disc?

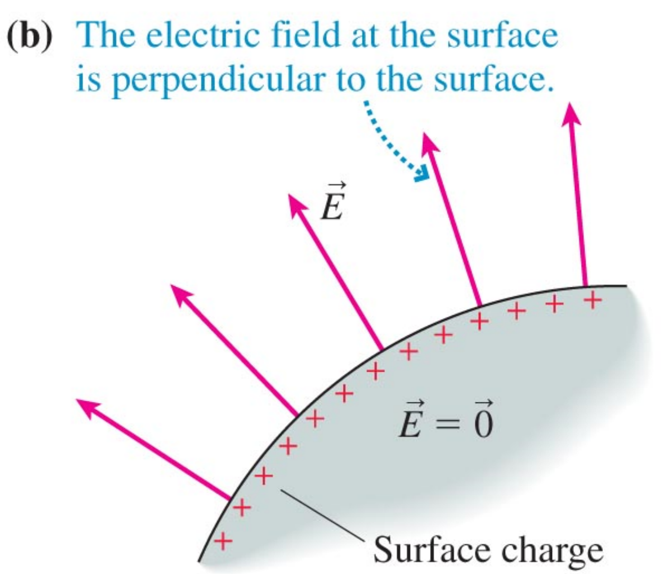
A. $Q/2\pi R^2$
B. $Q/\pi R^2$
C. $-Q/\pi R^2$
D. $\boxed{-Q/2\pi R^2}$

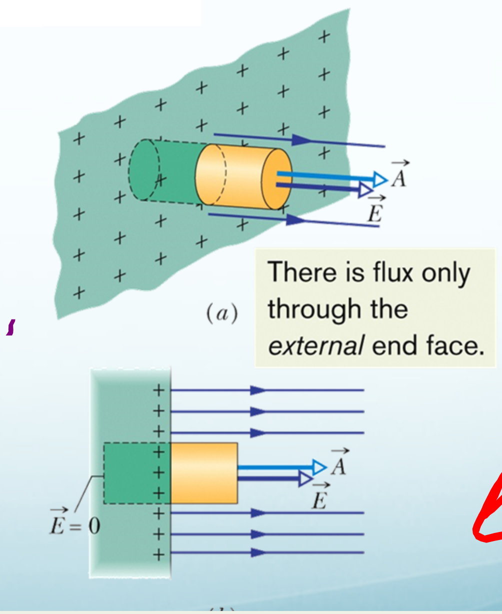
Summary of Conductors and Electric Fields











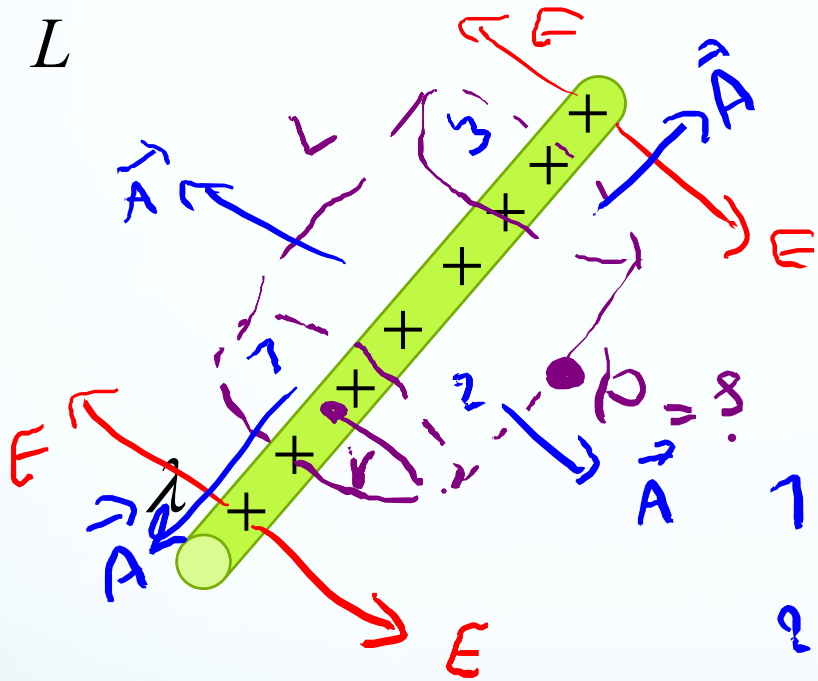
$$E = \frac{\sigma}{\varepsilon_0} \quad \text{(conducting surface).}$$

