PHYSICS 1B – Fall 2007

Electricity & Magnetism

Professor Brian Keating

SERF Building. Room 333

UCSD

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Info

- HW Solutions for CH 15 on Web today
- Quiz Friday covers:

1. Charges, Insulators, Conductors
2. Coulomb's Law
3. Electric Field/ Field Lines
4. Electrostatic Equilibrium/Millikan
5. Gauss' Law

Notes Allowed 1 page 8.5" x 11" letter size, both sides

I will give you constants (e.g., Coulomb's constant), ☺

…but not formulae…☹

Format: Multiple Choice, Bring your own Scantron Forms:

They are available at the Bookstore (no. X-101864-PAR) and the general store co-op.

Bring your own No. 2 pencils to fill in the Scantron.

Quizzes will be conceptual and quantitative.

No cell phones. Do not use or take into the testing room beeping, alarm, or calculator watches; pagers; cellular phones; books; rulers; cameras; radios; tape recorders; lapboards/deskboards; or aids of any kind. You may not wear earplugs during the test.

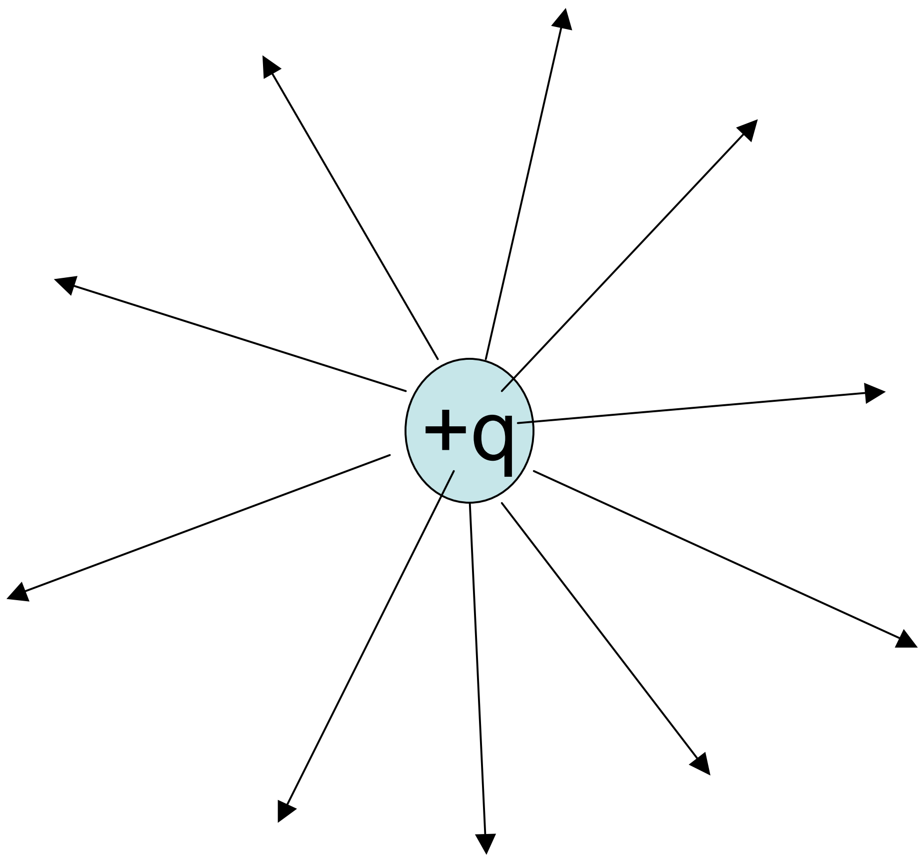
Problem Session!

- The Problem Session for Physics 1B will be tomorrow at 7pm to 8:50p in
- CENTER HALL

End of Chapter 15
Gauss' Law

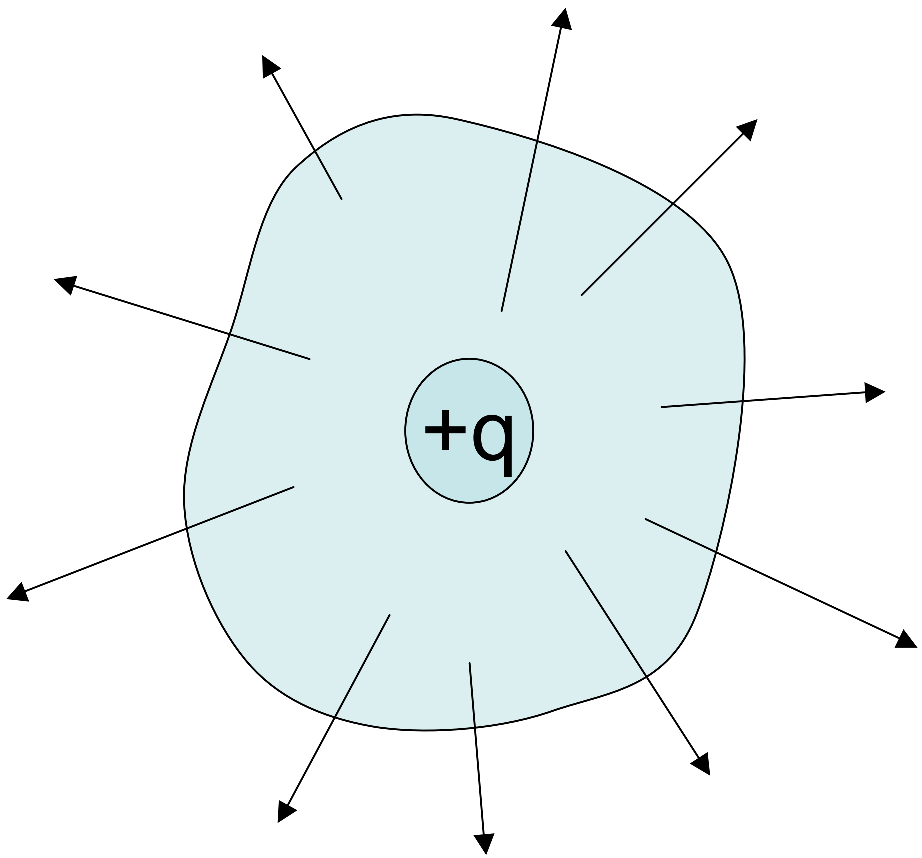
- Gauss' Law gives relation between electric fields and charges.
- Equivalent to Coulomb's Law…you can derive Coulomb's law FROM Gauss'.
- Useful for determining E for simple distributions of charge.

