PHYSICS 1B – Fall 2006

Electricity
&
Magnetism

Friday October 5, 2007

Course Week 1

Professor Brian Keating

SERF Building. Room 333

UCSD UCSD

Announcements

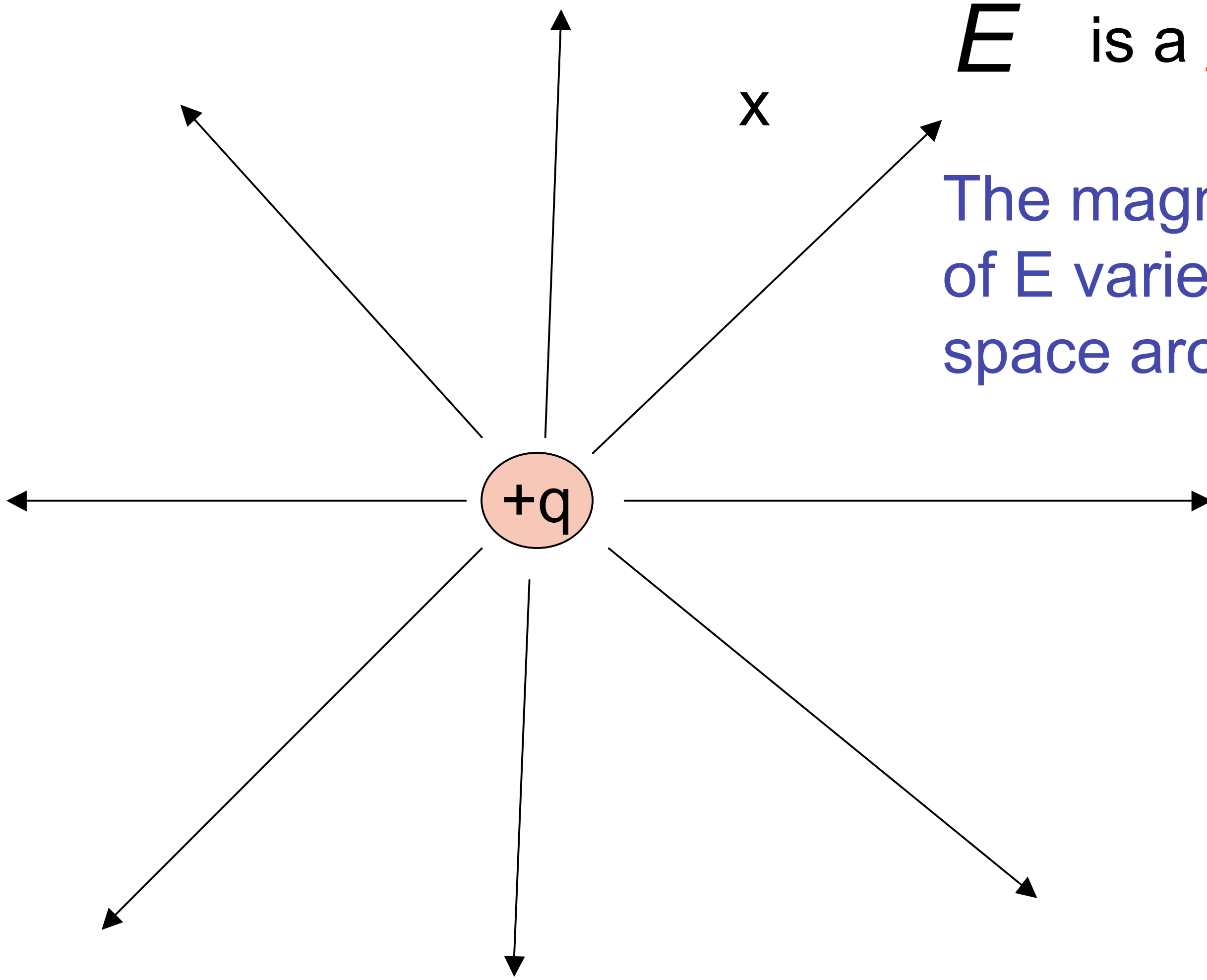
- Problem Session! The Problem Session for Physics 1B will be every Thursday at 7pm to 8:50p in CENTER HALL
- First Problem Session: next Thursday October 11
- Quiz next Friday October 12
- Get your clickers and make sure to bring to class, every class.
- **On Wednesday October 10, at the end of lecture, I will post 3 problems drawn from your HW from Ch 15. You will have 3 minutes to enter your answers to the three questions for Extra Credit.**
- **You can register your clickers using your PID number, with or without the "A" in front.**

Chapter 15.3
Electric Fields / Electric Field Lines

- Definition of electric field
- Interaction of electric fields with charges
- Electric field lines
- Electric field from a point charge
- Electric field from several point charges.

The Electric Field exists in space surrounding a charge

$\vec{E}$ is a ***vector quantity***

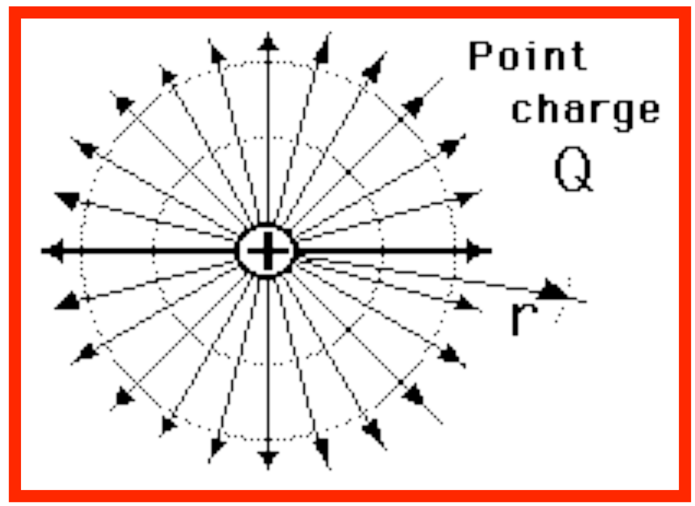


The magnitude and direction of E varies with position in space around a charge.

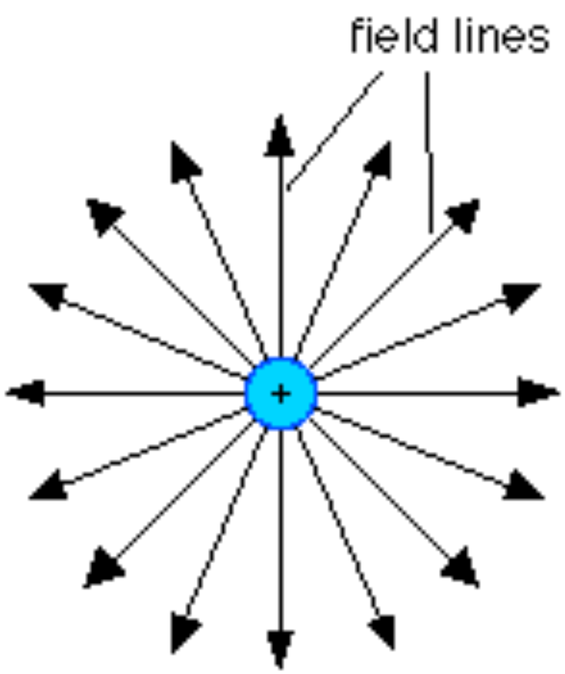
Lines are a way of visualizing how strong, and in what direction, an Electric Force will act on a test charge.

Electric field due to a point charge q at distance r, Coulomb's Law

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



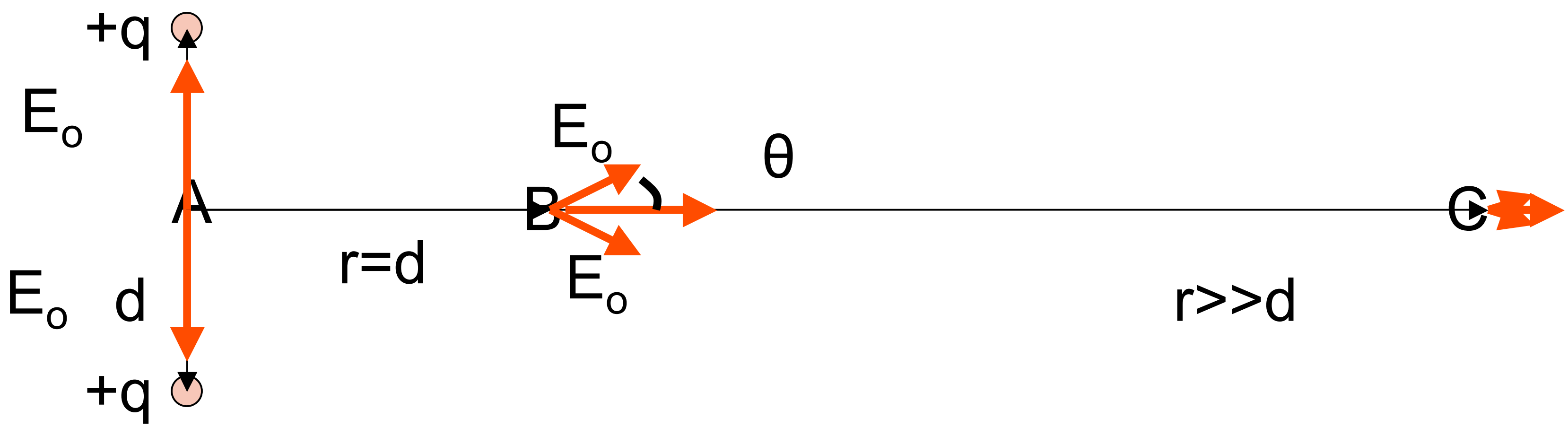
Electric field lines



The electric field vector **E** is tangent to the electric field line

The number of electric field lines per unit area through a surface perpendicular to the lines is proportional to the strength of the electric field in a given region

Electric field due to 2 + charges



E_A

$E_A=0$

E_B

$E_B = 2E_o \cos\theta$

This charge distribution is not neutral.

