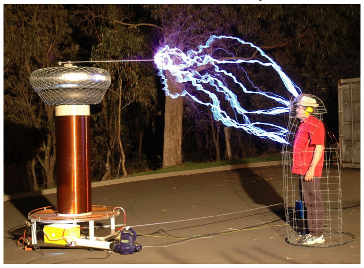
Static electricity



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

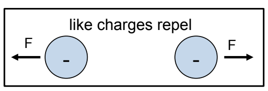
Reading quiz

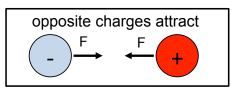
1. Coulomb's law describes
   a. The force between electrical point charges
   b. How dry your socks get in the dryer
   c. The friction force between items of clothing
   d. The operation of a conveyor belt

2. Electric charges
   a. Can never move from one object to another
   b. Can never move inside an object
   c. Can move inside an object but not from one object to another
   d. Can move both inside an object and between objects, depending on what the objects are.

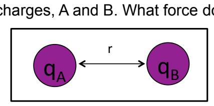
3. An object that is electrically neutral
   a. Contains more positively charged particles (protons) than negatively charged ones (electrons)
   b. Contains more electrons than protons
   c. Contains no charged particles
   d. Contains equal numbers of protons and electrons.
   e. Is unable to conduct electricity

Electrostatic force between charged particles





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



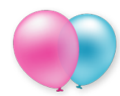
Observed behavior:
- Force depends on q_A and q_B : More charge, more force
- Force depends on distance between them (r) : More distance, less force

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

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

e = 1.6 × 10^{-19} is charge of electron or proton
Coulombs Coulomb (C) is the unit of charge

Balloon demo: Rub a balloon on sweater and stick it to the wall. What attracts the balloon to the wall?



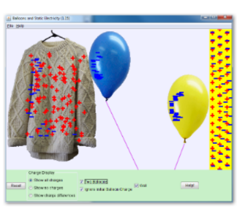
After I have rubbed the balloon on my sweater, predict what charges will be on the balloon and on sweater

a. Both have extra + charges.
b. Both have extra - charges
c. Balloon has extra + or - charges, sweater neutral,
d. Sweater has extra + or - charges, balloon neutral
e. Either sweater has extra - and balloon extra + or balloon extra – and sweater extra +.

Look at Phet and find out……..

Answer is e:
Remember atoms are initially neutral
Electrons in sweater atoms are bound to atom less strongly than in balloon atoms
Rubbing allows balloon atoms to steal electrons, making balloon negatively charged (excess of electrons) and sweater positively charged

Balloon Sim



http://phet.colorado.edu/en/simulation/balloons

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.

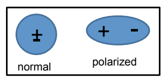
Rub a second balloon on the sweater.
The two balloons will ..

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?
d. - charges in wall will move away, + don't move.

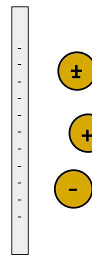
- Negative charge on balloon repels –charge and attracted to + charge in the wall
- Atoms in wall become stretched (or polarized)
- Remember force between charges = $\frac{kq_Aq_B}{r^2}$
- Balloon is closer to + charges in wall than – charges, so force of attraction is stronger than force of repulsion



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.



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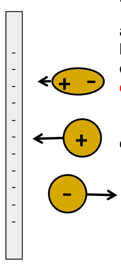


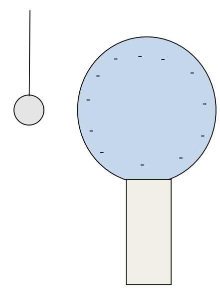
Bring uncharged metalized mylar balloon up to Van de Graaff.

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



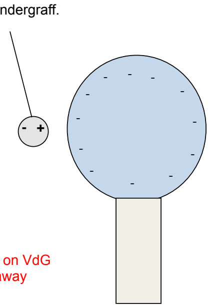
Bring uncharged metalized mylar balloon up to Vandergraff.

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

- Charges in neutral ball are polarized by – charge on VdG
- \+ charges move closer to VdG, - charges move away
- Force between charges = $\frac{kq_Aq_B}{r^2}$
- \+ charges on ball are closer to VdG, so force of attraction is strongest



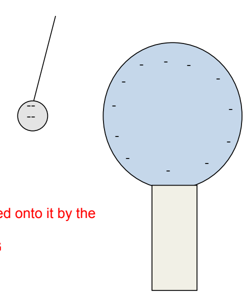
Bring uncharged metalized mylar balloon up to Vandergraff.

Predict what will happen:

1. Before it touches
2. After it touches

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

- When balloon touches, - charges are pushed onto it by the other – charges on the VdG
- Now balloon is negatively charged like VdG
- Like charges repel

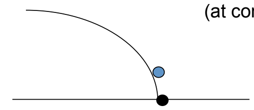


Discussion of Energy

- 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

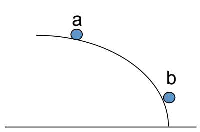
b) easier at first

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

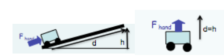
a) PEa > PEb

b) PEb > PEa

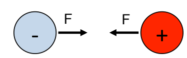
c) PEa = PEb

Mechanical work vs. Electrical

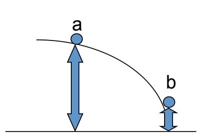
Think, climbing up a hill
stores energy in system