Basic Idea of Gauss' Law



Total number of E field lines is proportional to charge

Density of E field lines is proportional to the magnitude of E

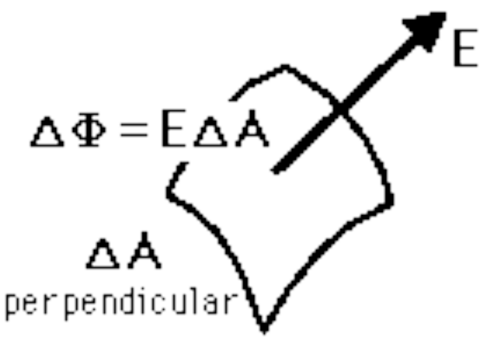


surround the charge by
a closed surface

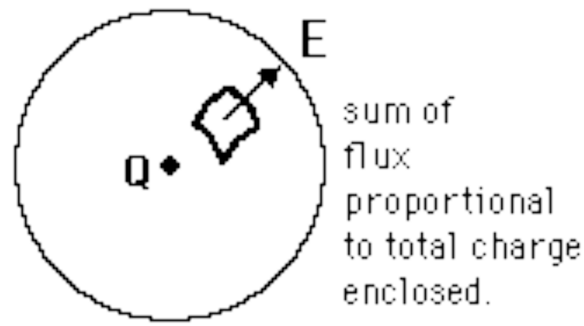
The density of E-field
lines (i.e. the E field) at
the surface can be related
to the charge q

Gauss's Law

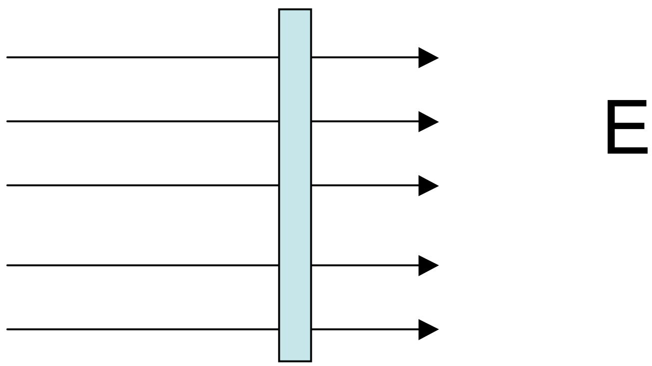
The total of the electric flux out of a closed surface
is equal to the charge enclosed divided by the permittivity.



$$\Phi_{electric} = \frac{Q}{\varepsilon_0}$$



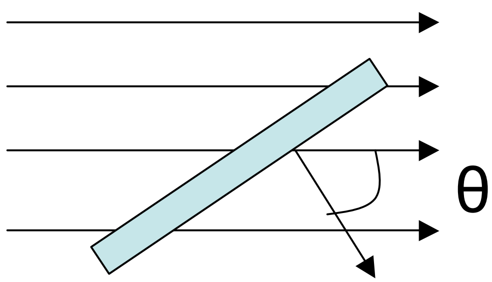
Electric Flux, Φ_E, through an area A



area A (perpendicular to electric field lines)

$$\Phi_E = EA \propto N$$

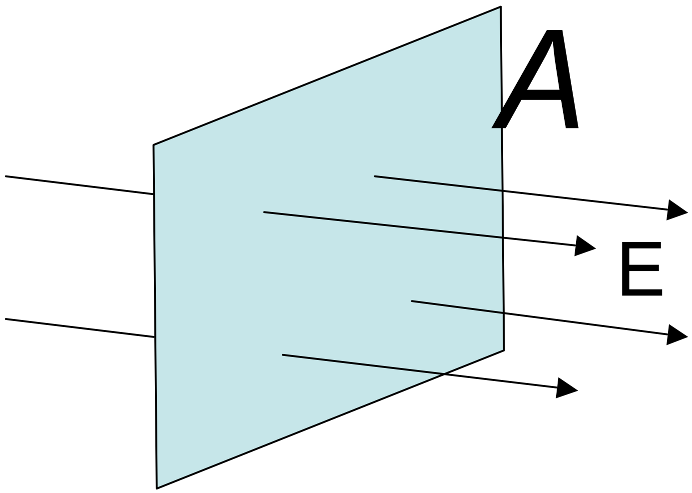
N = no. of electric field lines



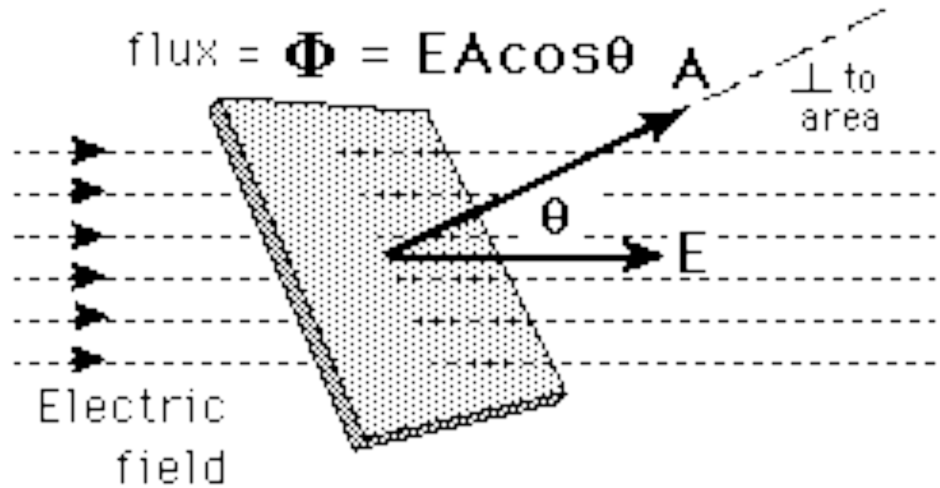
E at angle of Θ to surface normal (red).

