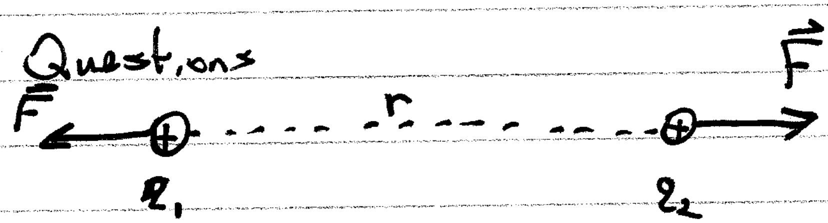
Phys 1402 2014-09-04 Lecture 3

- Charges
- Electric Field
- Electric Potential

HW Questions



@ q_2, E is caused by q_1

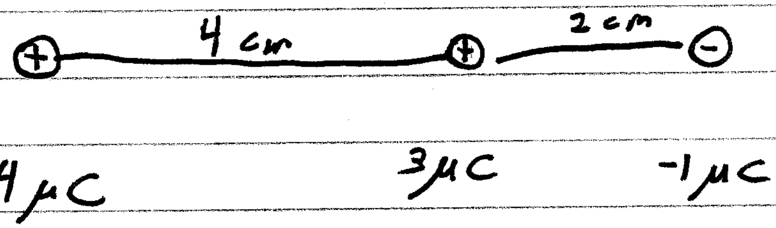
$$E = \frac{kq_1}{r^2}$$

The Force depends on E and q_2

$$F = q_2 E = \frac{kq_1 q_2}{r^2}$$

↑ Coulomb's Law

(2)



What is the Force on the $3\,\mu C$ charge?

Force of $4\,\mu C$ charge: toward right

$$F = \frac{k q_1 q_2}{r^2} = \frac{k(3\times10^{-6}\,C)(4\times10^{-6}\,C)}{(0.04\ m)^2} = 67.5\,N$$

Force of $-1\,\mu C$ charge: also toward right

$$F = \frac{k q_1 q_3}{r^2} = \frac{k(3\times10^{-6}\,C)(1\times10^{-6}\ C)}{(0.02\ m)^2}$$

$$= 67.5\ N$$

Total Force: 135 N to the right acting on $3\,\mu C$ charge

More about Electric Potential
aka Voltage
aka Potential Difference
aka Electromotive Force (EMF)
} All V

Like the height on a landscape.

- Steep slope makes things want to move.
- Dropped things must release energy
- Lifting things requires an energy supply.
- Two points have the same height difference no matter how you get from A to B.

E-Field related to V

$$E_{ave} = \frac{\Delta V}{\Delta x} \qquad \Delta V = E_{ave} \Delta X$$

V related to energy

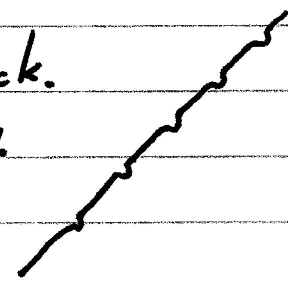
$$V = \frac{\text{Energy}}{\text{Charge}} \qquad \text{Energy} = q V$$

Example: Proton Accelerator
(See attached pages after Page 5)

Conductors vs. Insulators

Conductors allow charges to move freely.
Think of a smooth surface.
When tilted, stuff will slide or roll.
The tilt is like an E-Field.

Insulators hold charges in place.
Think of a dimpled surface.
When tilted, stuff is still stuck.
Unless you tilt it very steeply.
Then the stuff moves anyway.



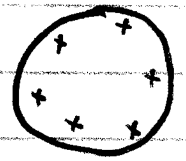
Breakdown or Dielectric Strength
Air can withstand $10^6\ V/m = 10^6\ N/C$
Glass $\sim 10^7\ V/m$

What if I had a 1.0 C charge.

$$E = \frac{kq}{r^2} \qquad (10^6\ N/C) = \frac{k(1.0\ C)}{r^2}$$

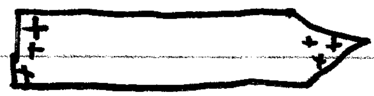
$$r = \sqrt{\frac{kq}{E}} = \sqrt{\frac{k(1.0\ C)}{(10^6\ N/C)}} = 95\ m$$

Charged Metal Objects

Sphere:  Charge spreads evenly.

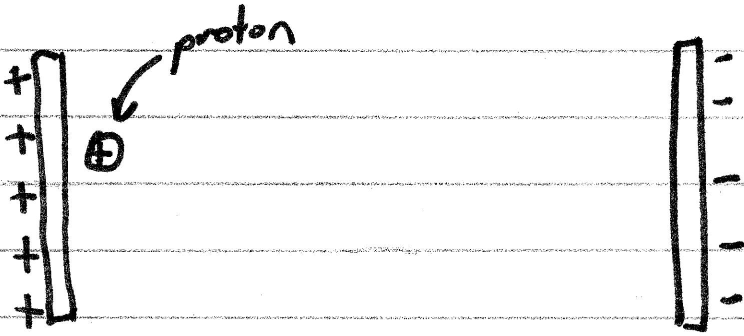
Rod:  Charge goes to ends

Pencil

 Charge finds points

Charge gathers @ corners.
This makes strong $\vec{E}$-Field.
Makes air break down more easily.
This is why lightning rods are pointed.

② Proton Accelerator



In between the plates,

$$\vec{E} = 8.0 \times 10^{4}\ N/C = 8.0 \times 10^{4}\ V/m$$

(to the right)

The proton moves

$$\Delta x = 0.50\ m$$

It starts at rest. How fast is it going at the end?

Method 1: Acceleration

$$F = qE = (1.6 \times 10^{-19}\ C)(8 \times 10^{4}\ N/C)$$
$$= 1.28 \times 10^{-14}\ N$$

$$F = ma$$

$$a = F/m = (\sim)/(1.67 \times 10^{-27}\ kg)$$
$$= 7.66 \times 10^{12}\ m/s^2$$

$$v^2 = v_0^2 + 2a\Delta x$$
$$= 2(\sim)(0.5\ m)$$
$$v = 2.77 \times 10^{6}\ m/s$$

③ Method 2: Voltage

$$\Delta V = -E\Delta x$$
$$= -(8\times10^4\ V/m)(0.5\ m)$$
$$= -40000\ V$$

(It's negative because the p^+ is pushed downhill.)

Energy gain is

$$\text{Energy} = q|\Delta V|$$
$$= (1.6\times10^{-19}\ C)(\sim)$$
$$= 6.4\times10^{-15}\ J$$

(Note: $1\ kWh = 3.6\times10^6\ J = \$0.12$)

Final velocity comes from

$$KE = K = \tfrac{1}{2}mv^2$$
$$v = \sqrt{2K/m} \quad \leftarrow 6.4\times10^{-15}\ J$$
$$= \sqrt{2(\sim)/(1.67\times10^{-27}\ kg)}$$
$$= 2.77\times10^6\ m/s$$

In a conductor, any $\vec{E}$ field gets immediately balanced by moving charges.
In electrostatics, $E=0$ in a conductor.
In a circuit, the elec field causes a continuous flow of charges.