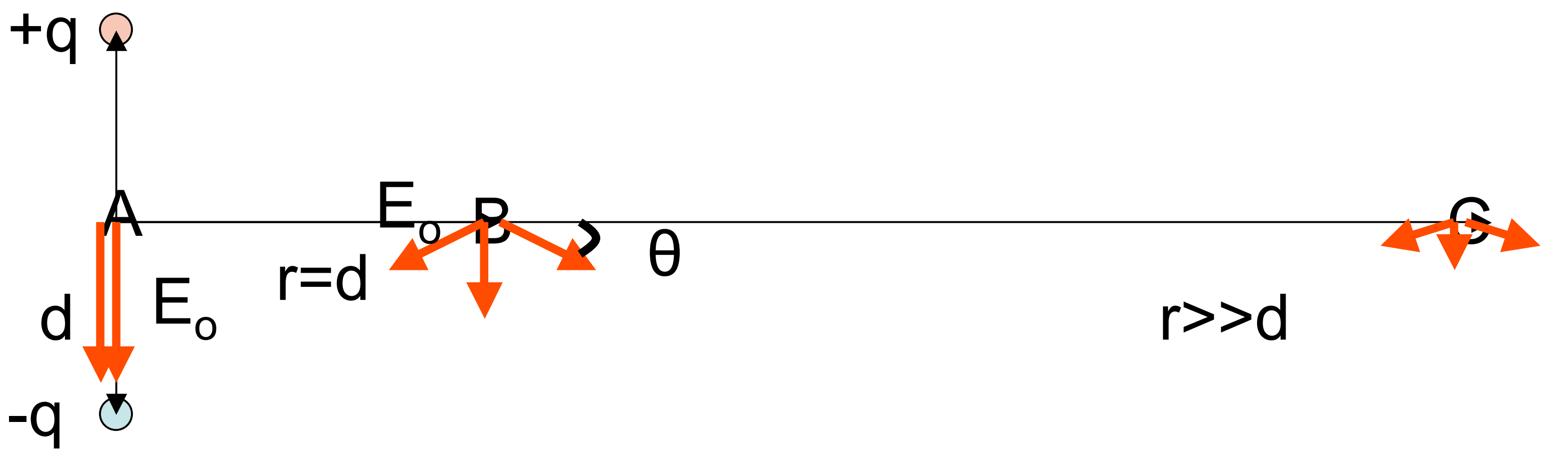
Total charge=+2q

$E_C = 2E_o \cos\theta \Rightarrow 2E_o$

as θ->0

looks like a point charge of 2q

Electric field due to a dipole dipole moment $qd=\mu$



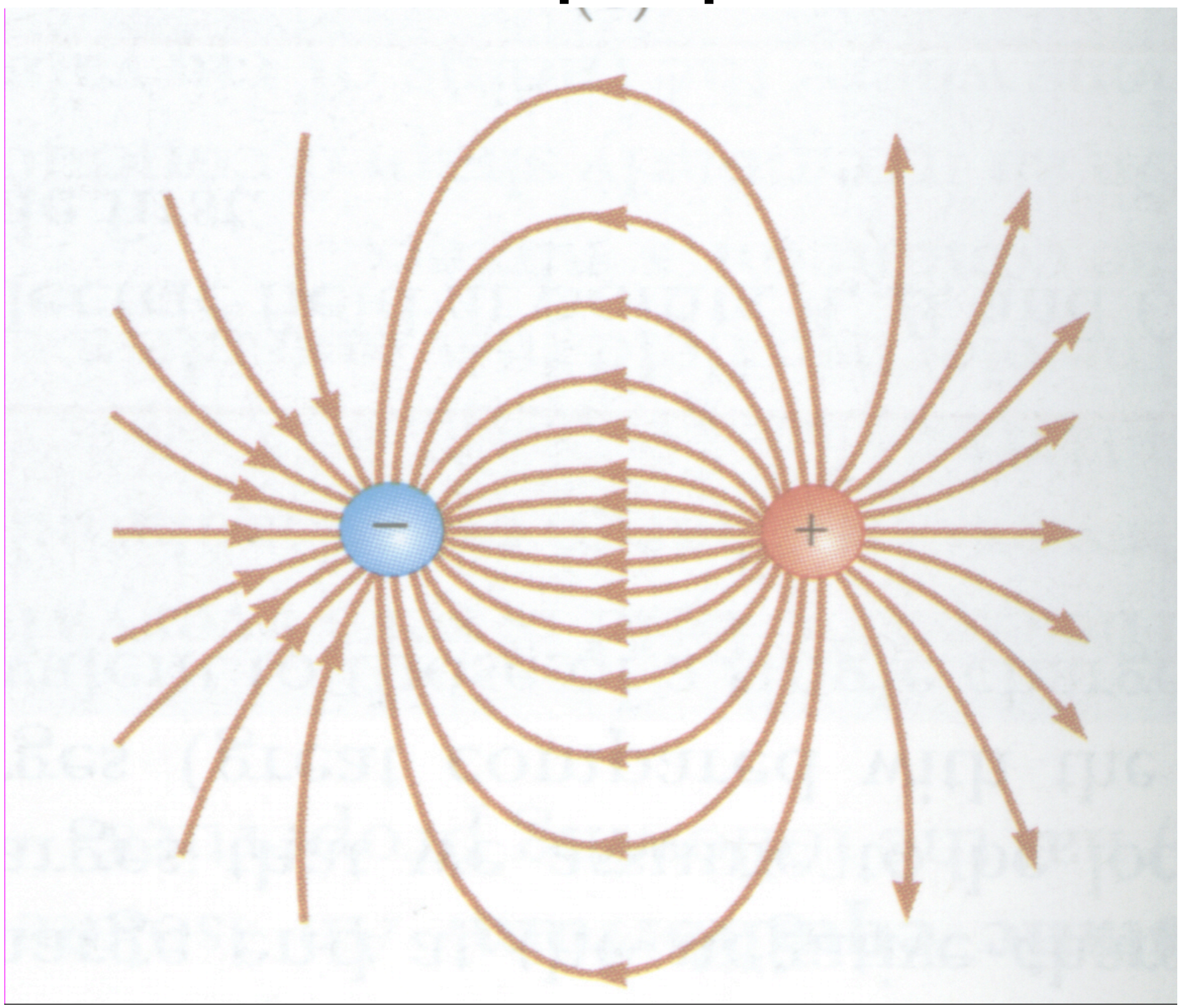
What is the total charge of this dipole distribution?