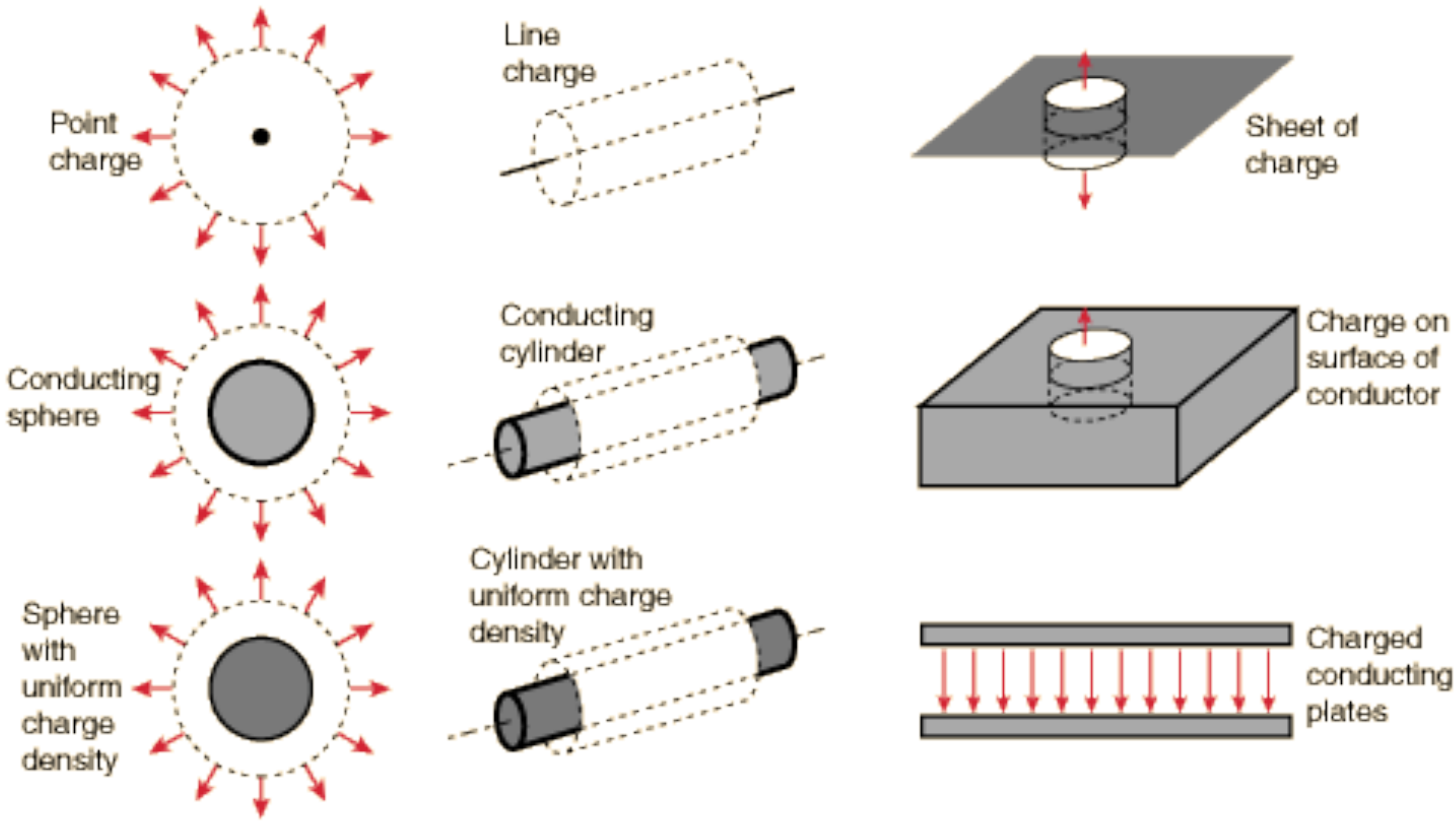
$$\Phi_E = EA\cos\theta$$

Finding E from the flux



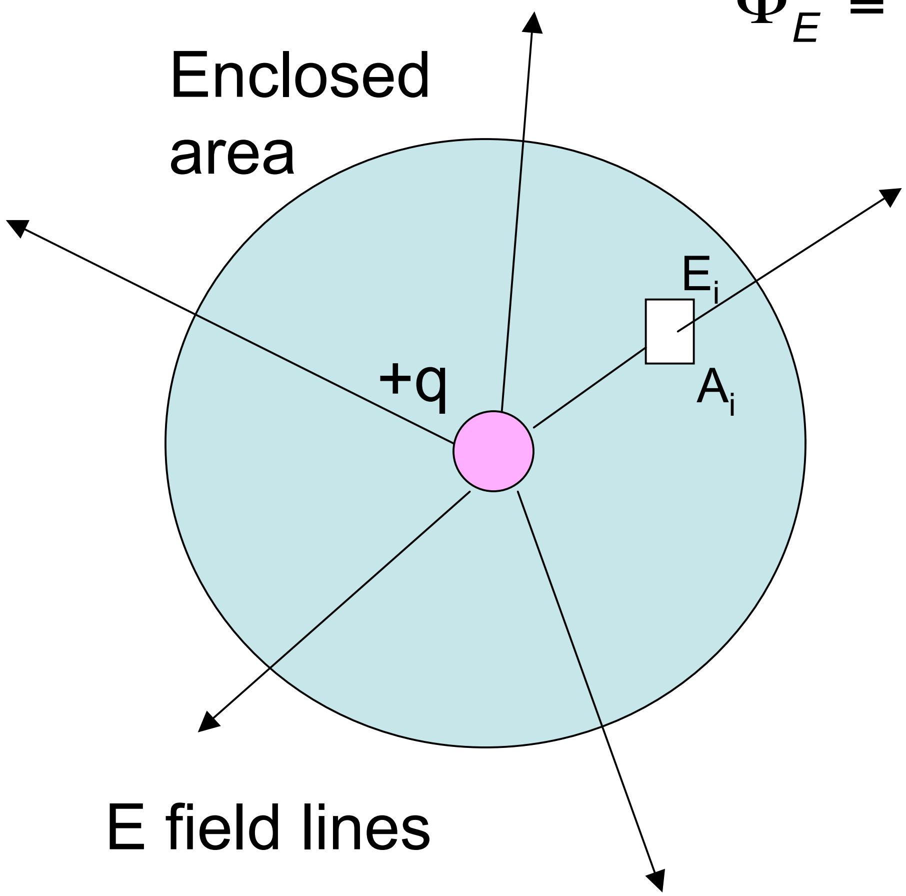
$$E = \frac{\Phi_E}{A_\perp}$$





Point charge
Line charge
Sheet of charge
Conducting sphere
Conducting cylinder
Charge on surface of conductor
Sphere with uniform charge density
Cylinder with uniform charge density
Charged conducting plates

