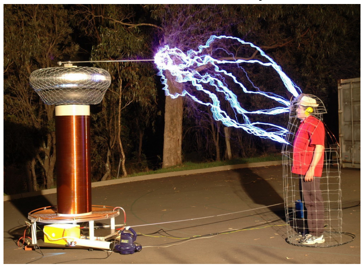
Static electricity



Try this for a home experiment this week – yes I'm kidding
Why does this person survive?
http://drmegavolt.com

Lecture 20 :
Static electricity

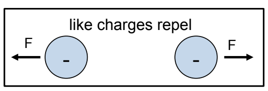
Reminders:
HW 8 due Monday 31st at midnight
Reading for Tuesday: 10.3

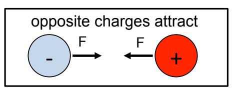
Reading quiz

1. Coulomb's law describes
   a. The force between electrical point charges
   b. How dry your socks get in the dryer
   c. The friction force between items of clothing
   d. The operation of a conveyor belt

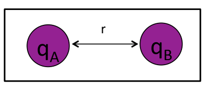
2. Electric charges
   a. Can never move ….

Electrostatic force between charged particles





Consider 2 'point' charges, A and B. What force does charge A feel?



Observed behavior:
- Force depends on q_A and q_B : More charge, more force
- Force depends on distance between them (r) : More distance, less force

Coulomb's Law:
$\text{Force}_{\text{of B on A (or A on B)}} = \frac{kq_Aq_B}{r^2}$

- Describes the force between 2 point charges
- k is Coulomb constant = 8.99×10^9 N m^2/C^2
- q_A and q_B are amount of charge in coulombs (C)
- r is separation in m

1 Coulomb = 6×10^{18} electron charges!

Rub a second balloon on the sweater.
The two balloons will ..

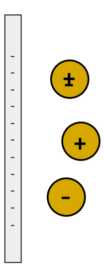
a. attract, b. repel, c. not exert a force on each other

b. repel:
- Balloons made of same material so must pick up same sign of charge from sweater
- Like charges repel

Move charged balloon close to wall. What will happen?

a. Wall is neutral (no extra + or -) so will not be affected.
b. - charges in wall will move away, + towards balloon
c. + charges in wall will move away, - towards balloon.
d. - charges in wall will move away, + don't move.

Electrostatic dust rag (think Swiffer™).
Rub it on surface, it's very good at attracting electrons and so becomes negatively charged.



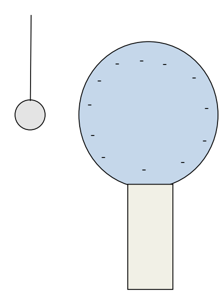
What kind of dust will this negatively charged rag pick up best?

a. Only dust with positive charges.
b. Only dust with negative charges.
c. The rag will pick up all dust equally.
d. The rag will pick up dust with positive charges, and also neutral dust particles, just not as well.
e. The rag will pick up dust with negative charges, and also neutral dust particles, just not as well.

Bring uncharged metalized mylar balloon up to Van de Graaff.

Predict what will happen:

1. Before it touches
2. After it touches



1. Before touching
   a. Not affected by VdG
   b. Attracted to it
   c. Repelled

2. After touching
   a. Not affected by VdG
   b. Attracted to it
   c. Repelled

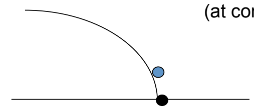
Discussion of Energy

- 3 Types of energy (there are others):
  - **Kinetic** - energy of motion - rock rolling down hill
  - **Potential** - ability to do work in future - rock at the top of a hill
  - **Thermal** - energy that dissipates as heat (e.g. friction, or smashing into a wall)
- How would this apply to charges?

⊕ ⊖

- Think of the analogy of a hill… pulling + away from valley…

Hill Analogy for energy



Effort (push) to get ball up the hill (at constant speed):

a) harder at first

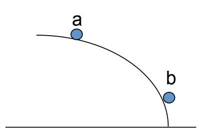
b) easier at first

c) takes same effort / push

Is it easier or harder to separate opposite charges when they get further away from each other?

$F = k q_1 q_2/r^2$

Hill Analogy for energy



Potential Energy of same ball

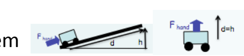
a) PEa > PEb

b) PEb > PEa

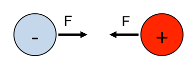
c) PEa = PEb

Mechanical work vs. Electrical

Think, climbing up a hill
stores energy in system

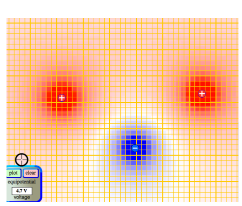


Same thing, separating charges…



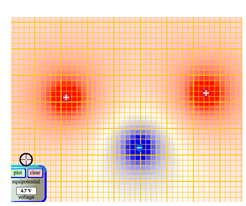
Voltage has to do with conditions of system

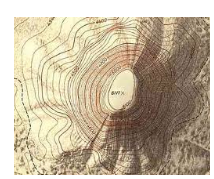
- Amount of charge
- Distance from that charge
- Like the electric force (related but different)



Voltage is like the height of mountain

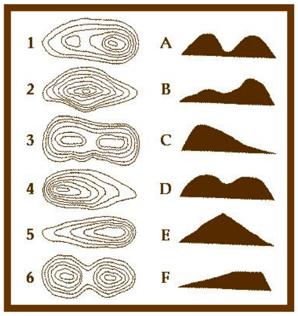
- Think Topographical maps





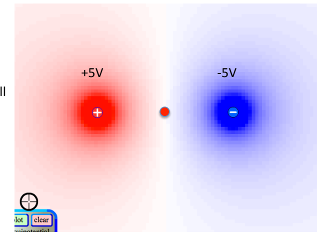
Topo- practice

- Which figure goes with #4



Voltage tells you what a + charge will do

+V is like top of hill
-V Is like valley



Where is 0 V?