A. +2q

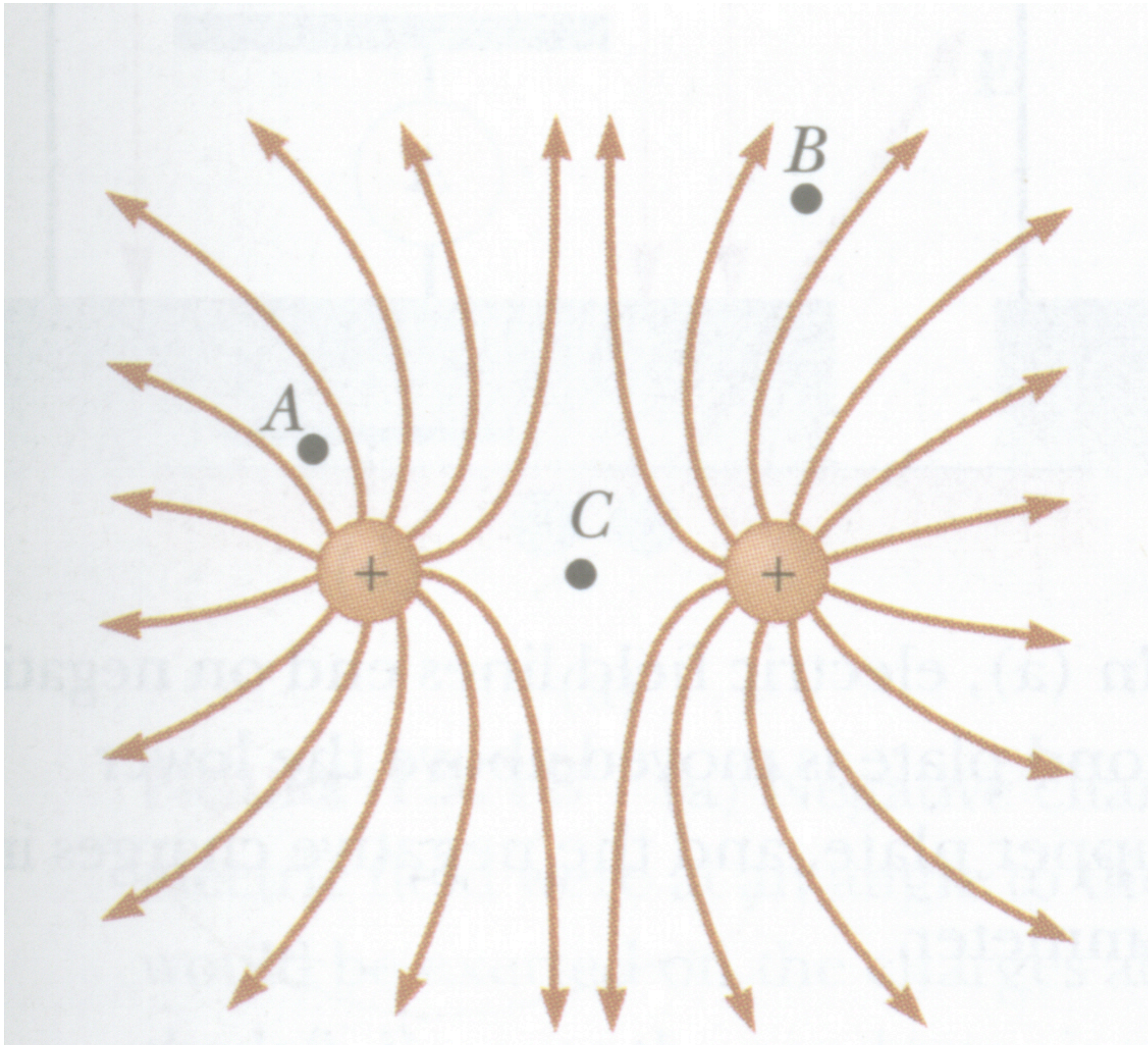
B. 0

C. -2q

Electric field lines from a dipole
+q, -q

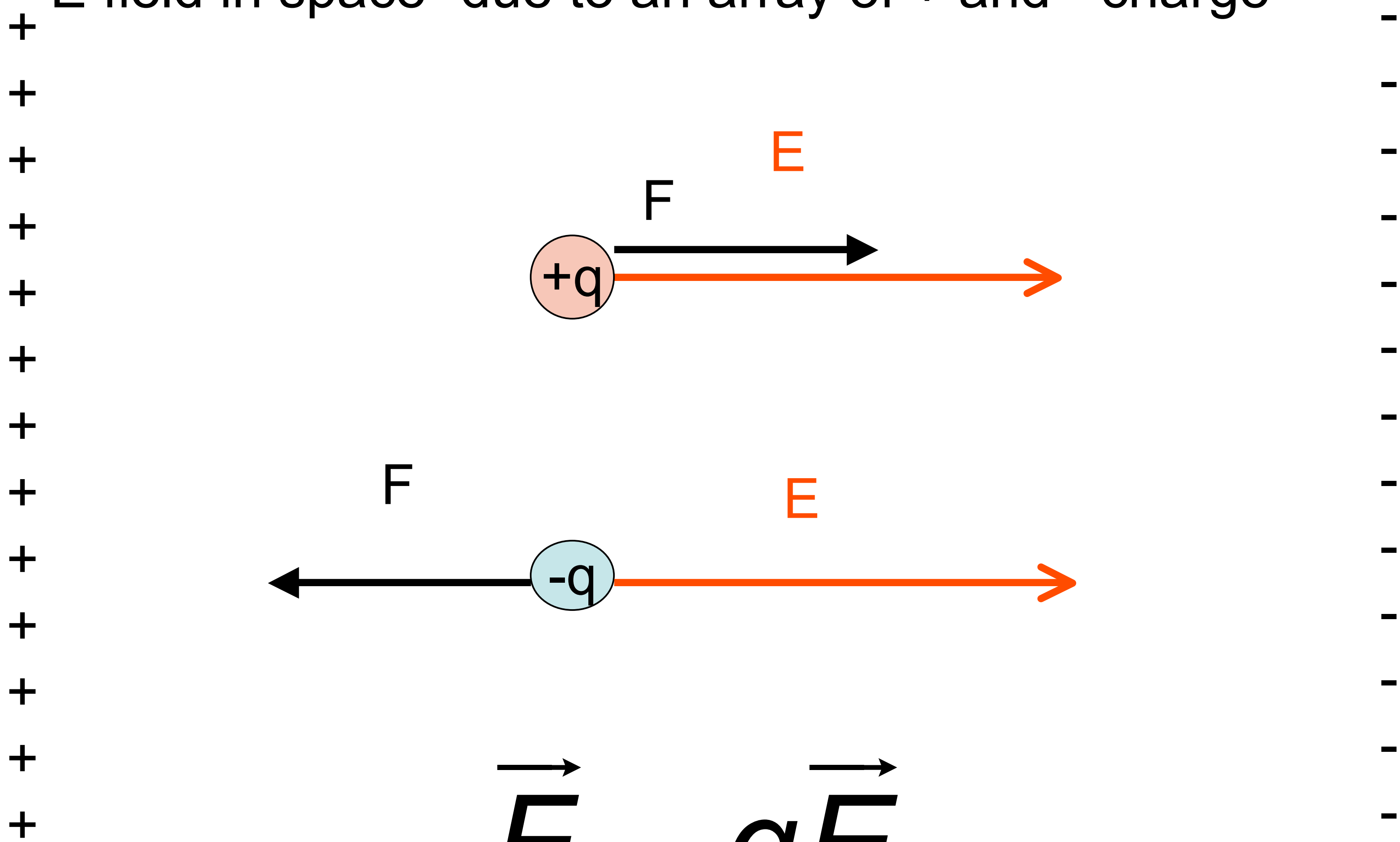


Electric field lines from 2 + q charges



The Electric Field exerts a Force on a Charge

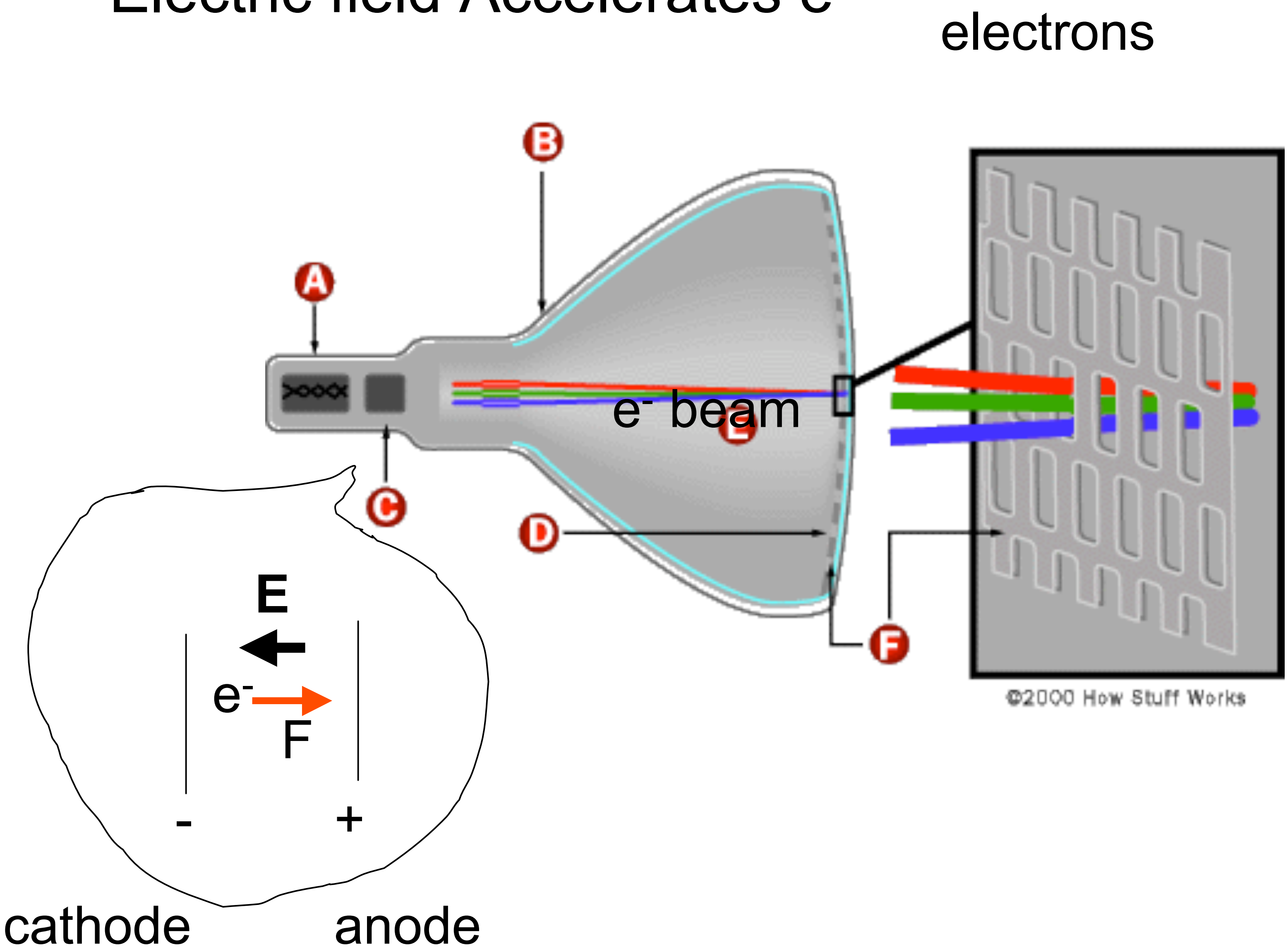
E field in space- due to an array of + and - charge



$$\vec{F} = q\vec{E}$$

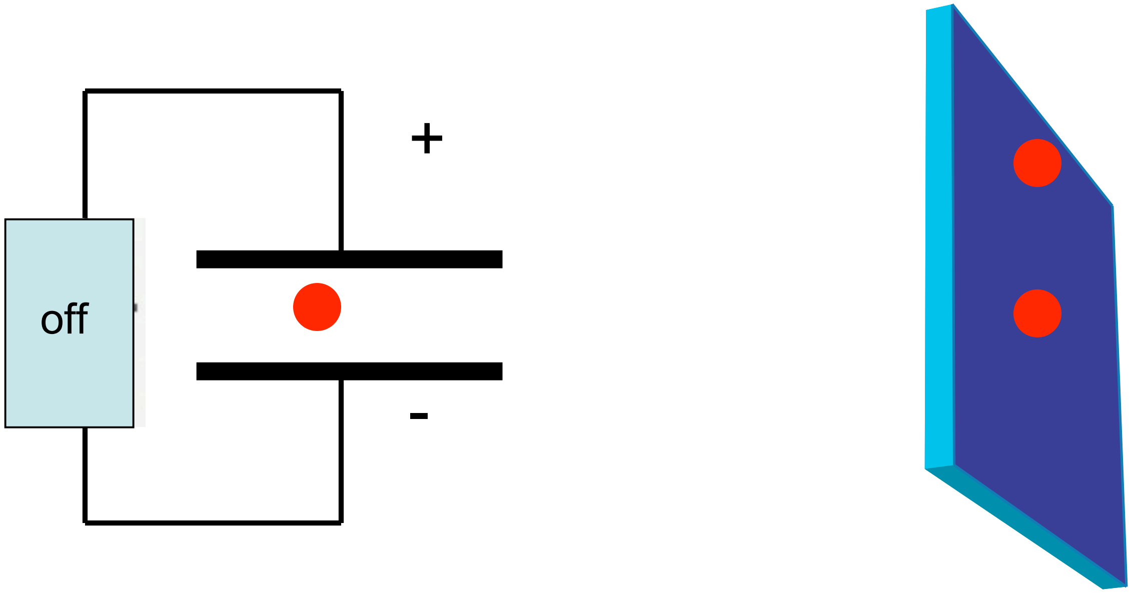
Cathode ray tube

Electric field Accelerates e-



Oscilloscope (ok, or a non Flat Panel TV)

J.J.Thomson
N.P. physics 1906

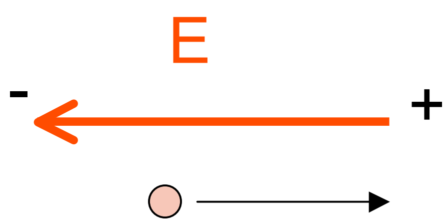


1. Shoot in an electron with battery, E field off

An electron moving horizontally at *constant velocity* flies into a *constant vertical electric field* of 1000 N/C for a distance of 3 cm. What happens to the electron in the field region?