Flux through an enclosed area is proportional to amount of charge enclosed



$$\Phi_E = \sum E_i A_i \cos\theta \propto N \propto q$$

Sum over enclosed area

Gauss's Law

$$\Phi_E = \frac{q}{\varepsilon_o}$$

Proportionality Constant

$$\varepsilon_o = \frac{1}{4\pi k_e}$$

$$= 8.85x10^{-12} C^2 / Nm^2$$

Permittivity of free space

$$\varepsilon_o = \frac{1}{4\pi k_e}$$

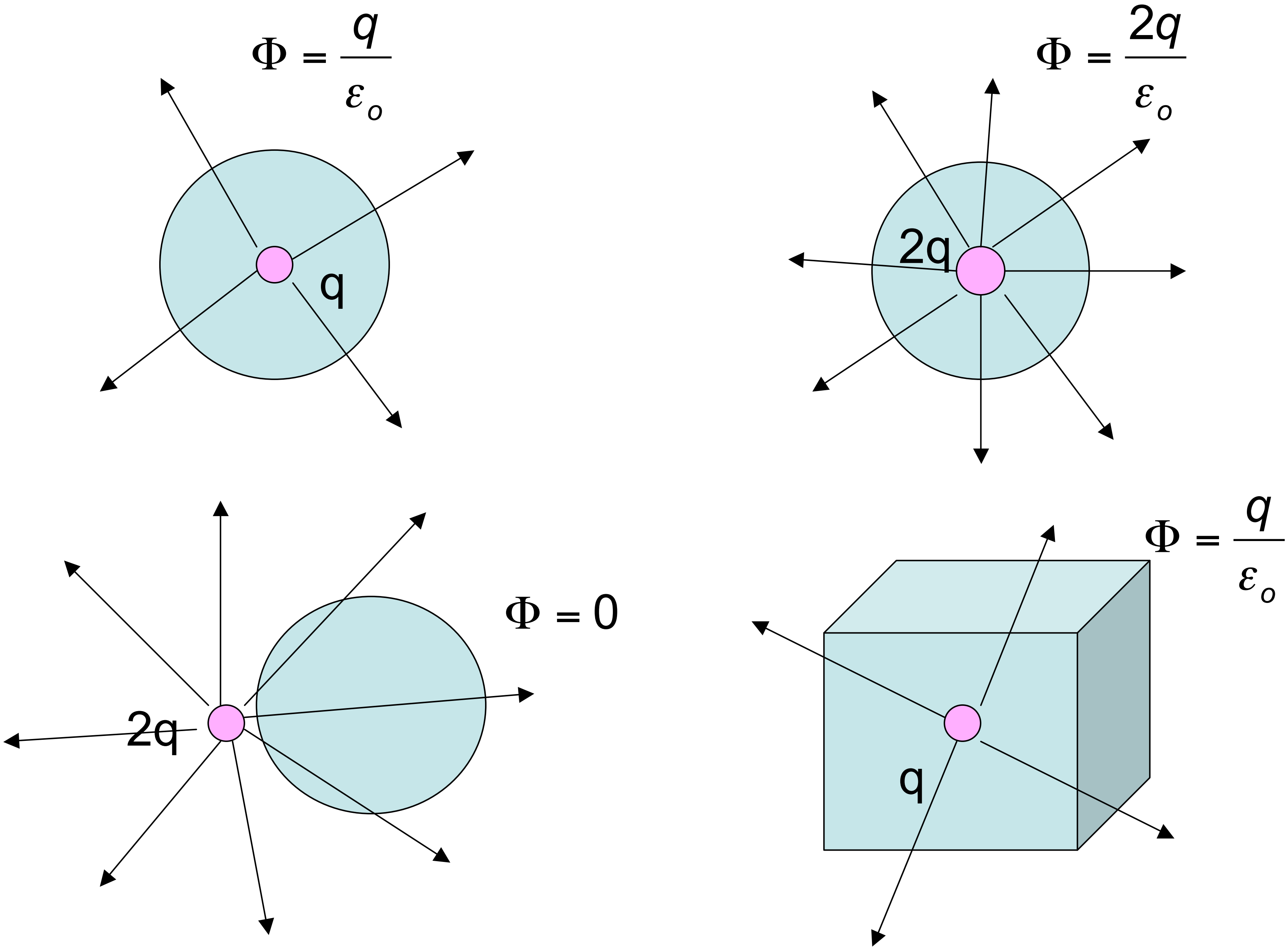
$$k_e = \frac{1}{4\pi\varepsilon_o}$$

Coulomb's Law

$$E = \frac{k_e q}{r^2} = \frac{q}{4\pi\varepsilon_o r^2}$$

Either ε_o or k_e can be used as the constant in Coulomb's Law.

Find the total Flux through the area

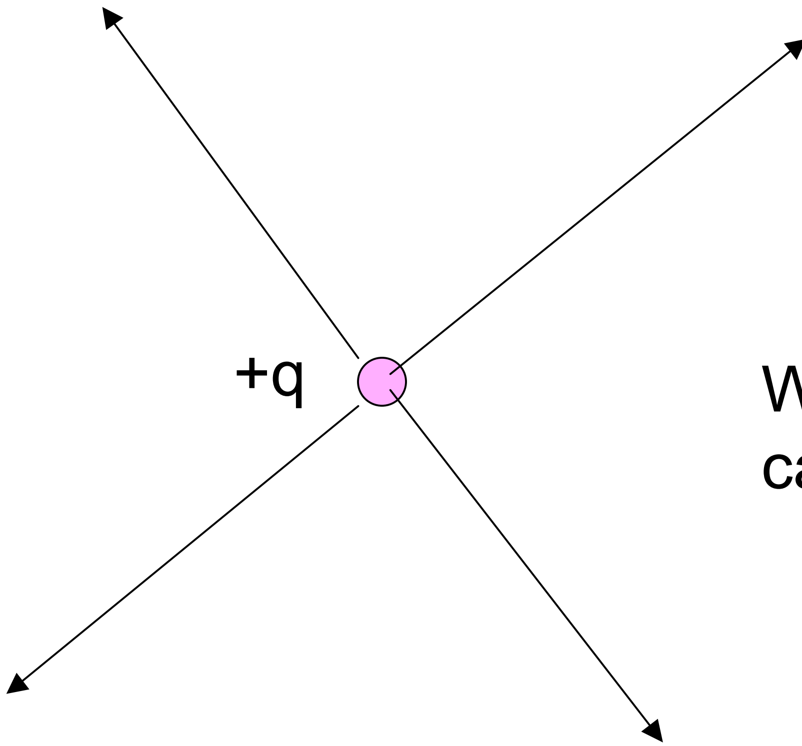


Determining the Electric Field using Gauss' Law

For some simple charge distributions (point charge, infinite plane of charge) the flux is equal to a constant E field times the area of the surface surrounding the charge. (Gaussian Surface)

$$\Phi_E = EA$$

Electric field due to a point charge

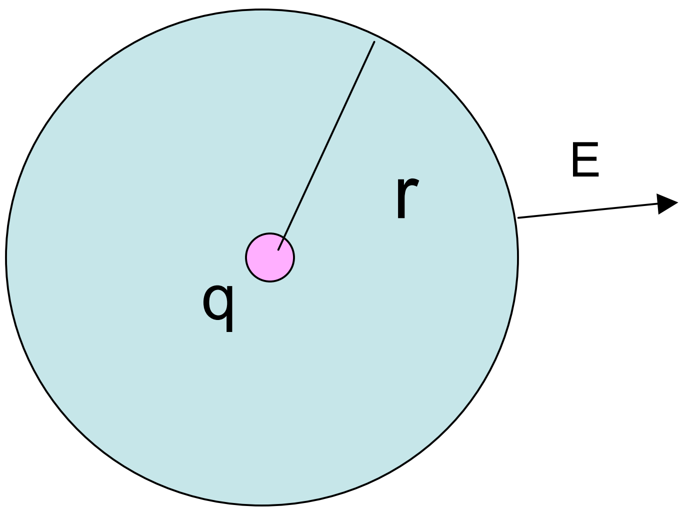


Electric field lines

What Gaussian surface can be used to find E?