23-4 to 23-6
5

$$\lambda = \frac{Q}{L}$$

23-4: Electric field of a long, charged wire

Infinitely long plastic wire



$$\Phi_e = \oint \vec{E}.d\vec{A} = \frac{Q_{in}}{\varepsilon_0}$$

$$\oint \vec{E}\cdot d\vec{A} = \int_1 \vec{E}\cdot d\vec{A} + \int_2 \vec{E}\cdot d\vec{A} + \int_3 \vec{E}\cdot d\vec{A} =$$

$$= \int_1 0 + \int_3 0 + \int_2 E\,dA$$

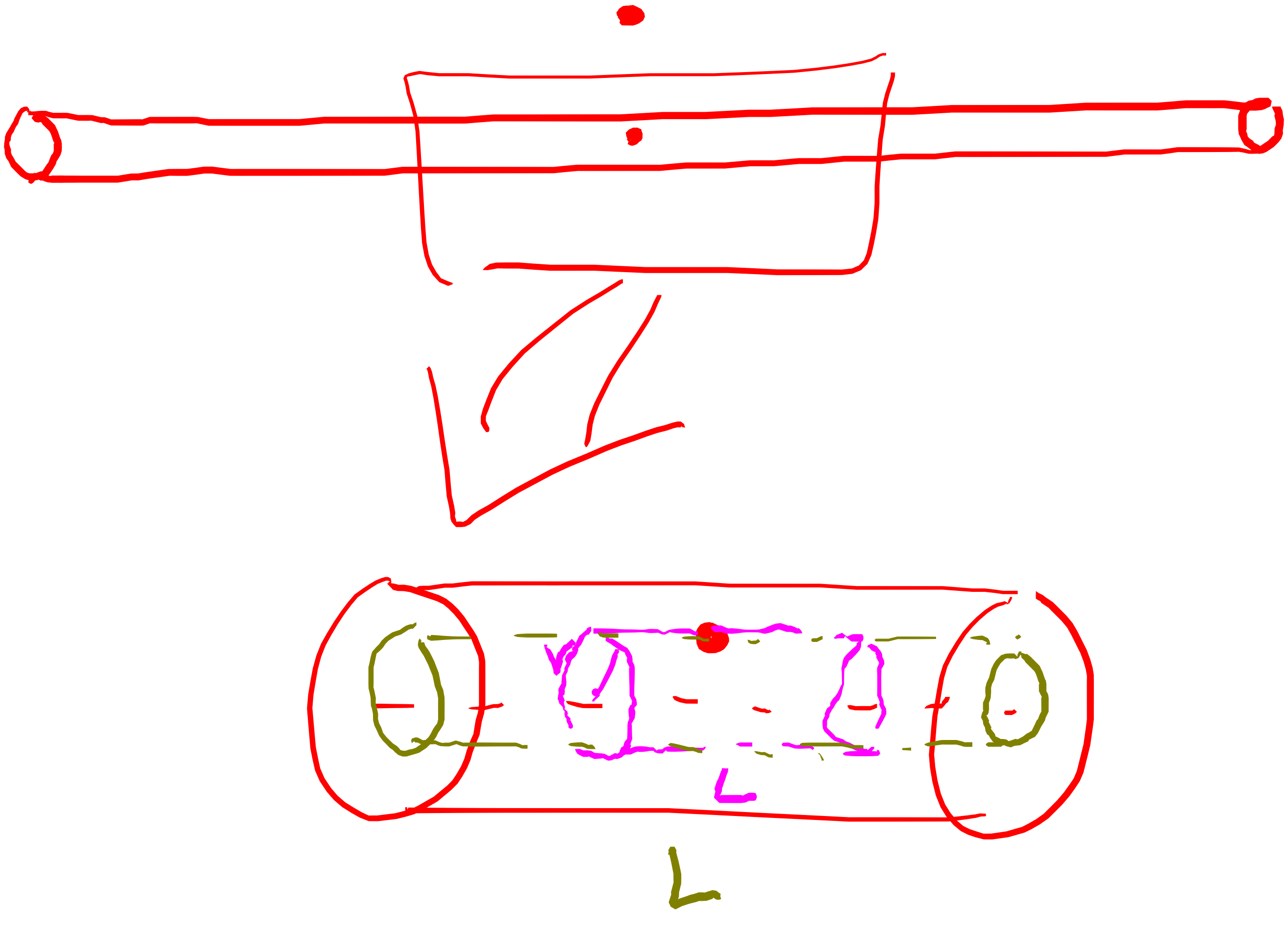
1: $\theta = 90^\circ$

2: $\theta = 0$

3: $\theta = 90$