- A. It continues to move with constant velocity
- B. It moves in quantum steps
- C. it moves with constant acceleration
- D. it stops moving

An electron is accelerated from rest in a constant electric field of 1000 N/C through a distance of 3 cm. Find the force on the electron. Find the velocity of the electron. m_e = $9x10^{-31}$ kg.



$$F = qE = 1.6x10^{-19}(1000) = 1.6x10^{-16}N$$

F=ma

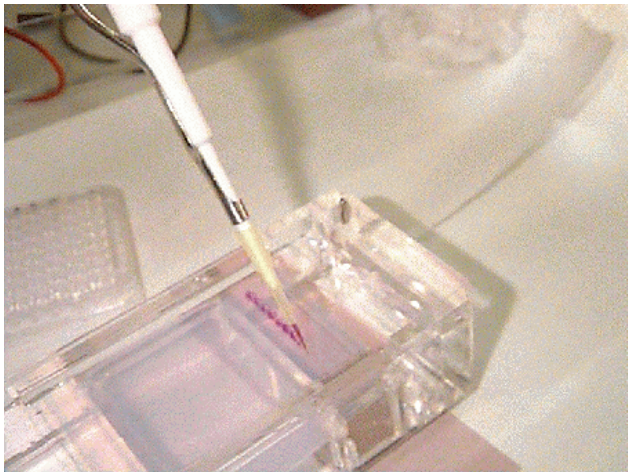
$$a = \frac{F}{m}$$

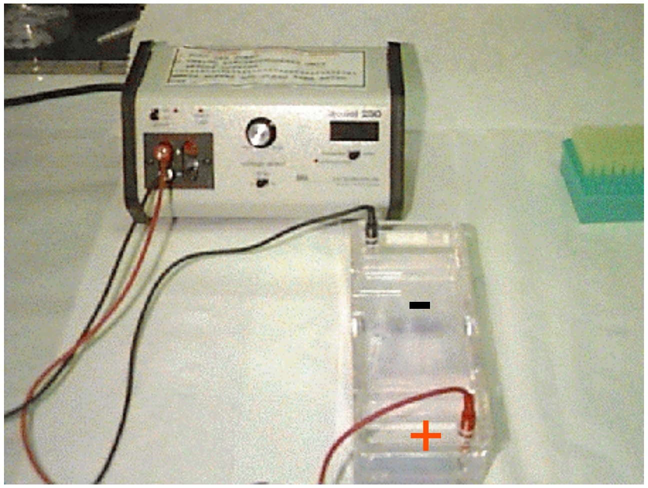
$$v^2 = v_o^2 + 2ax$$

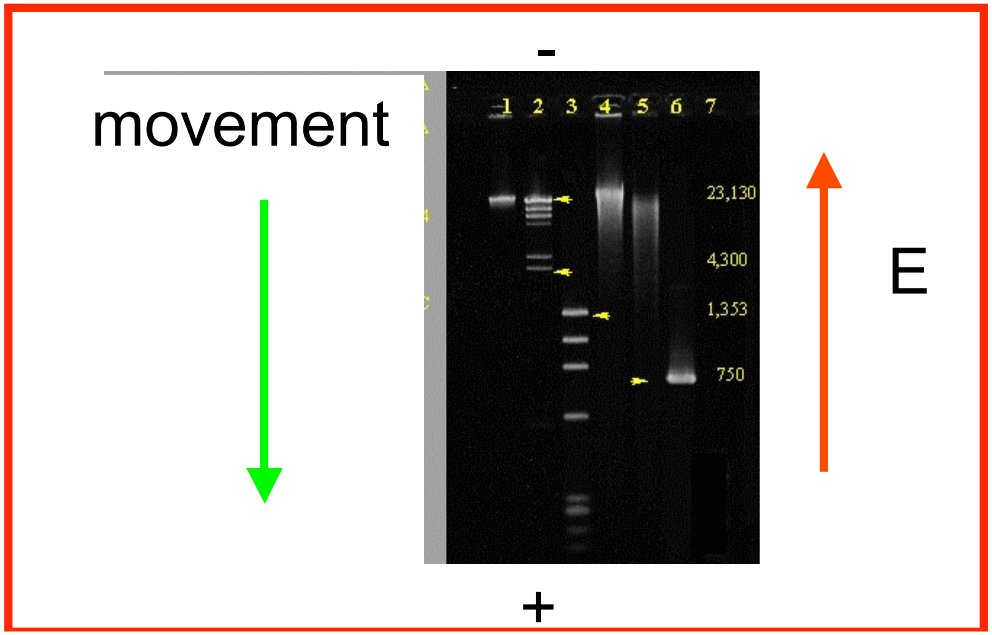
$$v = \sqrt{2ax} = \sqrt{2\frac{qE}{m}x} = \sqrt{2\frac{1.6x10^{-19}(1000)}{9x10^{-31}}(0.03)}$$

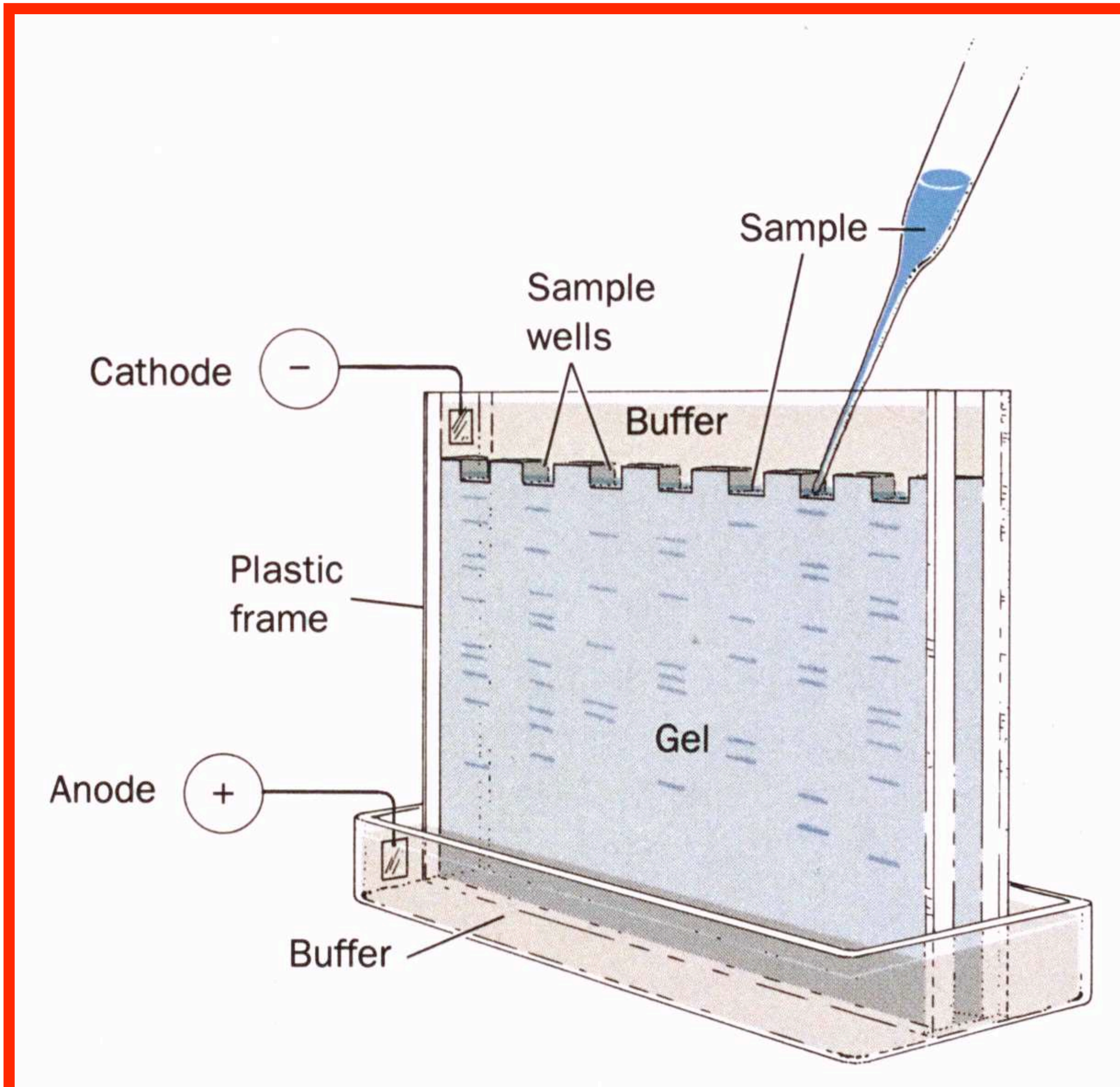
$$v = 3.3x10^6 m/s$$

Electrophoresis- Separation of DNA (Negatively charged ~ -1000 e) In an Electric field ~1000 N/C,