Gaussian surface for a point charge- a sphere at radius r around charge q. E is constant at the surface and perpendicular to the surface.

$$\Phi_E = EA = E(4\pi r^2) = \frac{q}{\varepsilon_o}$$



Rearranging

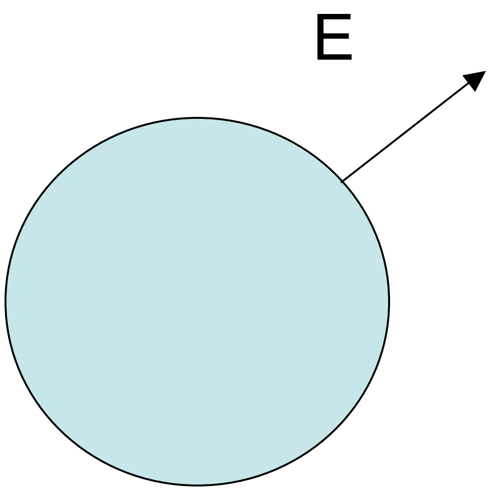
$$E = \frac{q}{4\pi\varepsilon_o r^2}$$

From the definition of ε_o

$$E = \frac{k_e q}{r^2}$$

Coulomb's Law

A charge of q is placed on a conducting sphere of radius r. What is the E field at the surface?



q is at the surface and uniformly distributed

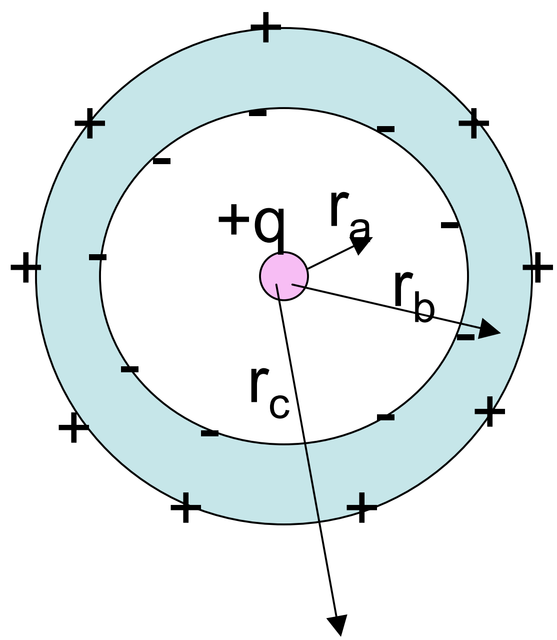
E is constant at the surface

E is zero inside the surface

Use a Gaussian surface just outside the sphere

$$E = \frac{q}{A\varepsilon_o} = \frac{q}{4\pi r^2 \varepsilon_o}$$

An uncharged conducting metal spherical shell surrounds a charge +q. Find the electric field at radius r_a, r_b, and r_c

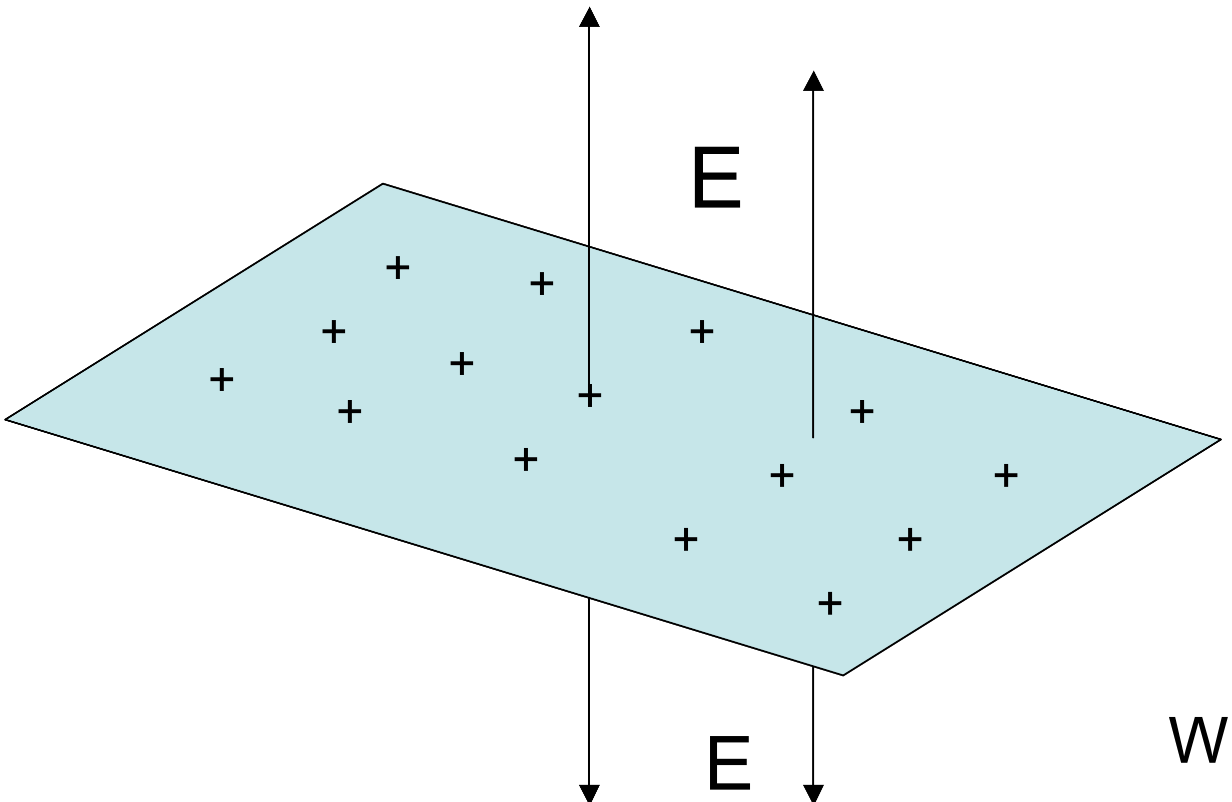


a. $$E_a = \frac{q}{4\pi\varepsilon_o r_a^2}$$

b. $$E_b = 0$$

c. $$E_C = \frac{q}{4\pi\varepsilon_o r_c^2}$$

Electric field due to an infinite plane of charge with constant charge density, $\sigma = q/A$.