$$\int_2 E\,dA = \frac{q_{en}}{\varepsilon_0} \rightarrow E\int_2 dA = \frac{q_{enc}}{\varepsilon_0} \rightarrow EA = \frac{q_{enc}}{\varepsilon_0} = E\,2\pi r L$$

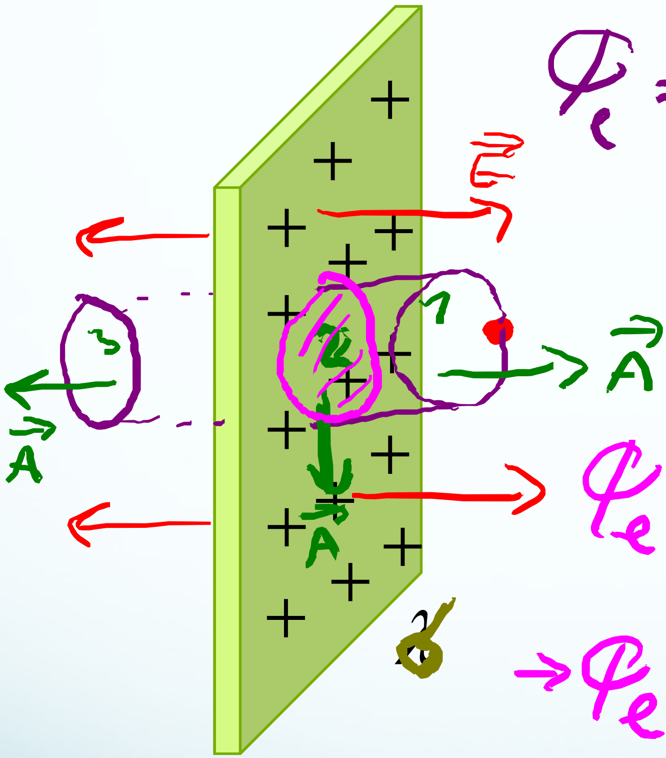
$$\rightarrow E = \frac{q_{enc}}{2\pi r L \varepsilon_0} = \frac{\cancel{L}\lambda}{2\pi r \cancel{L} \varepsilon_0} \rightarrow E_{wire} = \frac{\lambda}{2\pi\varepsilon_0 r}$$


L
L

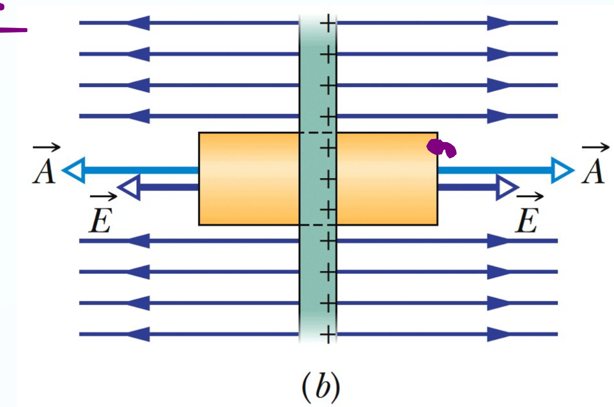
23-5: Electric field of a plane of charge