What will a +q do at 0V:
a) Be attracted to higher voltage
b) Be attracted to lower voltage
c) Not be impacted

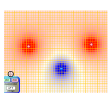
Voltage is like the height of mountain

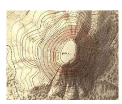
- Voltage
- Charge, q
- Electrical Potential Energy

- Height (and gravity)
- Mass, m
- Gravitational potential Energy

EPE = q Δ V

GPE = m g Δh





Electrostatic potential energy and voltage

New force: Electrostatic force between charges
New PE: Electric Potential Energy (EPE)

Forces and PE go in pairs - Remember gravitational force:
- Do work against gravitational force (mg) to raise an object's GPE (mgh)
- Similarly, do work against electric force to raise an object's EPE

EPE = q ΔV, where q = charge of object and ΔV is voltage difference
Like GPE with q ↔ m and ΔV ↔ Δh

Voltage (V)
- tells you EPE of any charge at that location in space
- Tells you work required to bring a unit charge from V = 0 to that location
- Determined by surrounding charges.
  Closer you are to + charge the more + the voltage
- A grounded object is always at V = 0
- Usually most interested in ΔV: voltage difference between 2 locations

Best understood by doing practice questions!

Conservation of energy and EPE

Remember conservation of energy equation:

Work Done on object = Change in Energy of object

$W_{ext} - |W_{friction}| = \Delta PE + \Delta KE$

Now we can add another PE term to this equation:

$W_{ext} - |W_{friction}| = \Delta GPE + \Delta EPE + \Delta KE$
$= mg\Delta h + q\Delta V + \Delta(1/2mv^2)$

Two metal plates connected by a battery.
Battery maintains a voltage difference of V between the plates

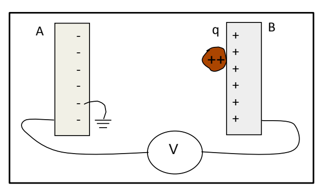
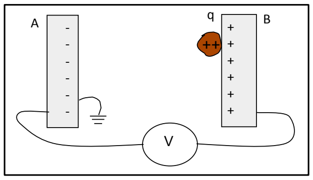


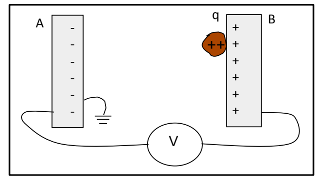
Plate A is grounded (set to zero V)
What is the voltage of plate B?

a) 0
b) +V
c) -V
d) Can't determine from information given



What will happen to the charge q if we let go of it (ignore gravity)?

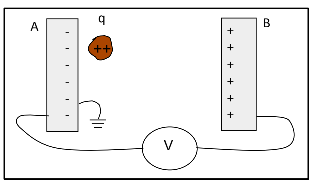
a) Nothing
b) It will fly over to plate A
c) Sparks will fly
d) Something else



EPE = $q\Delta V$

What is the change in EPE of charge as it flies from plate B to plate A?

a) 0
b) +qV
c) -qV
d) Can't determine



Conservation of energy:
$W_{ext} - |W_{friction}| = \Delta GPE + \Delta EPE + \Delta KE$

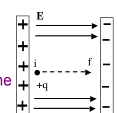
Charged particle loses EPE as it flies from B to A.
What form has this energy turned into just before it hits plate A

a) KE
b) Thermal energy
c) GPE
d) PPE

A *positive* charge q is released from position i to position f between the charged plates.

Did the electric potential energy (PE) increase or decrease?

Did the voltage (V) at the position of the test charge increase or decrease?

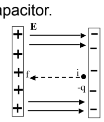


A: PE↑, V↑ B: PE↑, V↓
C: PE↓ V↑ D: PE↓, V↓
E: None of these.

A negative charge -q is released from position i to position f between the charged plates of a charged capacitor.

Did the potential energy (PE) increase or decrease?

Did the voltage (V) at the position of the test charge increase or decrease?



A: PE↑, V↑ B: PE↑, V↓
C: PE↓, V↑ D: PE↓, V↓
E: None of these.

Hint:
EPE = $q\Delta V$

Electrostatics Summary

- Positive and negative charge: Like charges repel, opposites attract
- Coulombs law for point charges: $F = k \frac{q_A q_B}{r^2}$
  Force acts along line joining particles
- Voltage: Determines EPE of charge at that location in space
  Close to + charges voltage is more + and vice versa
  Grounded object is at 0V
  (Also called Electric Potential)
- EPE: = $q\Delta V$
  New form of potential energy
  Lots of analogies to GPE ($\Delta V \leftrightarrow \Delta h$, $q \leftrightarrow m$)