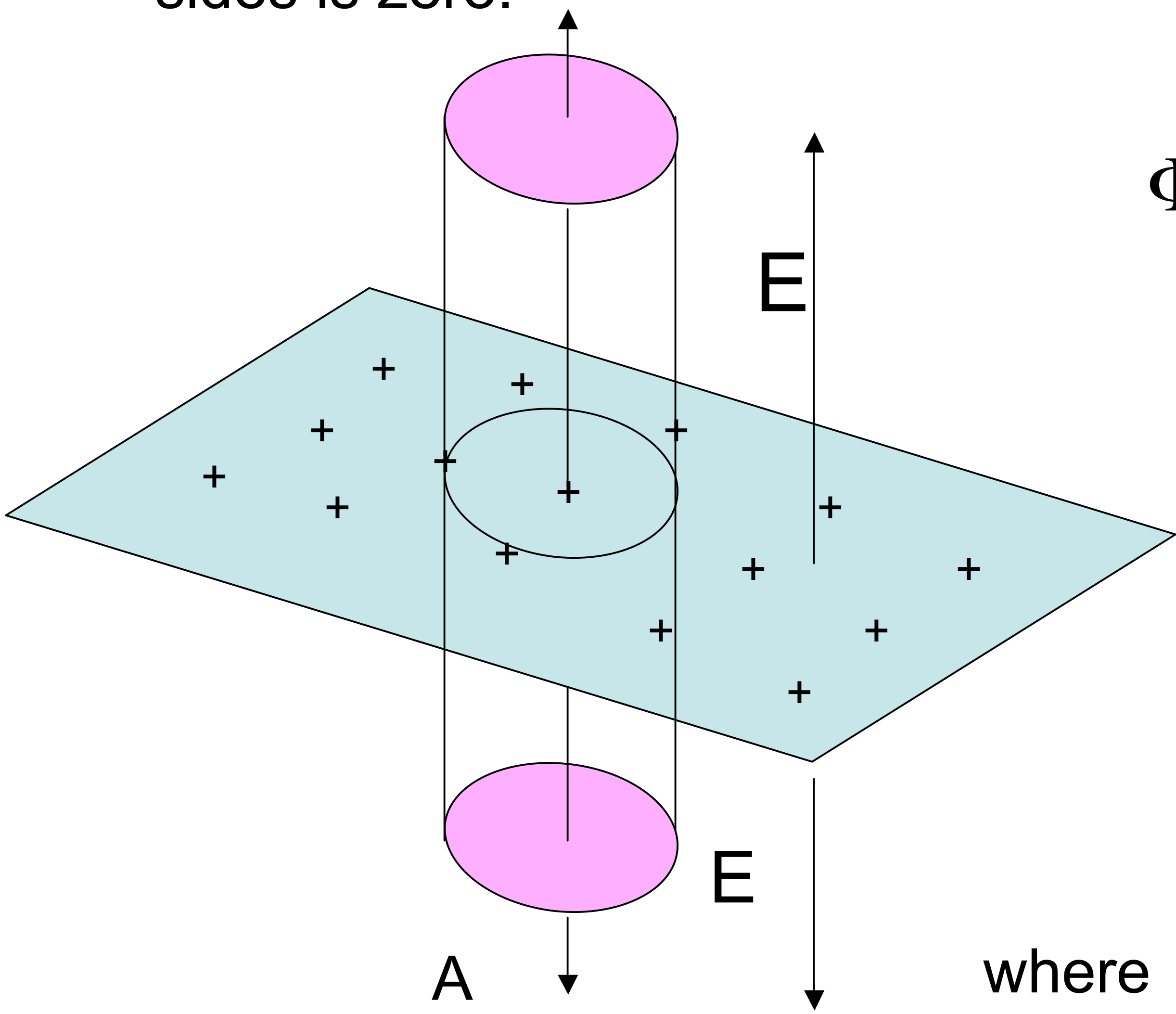


The direction of the E field is perpendicular to the surface.

The magnitude of E is constant over the surface

What Gaussian surface can be used to find E?

Gaussian surface- a cylinder with sides perpendicular to the plane. E is constant at ends. Flux through sides is zero.