Nonconduction infinite sheet

$$\Phi_e = \oint \vec{E}.d\vec{A} = \frac{Q_{in}}{\varepsilon_0} = \frac{q_{enc}}{\varepsilon_0}$$



$$\Phi_e = \oint E.dA = \frac{q_{enc}}{\varepsilon_0} \Longrightarrow$$



(b)

$$\Phi_e = \int_1 + \cancel{\int_2}^{\,0} + \int_3$$

1: $\theta = 0$

2: $\theta = 90°$

3: $\theta = 0$

$$\to \Phi_e = \int_1 EdA + \int_3 EdA$$

$$\to \Phi_e = 2\int EdA = 2E\int dA = 2EA$$

$$\to 2E\cancel{A} = \frac{q_{enc}}{\varepsilon_0} = \frac{\sigma \cancel{A}}{\varepsilon_0} \to E_{plane} = \frac{\sigma}{2\varepsilon_0}$$

-2σ 5σ

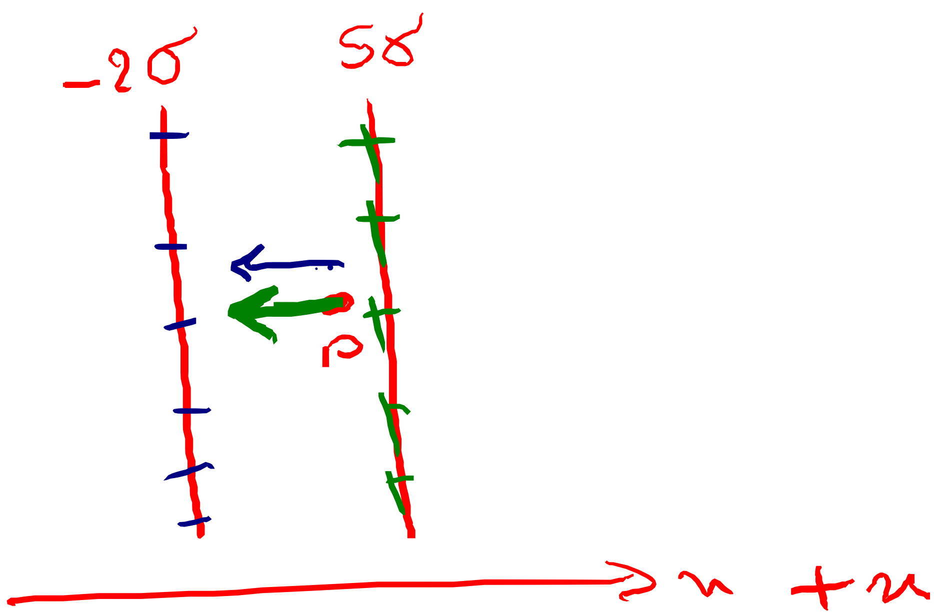
Q2) Two very thin infinite sheets are uniformly charged with surface charge densities -2η and +5 η as indicated in the figure. What is the magnitude and direction of the electric field at point P located between the sheets? (note the direction of +x in the figure)