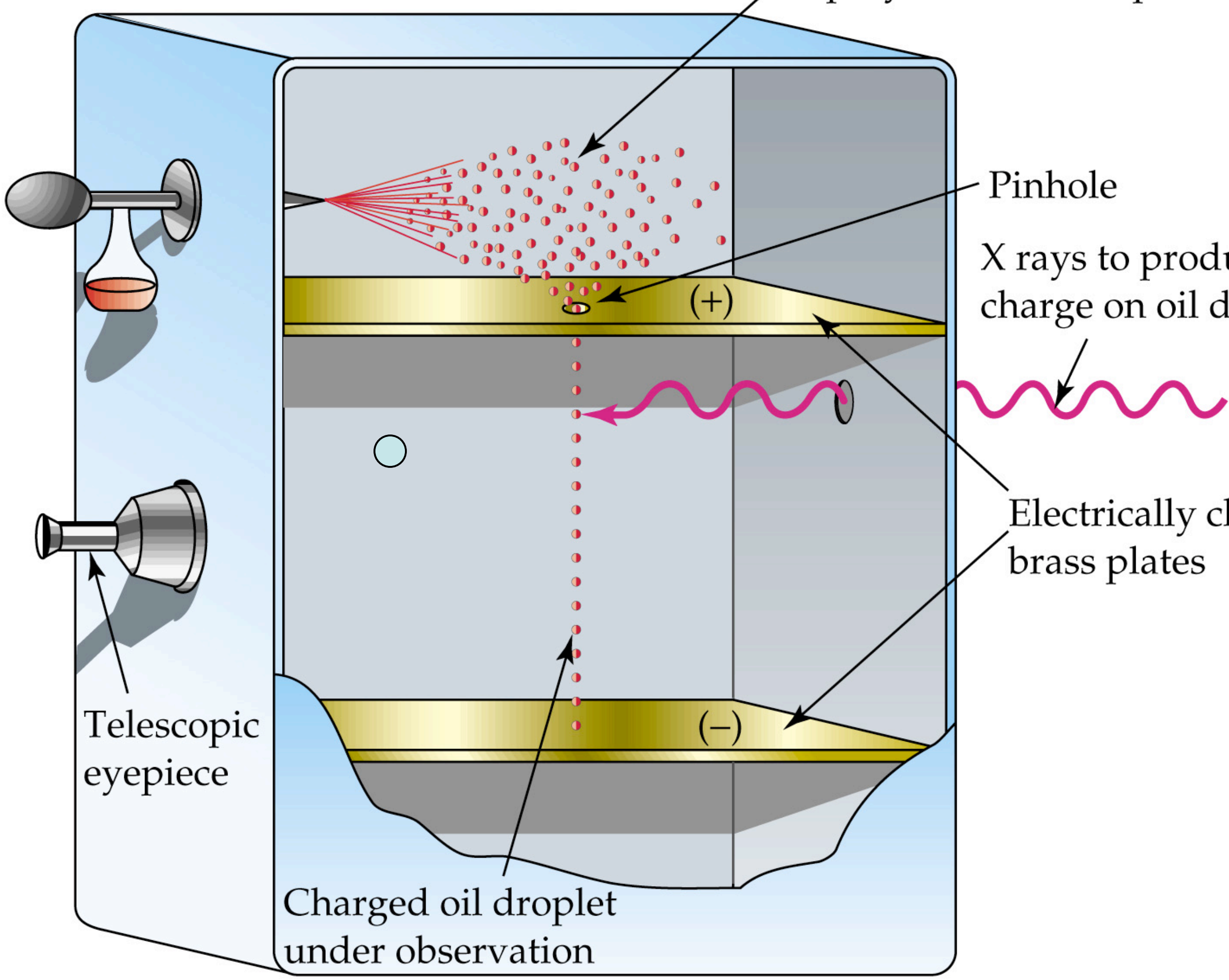







Sample
Sample
wells
Cathode
−
Buffer
Plastic
frame
Gel
Anode
+
Buffer

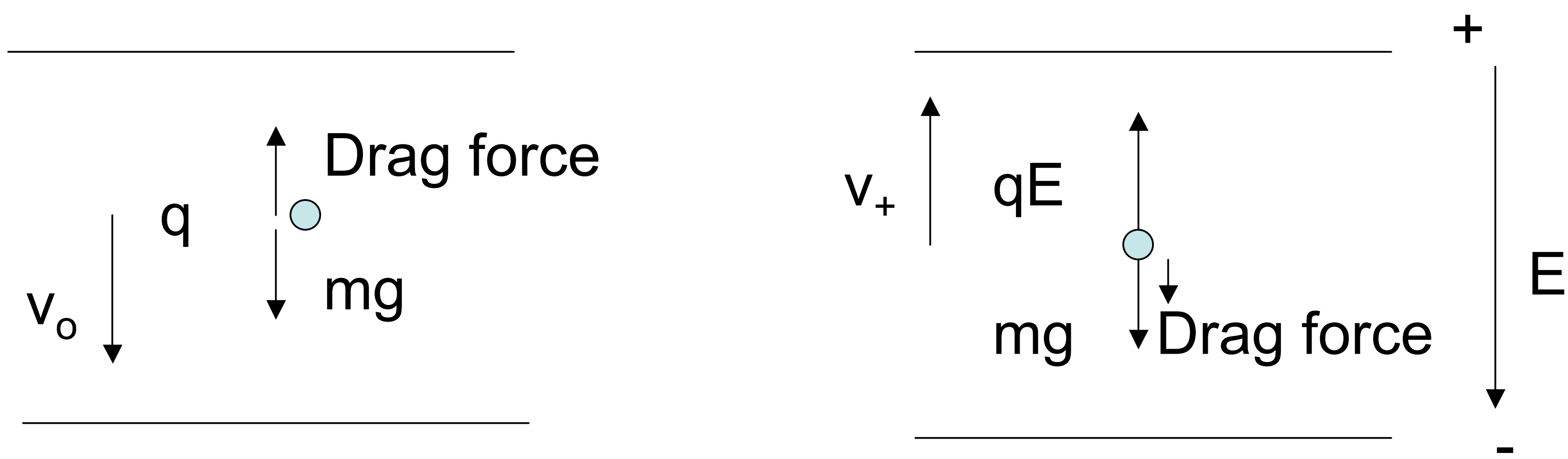
Milliken Oil drop experiment



Robert Milliken
(1868-1953)

Millikan oil-drop Experiment

A drop of oil containing negative charge is viewed through a microscope in the absence and presence of an electric field.

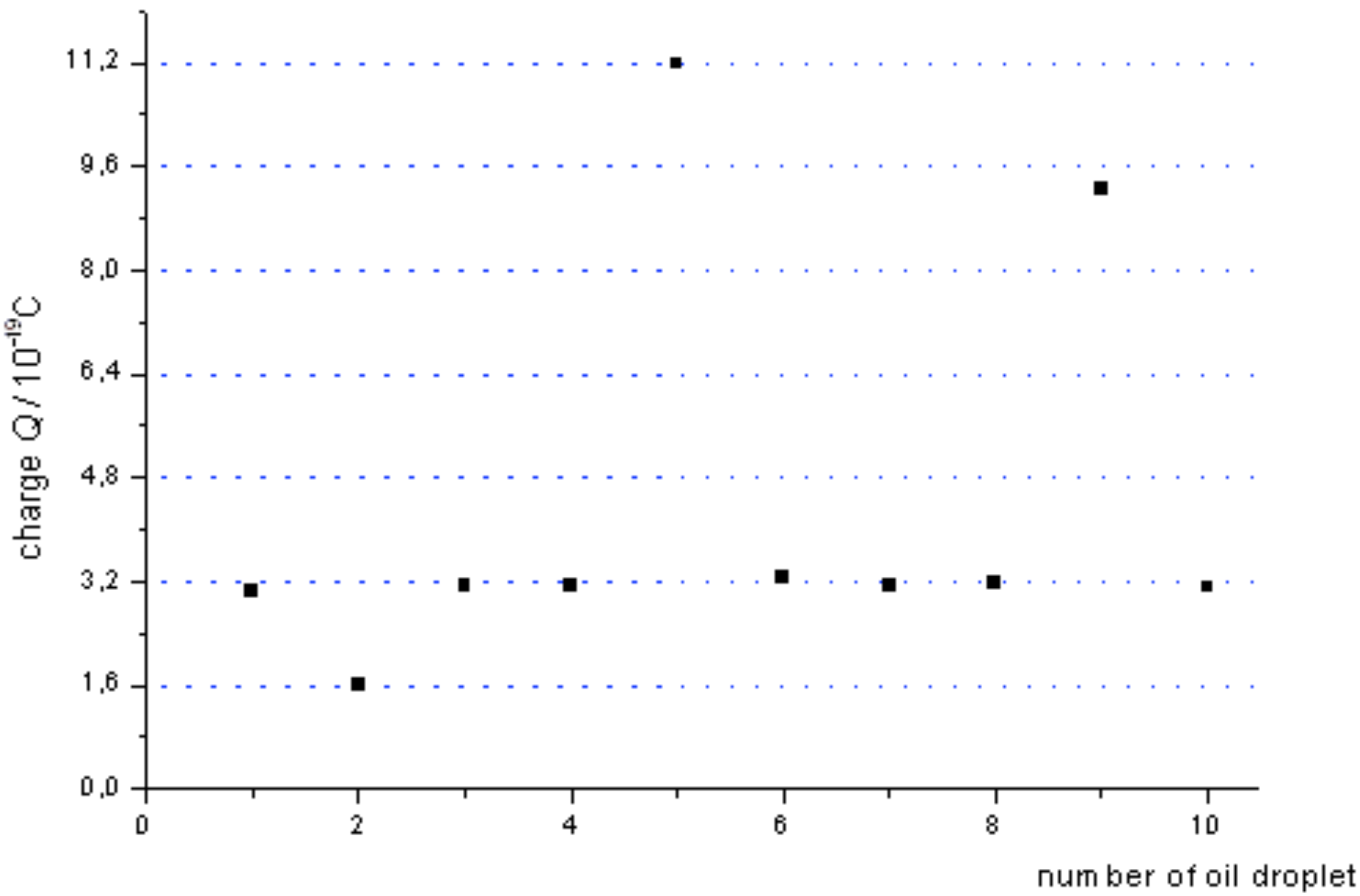


Find the value of q by measuring velocity of the drop.

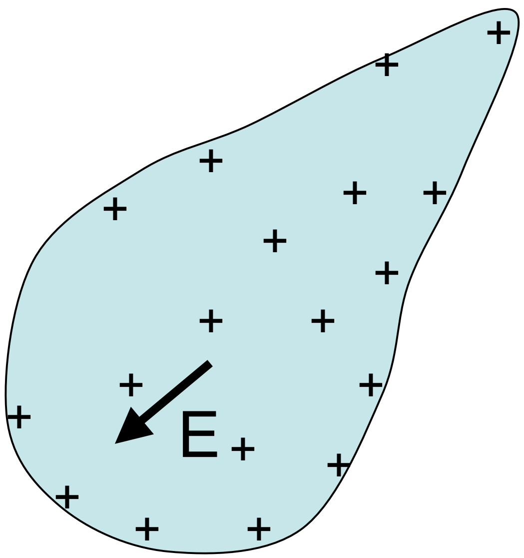
Drag force $=6\pi\eta rv$

η is the viscosity

Results of Oil Drop Measurments



15.6 Conductors in electrostatic equilibrium



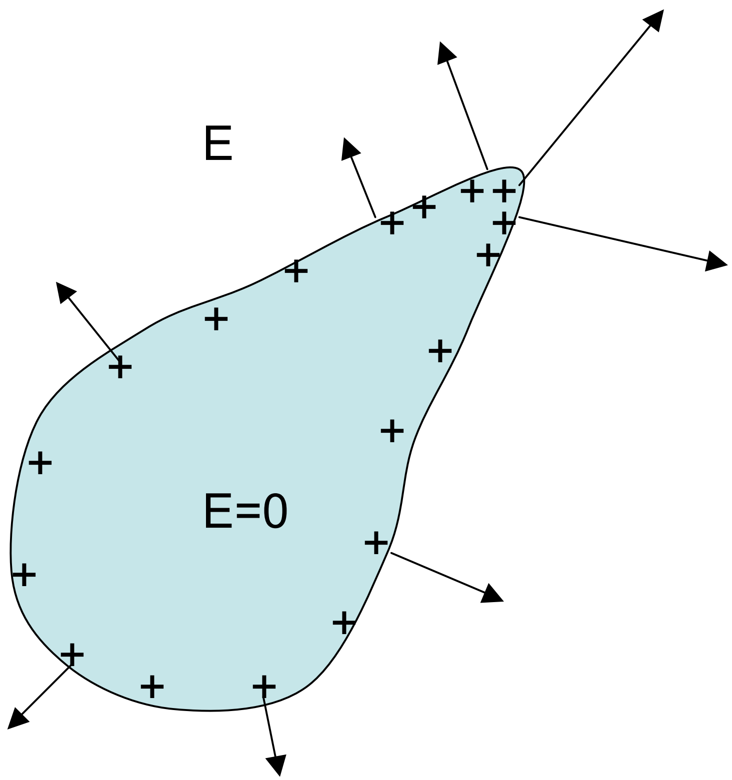
initial state
non-equilibrium

Like Charges Repel

Charges can move freely in a Conductor

At Equilibrium – the charges are not moving

15.6 Conductors in electrostatic equilibrium



At Equilibrium

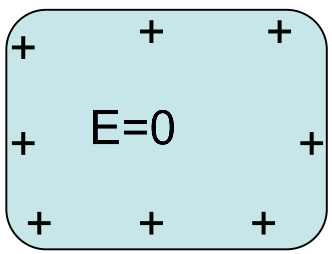
Charge is on surface (no charge inside the conductor)