$$\Phi_E = 2AE = \frac{q}{\varepsilon_o}$$

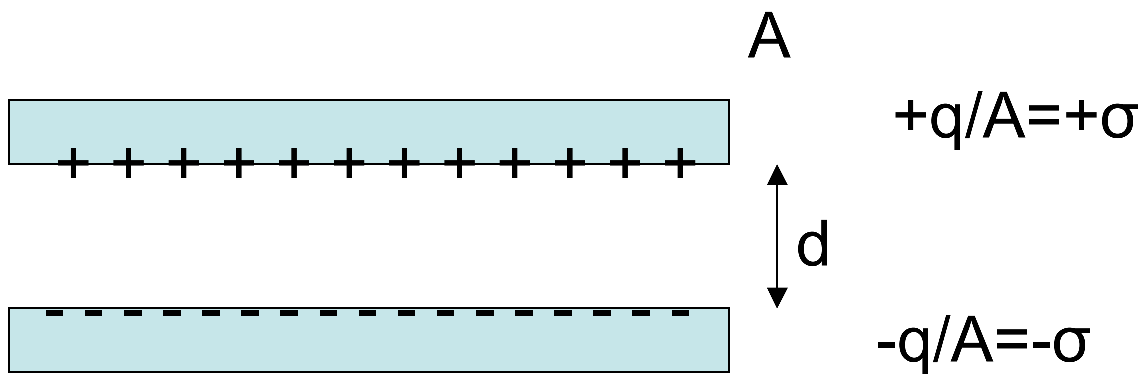
$$E = \frac{q}{2A\varepsilon_o}$$

$$E = \frac{\sigma}{2\varepsilon_o}$$

where $\sigma = \dfrac{q}{A}$

Parallel plate capacitor

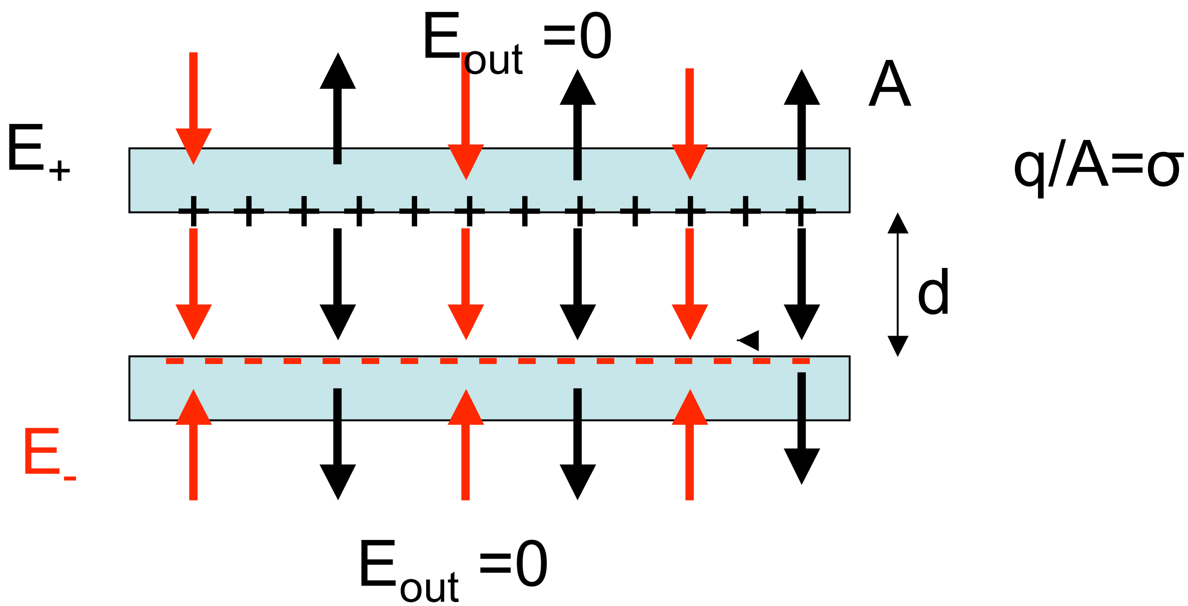
two "infinite" planes of charge area A separated by distance d where d<< A, carry charge +q, -q



The charges are at the inner surface of the capacitor

Field inside the capacitor plates

By superposition of charges due to sheet of charge

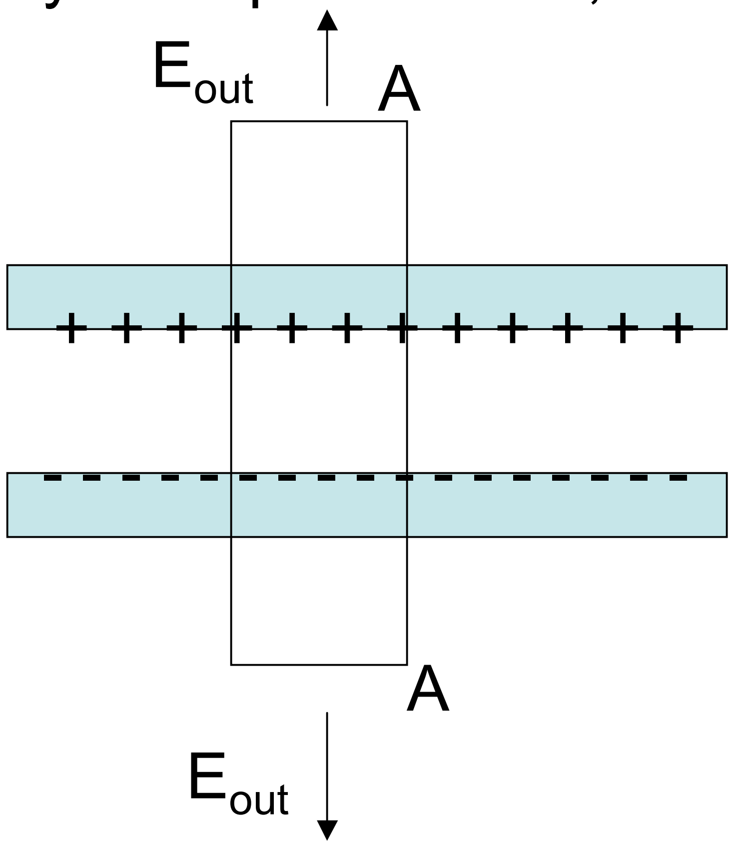


$$E_{in} = \frac{\sigma}{\varepsilon_o}$$

$$E_{in} = E_+ + E_- = 2\frac{\sigma}{2\varepsilon_o} = \frac{\sigma}{\varepsilon_0}$$

E field outside the capacitor using Gauss's Law

use a cylinder as the Gaussian surface, ends of the cylinder parallel to A, sides perpendicular to A



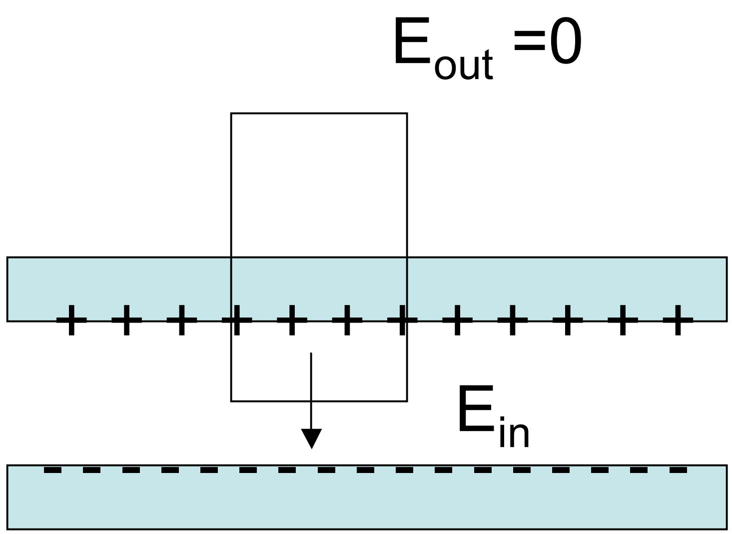
$$\Phi_E = \frac{q - q}{\varepsilon_o} = 0 = 2E_{out}A$$

$$E_{out} = 0$$

The charge in the Gaussian surface is zero.