a) $-3\sigma/2\varepsilon_0$

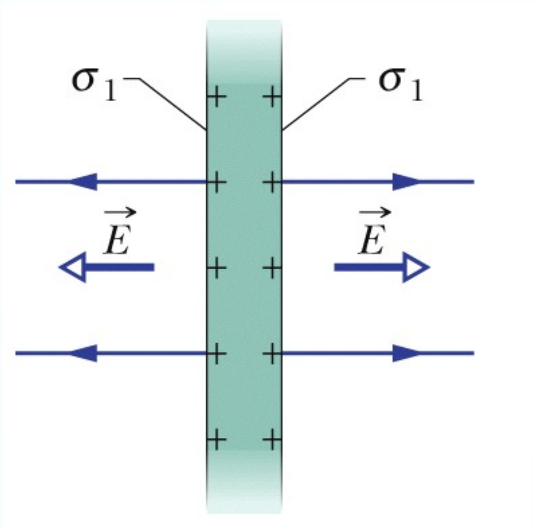
b) $3\sigma/2\varepsilon_0$

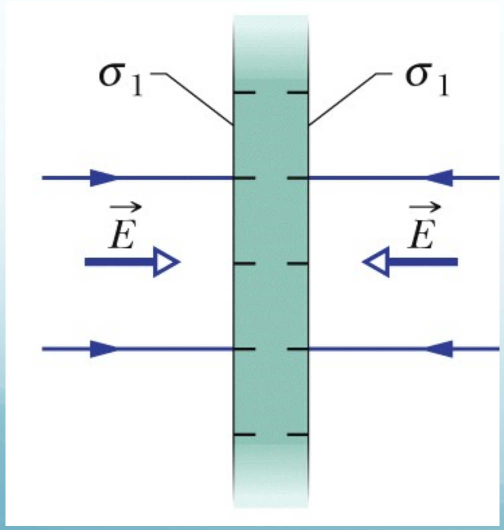
c) $-7\sigma/2\varepsilon_0$

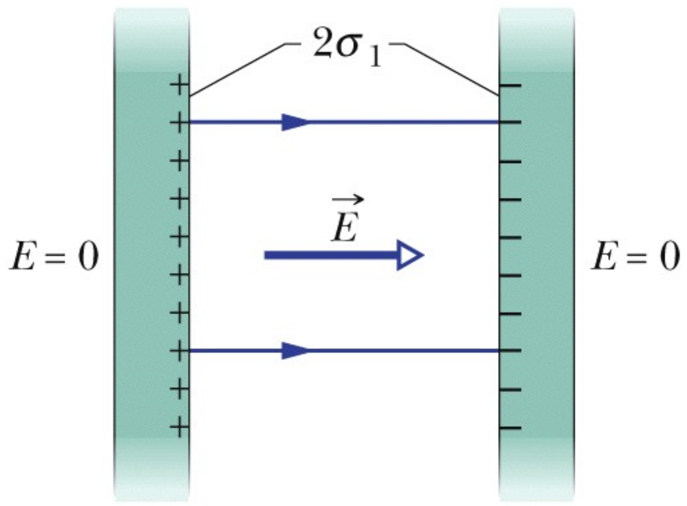
d) $7\sigma/2\varepsilon_0$



Two conducting Plates





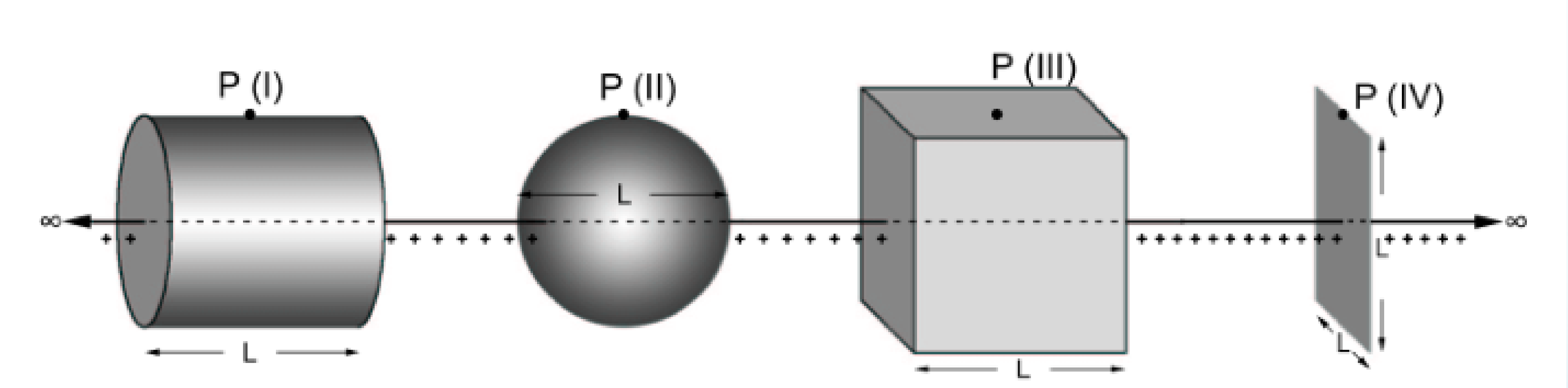


(c)

$$E = \frac{2\sigma_1}{\varepsilon_0} = \frac{\sigma}{\varepsilon_0}.$$

TopHat Question

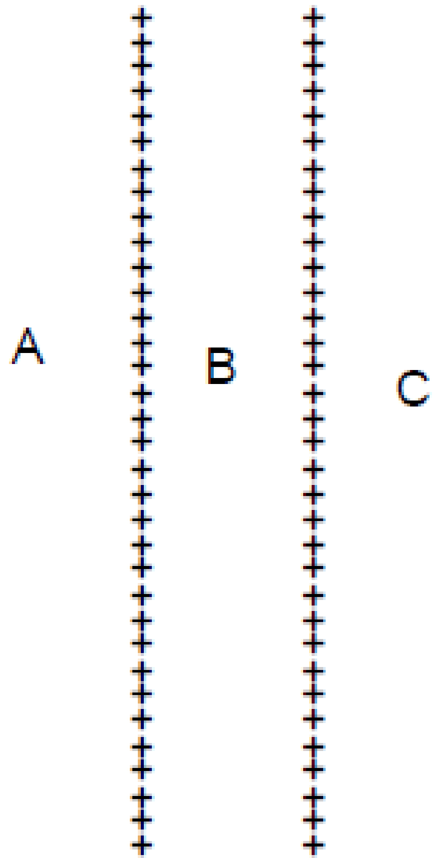
4 surfaces are coaxial with an infinitely long line of charge with a uniform linear charge density = λ. Choose all the surfaces through which $\Phi_E = \lambda L / \varepsilon_0$