Electric field is zero inside the conductor

Electric field is perpendicular to surface

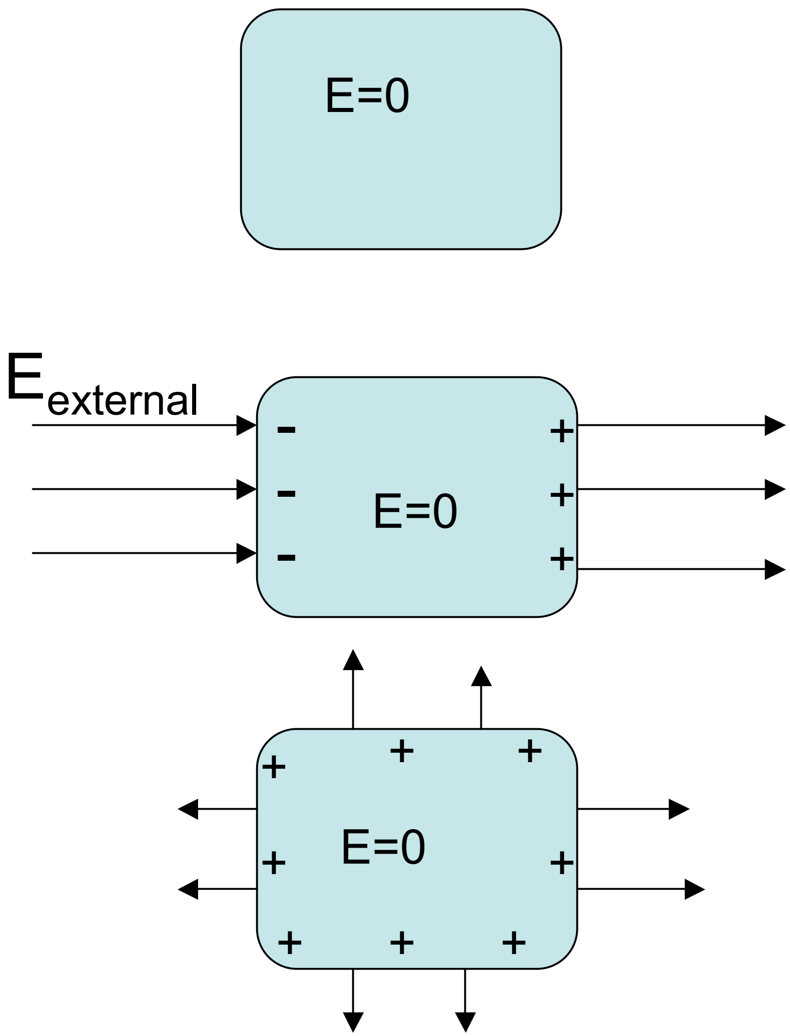
Charge accumulates at sharp points (small radius of curvature)

Excess charge is on the surface



Excess charge moves to the surface due to repulsion. They move as far apart as is possible.

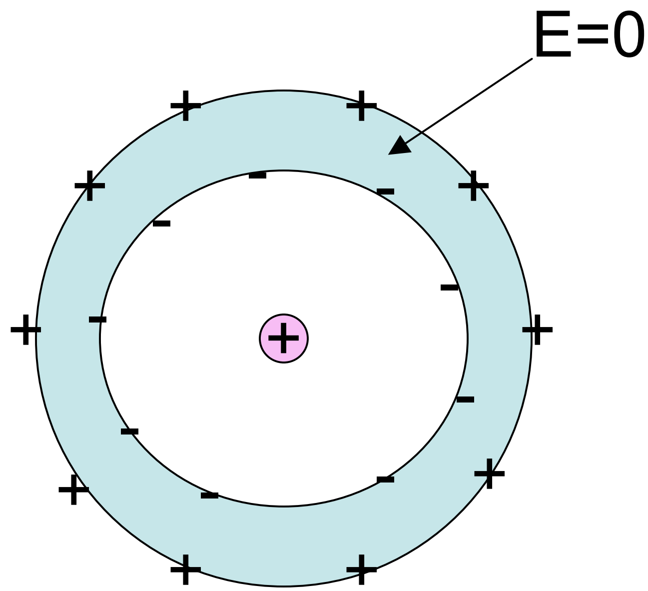
E field is zero in the conductor



If E≠0, then mobile charges would move and not be in equilibrium. When motion stops E=0.

This is true in an external E field or a net charge

Example – spherical metal shell



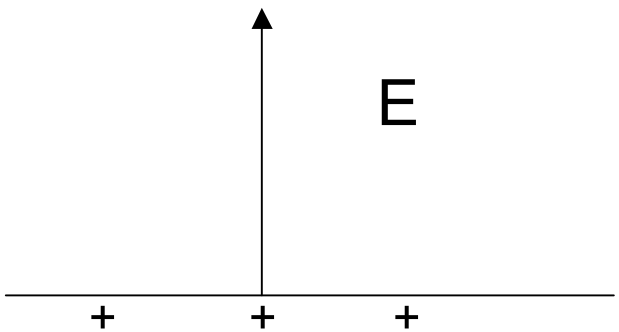
+q placed at center

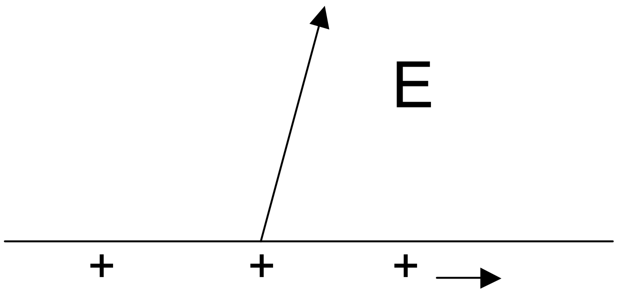
- charges accumulate inside

+ charges accumulate outside

E =0 in the metal

Electric field outside is perpendicular to the surface

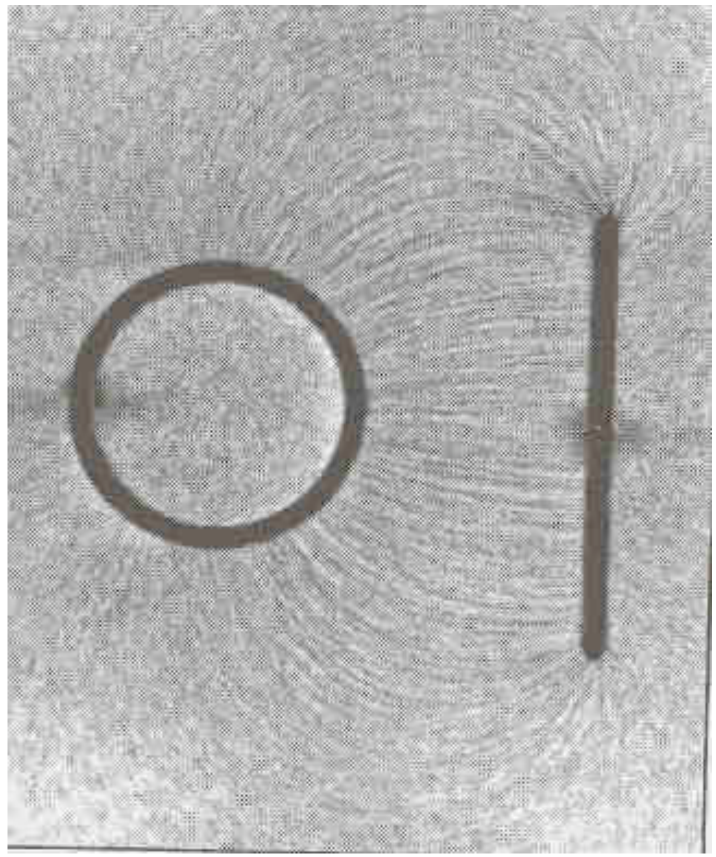




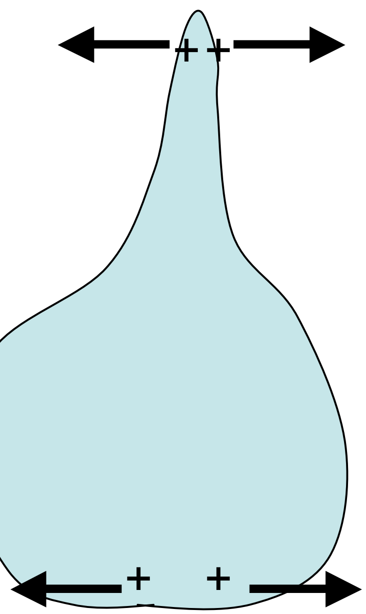
Component of E $\perp$ to the surface =0

If not, charges would move

Electric Field lines around charged conductors

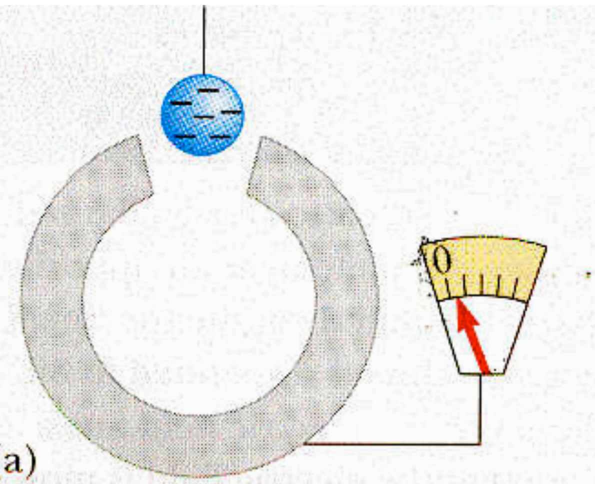


Charge accumulates at smaller radius of curvature



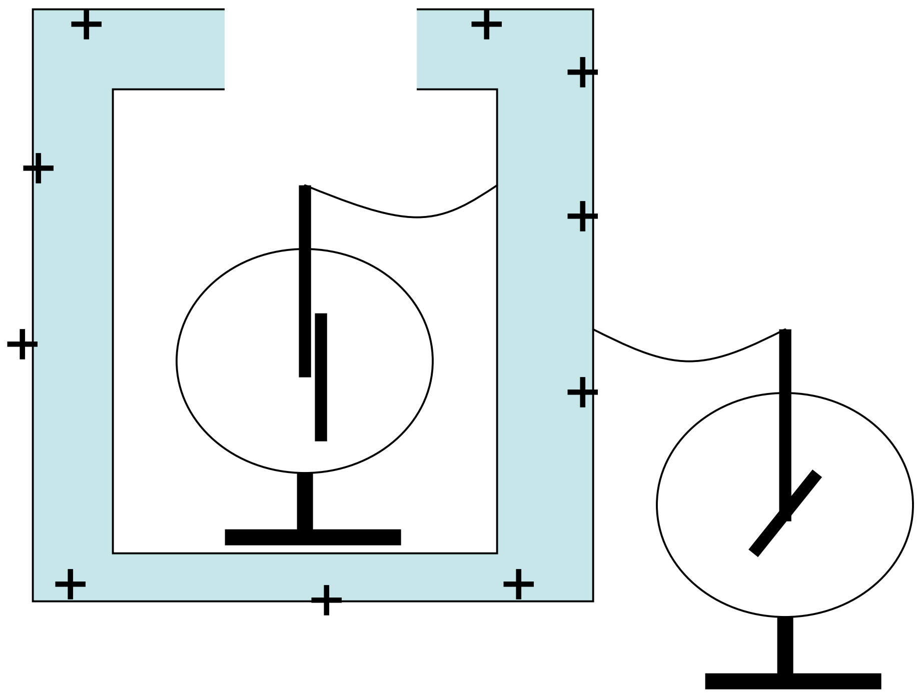
$F_{\perp}$ to surface is less.
Therefore the charges can be closer together