Same thing, separating charges…



Hill Analogy for energy



Energy of ball (Potential Energy, PE)

a) PEa > PEb

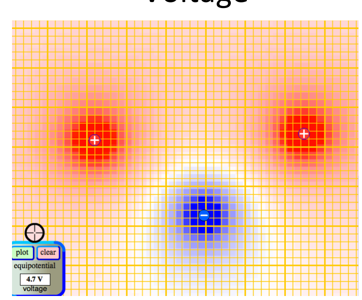
b) PEb < PEa

c) PEa = PEb

Gravitational PE = mgh

Remember Work?
W = F x distance

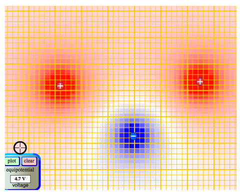
Voltage



http://phet.colorado.edu/sims/charges-and-fields/charges-and-fields_en.html

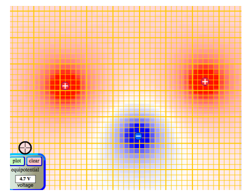
Voltage has to do with conditions of system

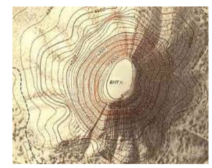
- Amount of charge
- Distance from that charge
- Like the electric force (related but different)



Voltage is like the height of mountain

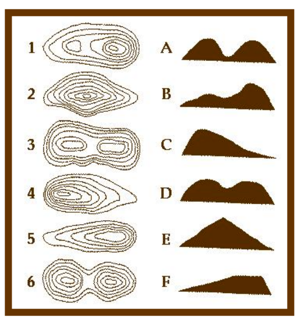
- Think Topographical maps





Topo- practice

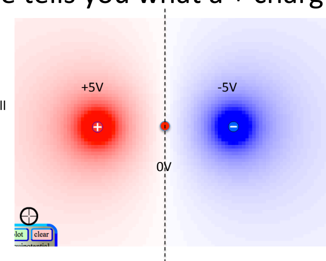
- Which figure goes with #4
- Answer C



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

b) Just like a ball rolls down hill

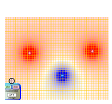
Voltage is like the height of mountain

- Voltage
- Charge, q
- Electrical Potential Energy

EPE = q Δ V

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

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

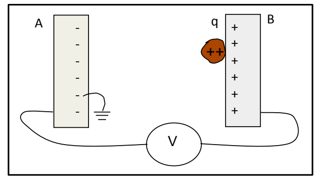


Plate A is grounded (set to zero V)
What is the voltage of plate B?

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

Two metal plates connected by a battery.
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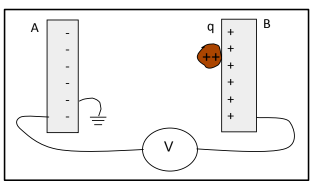

Plate A is grounded (set to zero V)
What is the voltage of plate B?

a) 0
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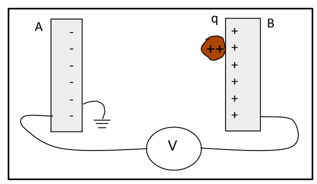
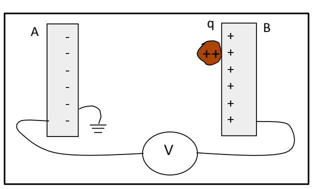
d) Can't determine from information given

Note: Conductors (bits of metal, wires etc) are a constant voltage all over



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

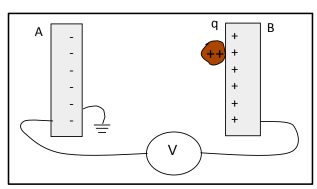
a) Nothing
b) It will fly over to plate A
c) Sparks will fly
d) Something else



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

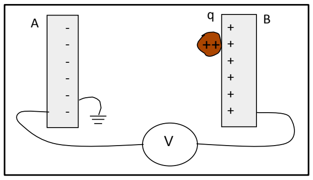
q has a + charge. It will be repelled by + charges on plates B and attracted to - charges on plate A



$EPE = q\Delta V$

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

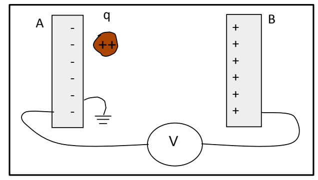
a) 0
b) +qV
c) -qV
d) Can't determine



$EPE = q\Delta V$

What is the change in EPE as charge flies from plate B to plate A?
c) -qV

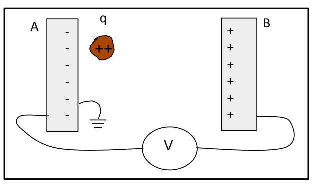
At B: EPE = q V
At A: EPE = q × 0 = 0
Change in EPE = $EPE_f - EPE_i = 0 - qV = -qV$
Plug in numbers:
$q = +2e = 2\times1.6\times10^{-19}C = 3.2\times10^{-19}C$
V = 100 V
$\Delta EPE = -3.2\times10^{-17}J$



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



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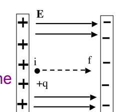
What form has this energy turned into just before it hits plate A

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

Just before it hits plate: $qV = 1/2mv^2$
Just after it hits plate, all this energy has turned into thermal energy

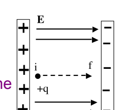
A *positive* charge q is released from position i to position f between the charged plates.



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



Did the electric potential energy (PE) increase or decrease?
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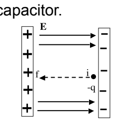
A: PE↑, V↑ B: PE↑, V↓
C: PE↓ V↑ D: PE↓, V↓
E: None of these.

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:
$EPE = q\Delta V$