A) I only
B) I and II only
C) I and III only
D) I, II, and III only
E) All four.

TopHat Question

Two infinite planes are uniformly charged with the same charge per unit area σ (or η in your textbook). If <u>**one plane only**</u> were present, the E-field magnitude due to the **one** plane would be E. With both planes in place, the E-field magnitude in region B has magnitude:



A: zero B: E C: 2E

D: depends on exact position.

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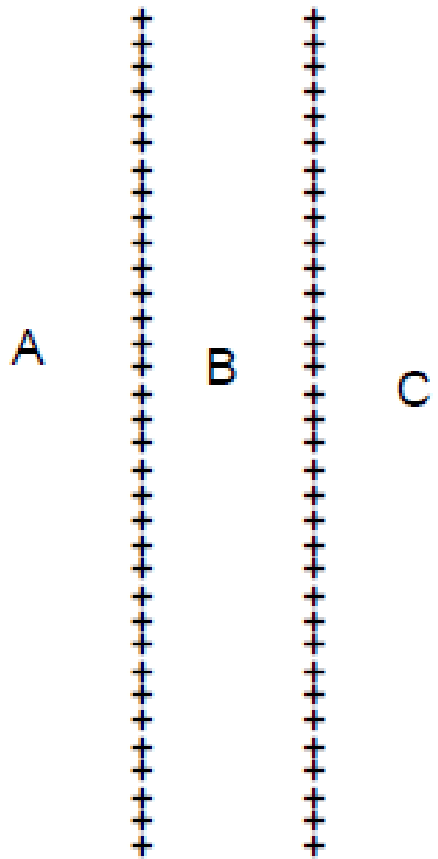