Charge moves to the outer surface of the conductor

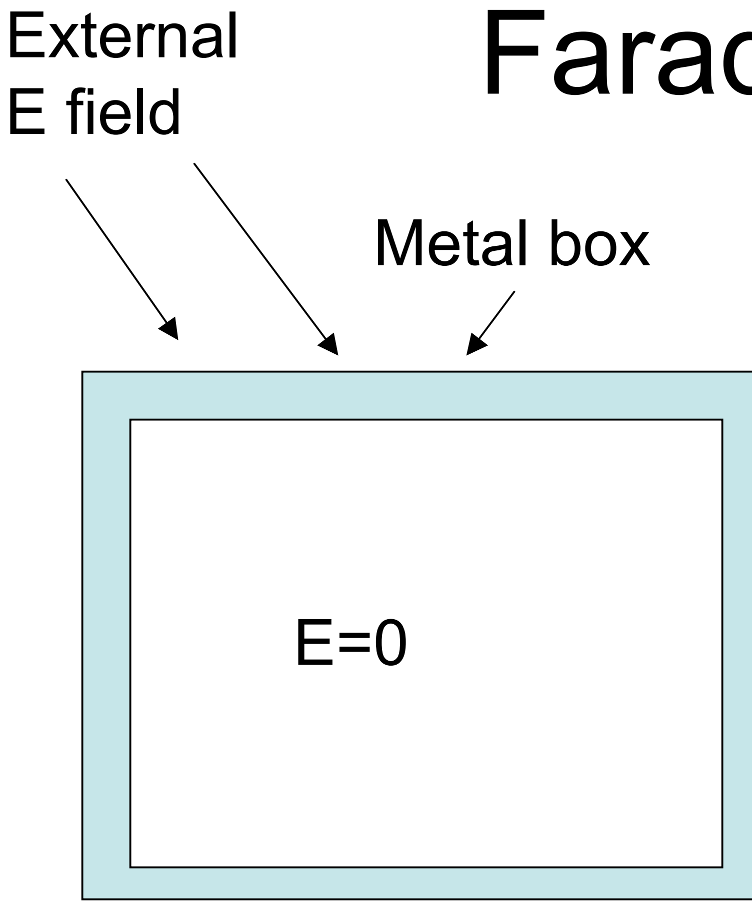


(a)

Charge is zero inside a conductor



Faraday Cage



The E field is zero inside a closed conducting surface.

Metal boxes protect electronic equipment, computers etc. from external electric fields.

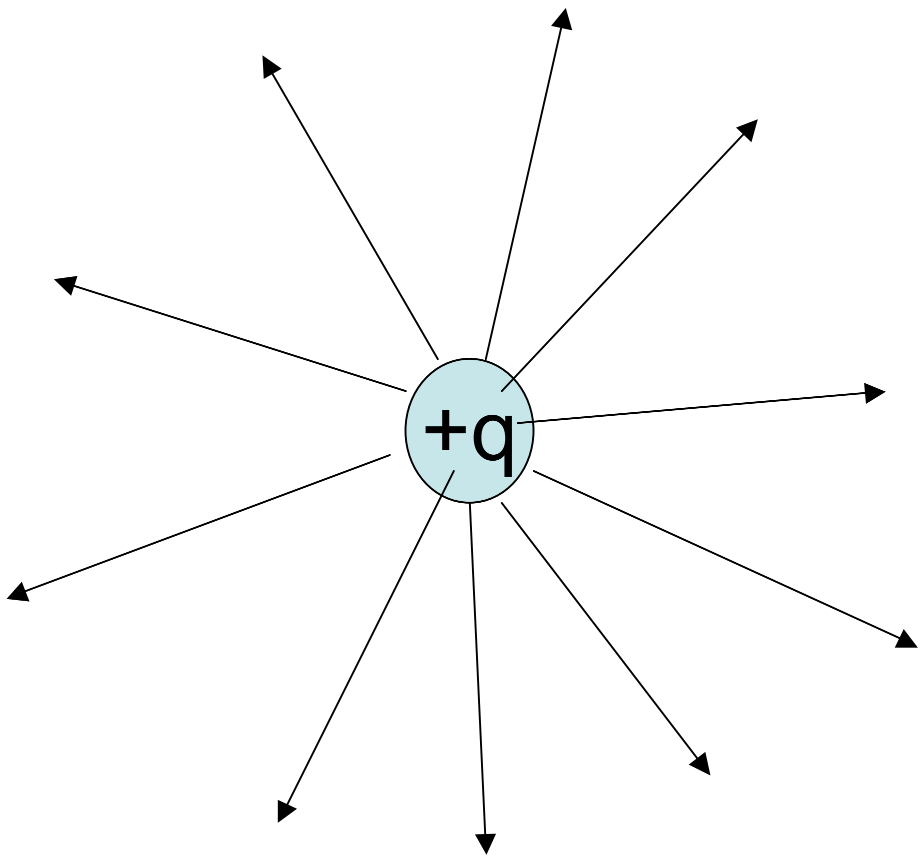
A car is a good place to be in a thunderstorm.

A metal enclosure blocks electromagnetic waves (radio, tv, cell phone)

Chapter 15.9
Electric Flux Gauss' Law

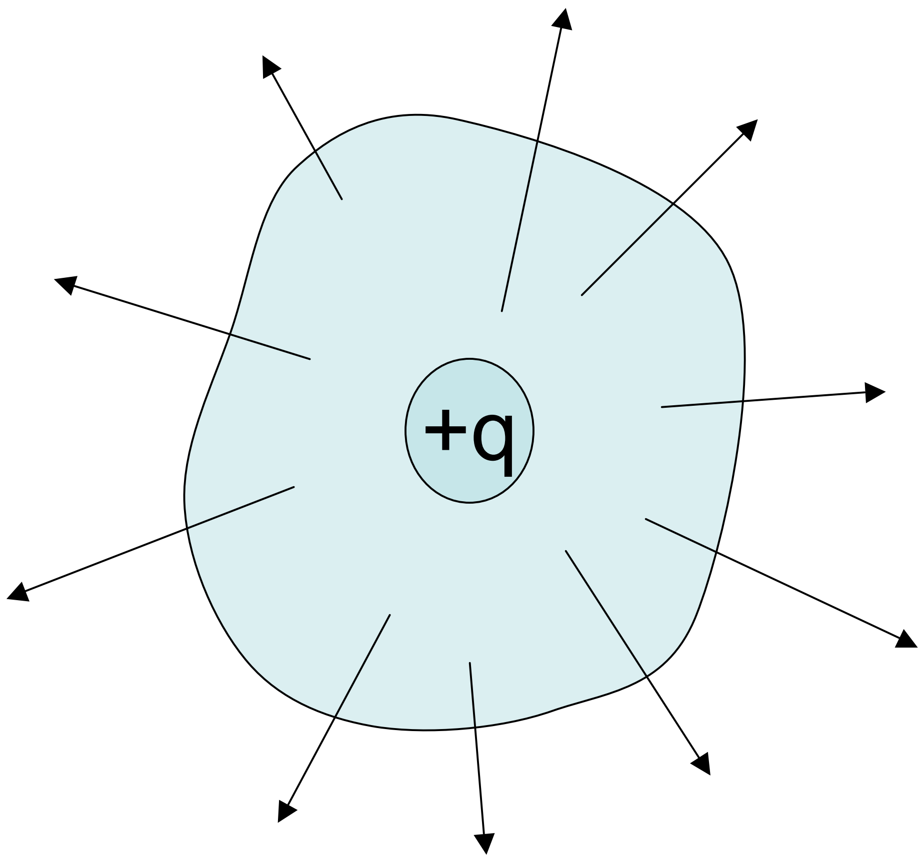
- Gauss's Law gives relation between electric fields and charges.
- Equivalent to Coulomb's Law
- Useful for determining E for simple distributions of charge.

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

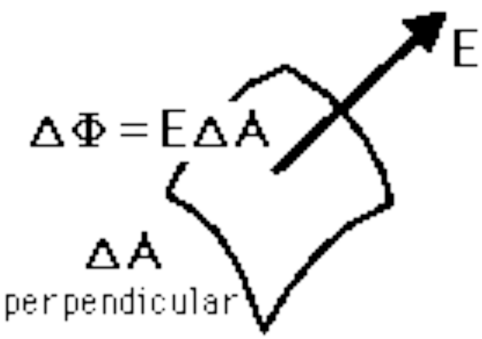


surround the charge by
a closed surface

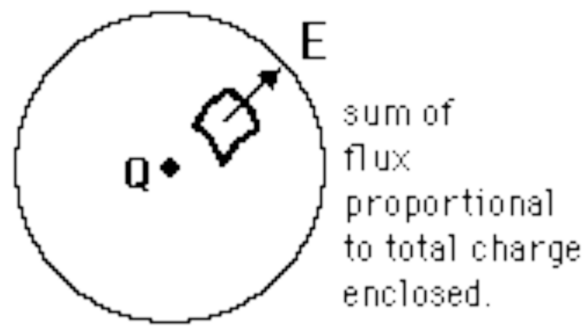
The density of E-field lines (i.e. the E field) at the surface can be related to the charge q

Gauss's Law

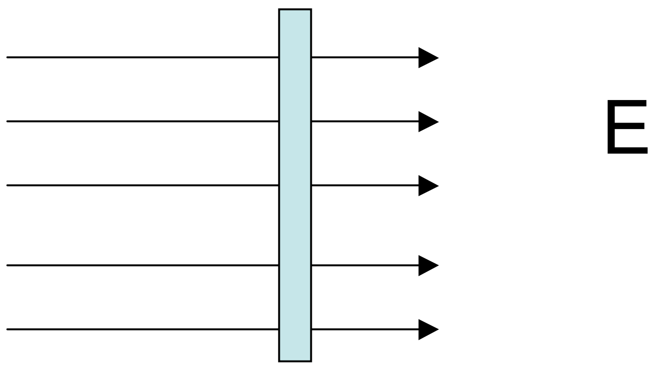
The total of the electric flux out of a closed surface
is equal to the charge enclosed divided by the permittivity.