The E field outside the capacitor is zero

E field inside the capacitor using Gauss's Law



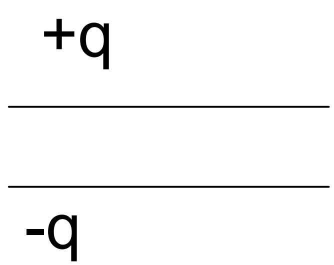
$$\Phi_E = E_{in} A = \frac{q}{\varepsilon_o}$$

$$E_{in} = \frac{q}{A\varepsilon_o} = \frac{\sigma}{\varepsilon_o}$$

The field in the capacitor is also.

$$E_{in} = \frac{\sigma}{\varepsilon_o}$$

At electric fields higher than $3x10^6$ N/C air ionizes and becomes conducting. For a parallel plate capacitor separated by air, with an area of 1 m^2 find the maximum amount of charge that can be stored.



$$E = \frac{\sigma}{\varepsilon_o} = \frac{q}{A\varepsilon_o}$$

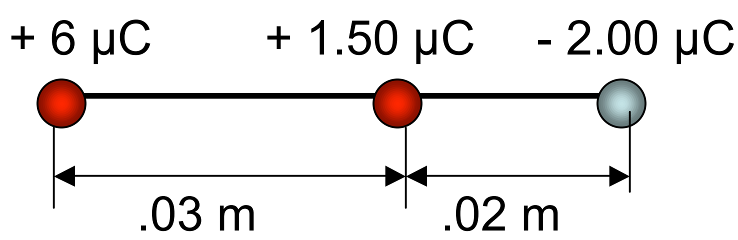
$$q = EA\varepsilon_o = (3x10^6)(1)(8.8x10^{-12})$$

$$q = 2.6x10^{-5}C$$

Homework: Extra Credit

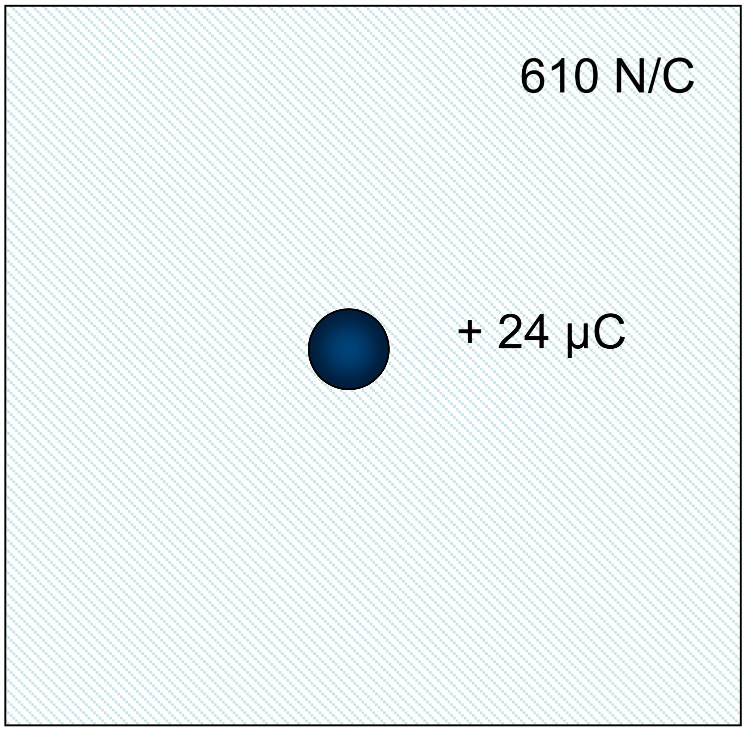
- Take out your clickers
- The problems are all from your HW
- I give you the question number, description, and then you answer.
- You'll only have 1 minute for each: NO TIME WILL BE GIVEN AFTER CLASS.
- Your worst HW score will not count against you.

15.10) Calculate the magnitude and direction of the Coulomb force on left-most positive charge as shown:



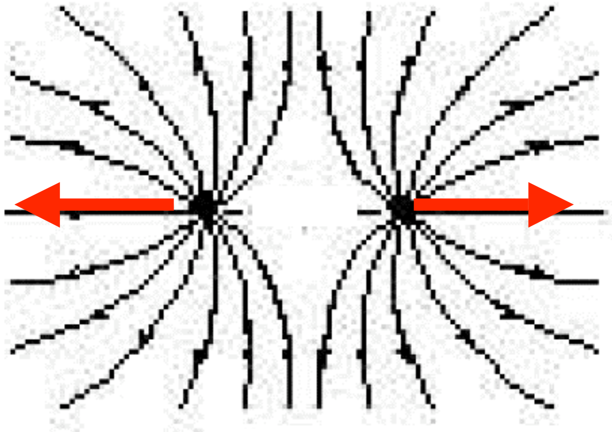
- A) 133.1 N (to the left)
- B) 133.1 N (to the right)
- C) 46.7 N (to the left)
- D) 46.7 N (to the right)

15.17) An object with net a net charge of 24 μC is placed in a uniform electric field of 610 N/C, directed vertically. What is the mass of the object if it “floats” in the electric field?

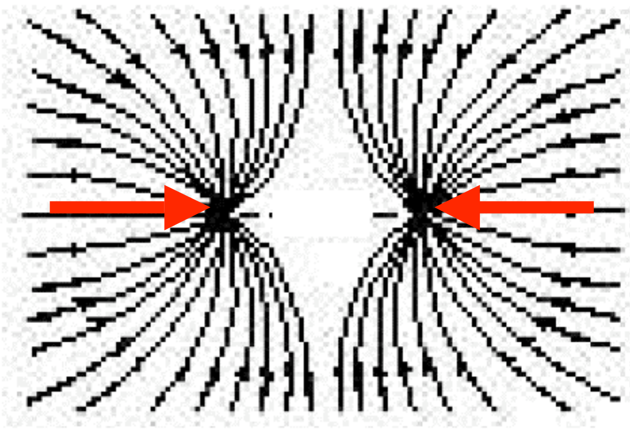


- A) 62.2 kg
- B) 1.5 x 10^{-3} kg
- C) 610 kg
- D) 3.6 x 10^{-8} kg

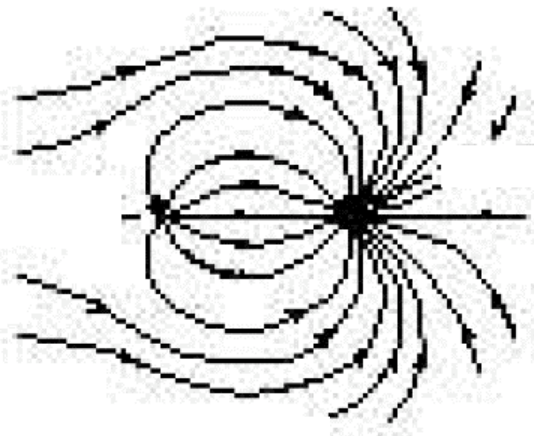
15.30.a) Which of the following best depicts the electric field pattern around two positive point charges of magnitude 1 μC placed close together?



(A)



(B)



(C)