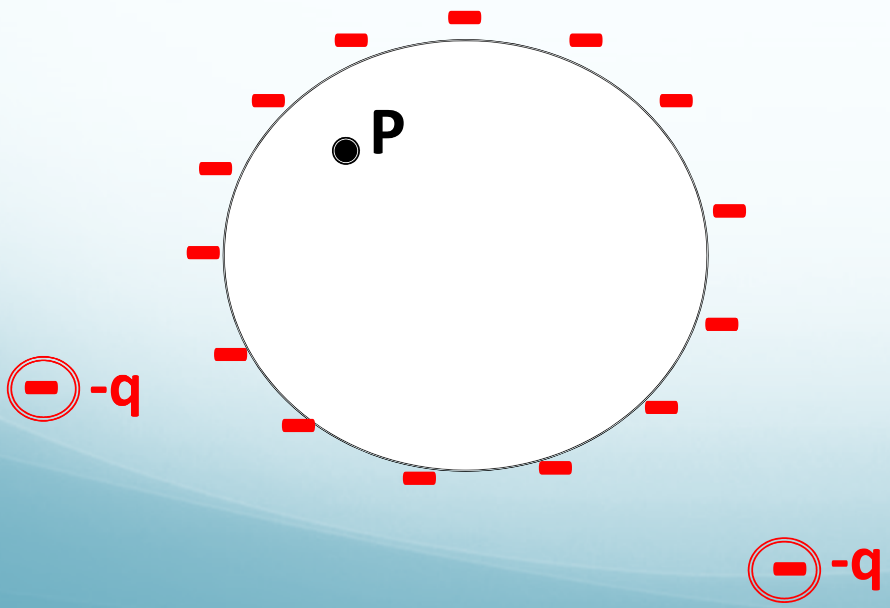
A: zero B: E C: 2E

D: depends on exact position.

TopHat Question

Negative charges are uniformly distributed on the surface of an insulating sphere with charge density σ. Two additional point charges -q are placed outside of the spherical charge distribution.

What is the magnitude of the E field at point P?



A: 0

B: non-zero

C: Not enough info given

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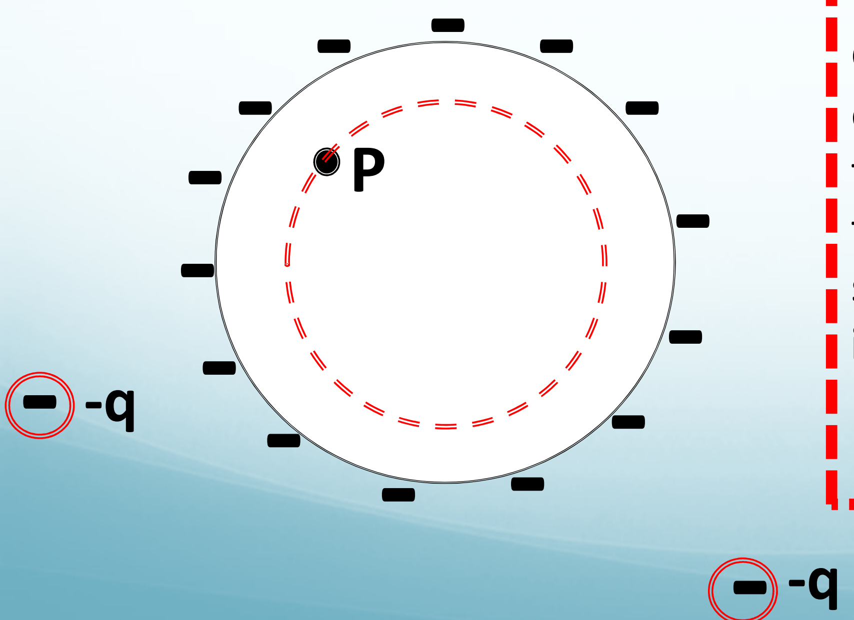
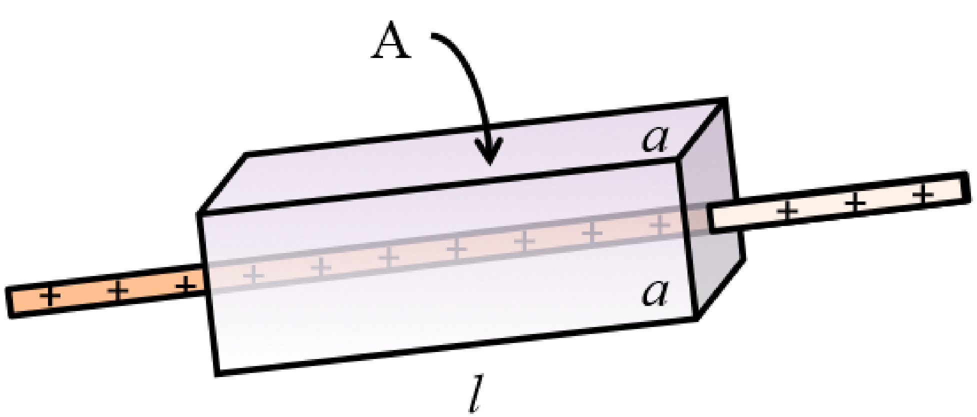