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



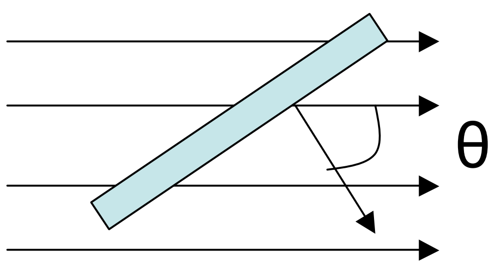
Electric Flux, Φ_E, through an area A



area A (perpendicular to electric field lines)

$$\Phi_E = EA \propto N$$

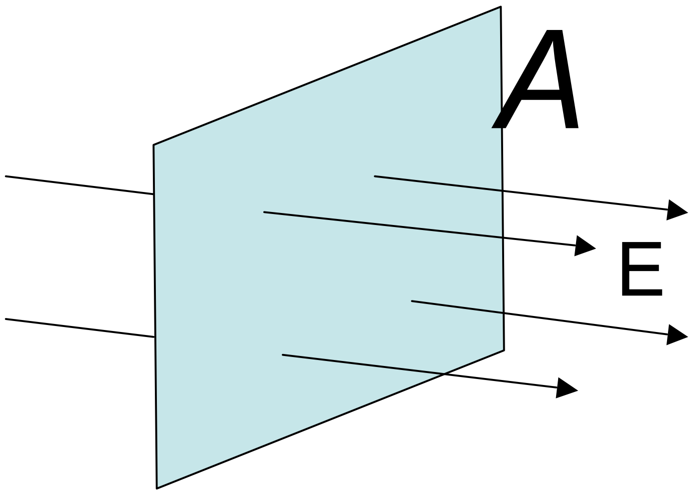
N = no. of electric field lines

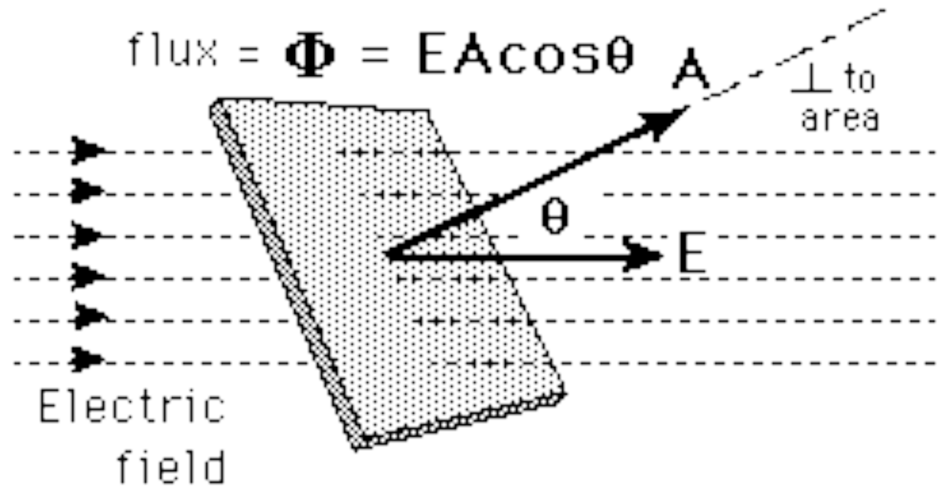


E at angle of Θ to surface normal (red).

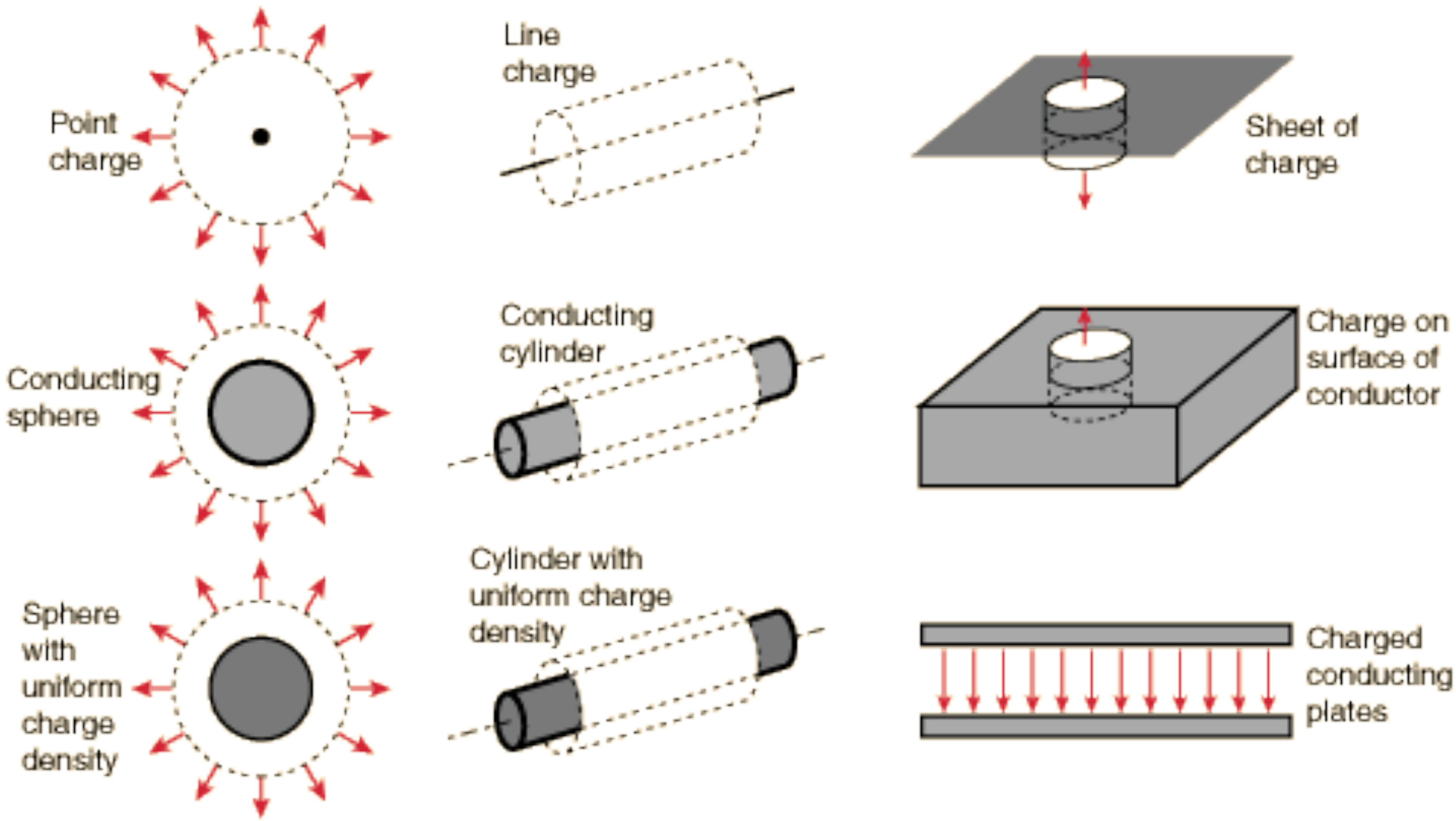
$$\Phi_E = EA\cos\theta$$

Finding E from the flux

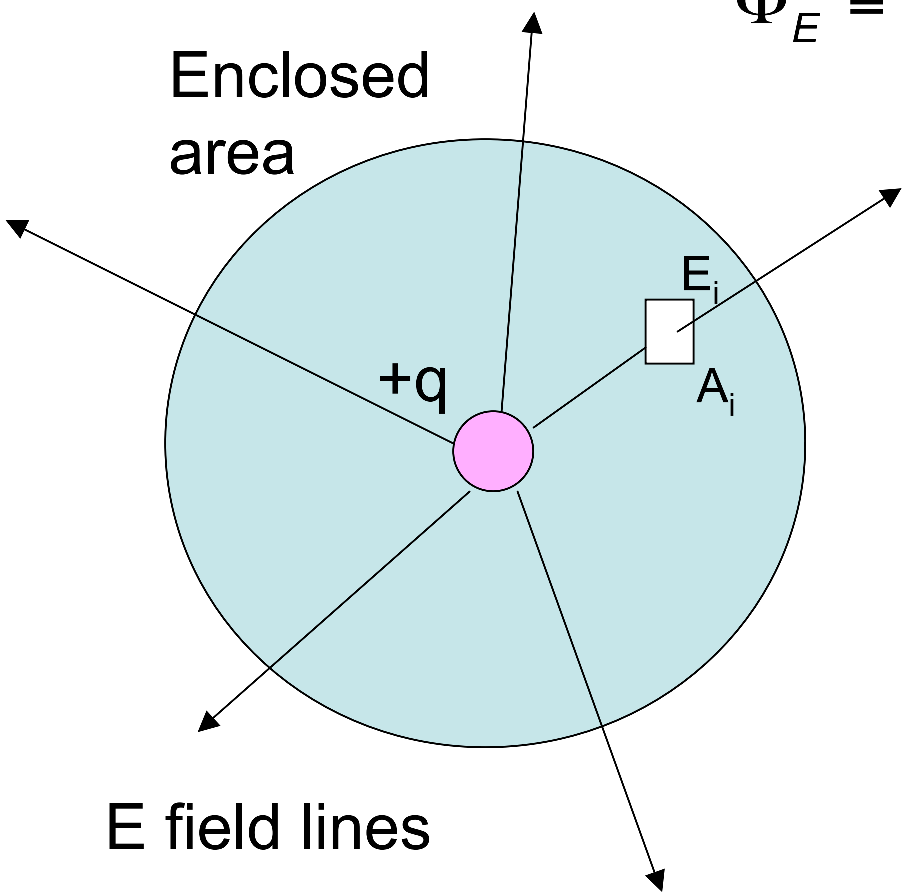




$$E = \frac{\Phi_E}{A_\perp}$$


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

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

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

Info

- HW Solutions for CH 15 on Web next week

1 page, front and back Notes Allowed.

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 half conceptual and half quantitative.

Scientific calculators ***will be allowed***, but no laptops, cellphones. Graphing calculators are allowed, but formulae cannot be programmed in nor can any notes be programmed into the calculator. Students violating this requirement will be in violation of the UCSD academic honesty policy, and will receive an 'F' in Physics 1B.

Sample Quiz Problem #1

YOUR NAME ____

YOUR IDENTIFICATION NUMBER__________________________________

INSTRUCTIONS: THERE ARE 10 QUESTIONS ON THIS QUIZ. PLEASE FILL IN THE SCANTRON FORM USING A NUMBER 2 PENCIL. PUT YOUR NAME AND THE IDENTIFICATION NUMBER YOU WERE ASSIGNED IN THE SPACES ABOVE.

Note: Any confirmed case of cheating will result in an "F" grade in Physics 1B and referral to the dean for disciplinary action.

1. Doug rubs a piece of fur on a hard rubber rod, giving the rod a negative charge. What happens?

   a. Protons are removed from the rod.
   b. Electrons are added to the rod.
   c. The fur is also charged negatively.
   d. The fur is left neutral.

Sample Quiz Problem #2

In x-ray machines, electrons are subjected to electric fields as great as 6.0×10^5 N/C. Find an electron's acceleration in this field. ($m_e = 9.11 \times 10^{-31}$ kg, $e = 1.6 \times 10^{-19}$ C)

a. 1.1×10^{17} m/s^2
b. 5.4×10^{13} m/s^2
c. 4.6×10^{10} m/s^2
d. 3.6×10^{8} m/s^2