The two outside charges –q break the spherical symmetry.
If the 2 outside charges were **removed**,
the E field at point P would indeed be ZERO.

In order to find the E field at point P, we draw a Gaussian surface that goes through point P. If the 2 outside charges were removed (*just for a moment*), the spherical charge distribution would insure that the E field = 0 at point P (also anywhere inside the spherical charge distribution). THEN, once we **re-insert** the 2 outside charges –q, they would produce their own E field at point P...therefore resulting in a net E field at point P.

Field of a line charge

Consider an infinitely long, positively charged rod of linear charge density λ. How large is the flux through side A of the box? Suppose the values for l, a and λ are given.



Field of a line charge

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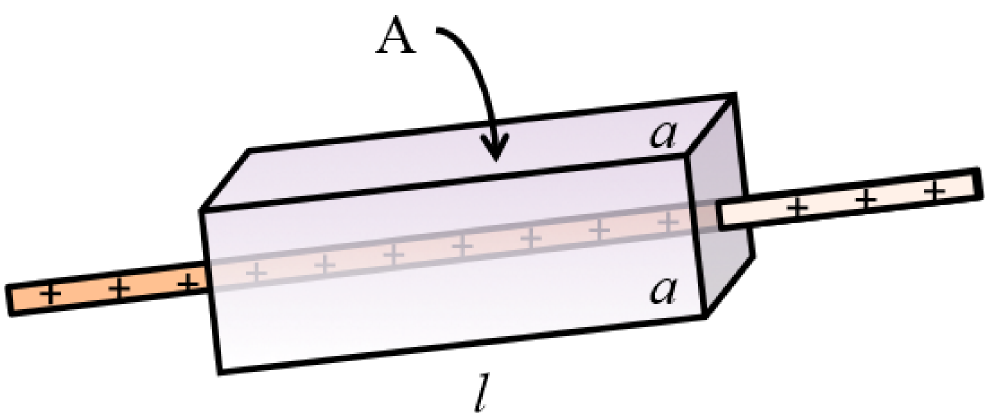
- Gauss' law tells us that the total electric flux only depends on the enclosed charge – not the shape of the (closed) Gaussian surface:

  $$\Phi_{tot} = Q_{encl}/\varepsilon_0 = \lambda l/\varepsilon_0$$



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  $\Phi_{tot} = Q_{encl}/\varepsilon_0 = \lambda l/\varepsilon_0$
- The total flux must be equally partitioned into flux through the four surfaces whose area vectors are parallel to the electric field.
  Hence, $\Phi_A = \lambda l/4\varepsilon_0$