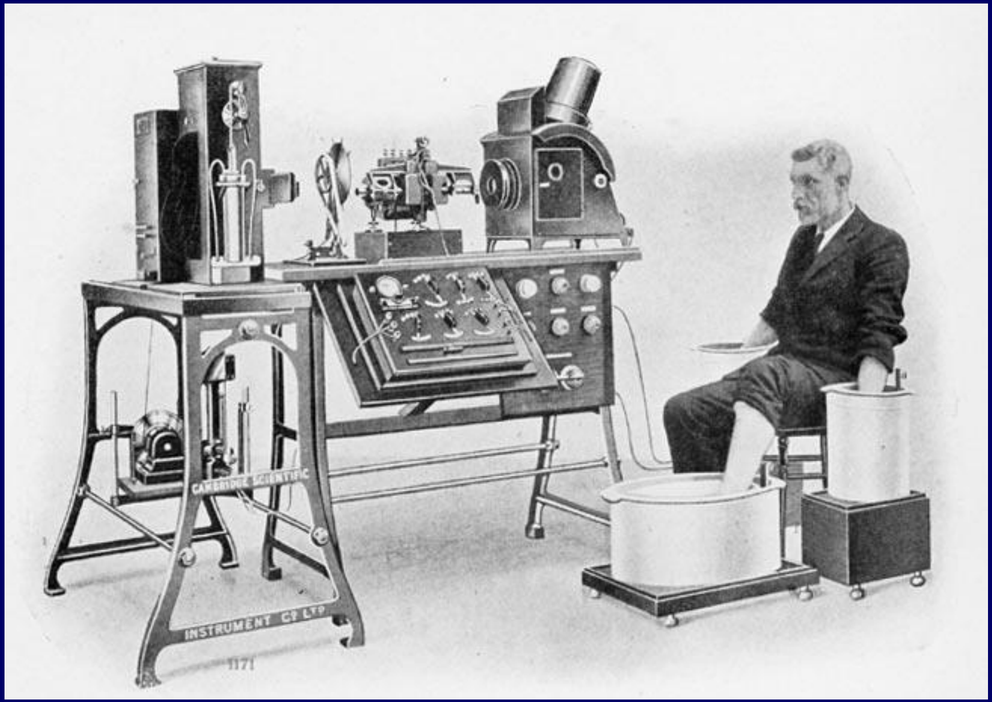
Physics 102: Lecture 3

Electric Potential Energy & Electric Potential



Overview for Today's Lecture

- Electric Potential Energy & Work
  - Uniform fields
  - Point charges

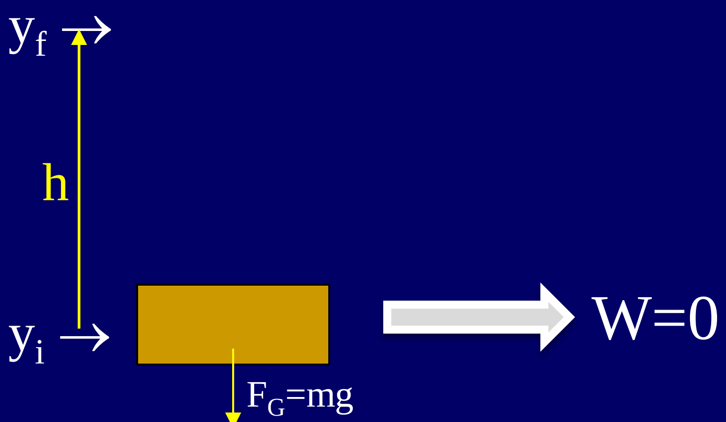
- Electric Potential (like height)
  - Uniform fields
  - Point charges

Work

$$W = F\, d \cos(\theta)$$

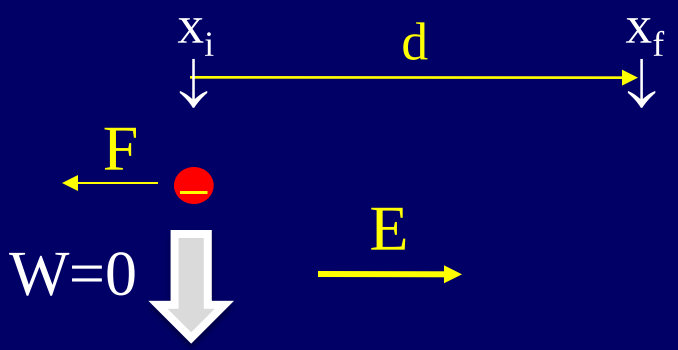
Gravity

- Brick raised $y_i \rightarrow y_f$
  - $F_G = mg$ **(down)**
  - $W_G = -mgh$
  - $W_{you} = mgh$

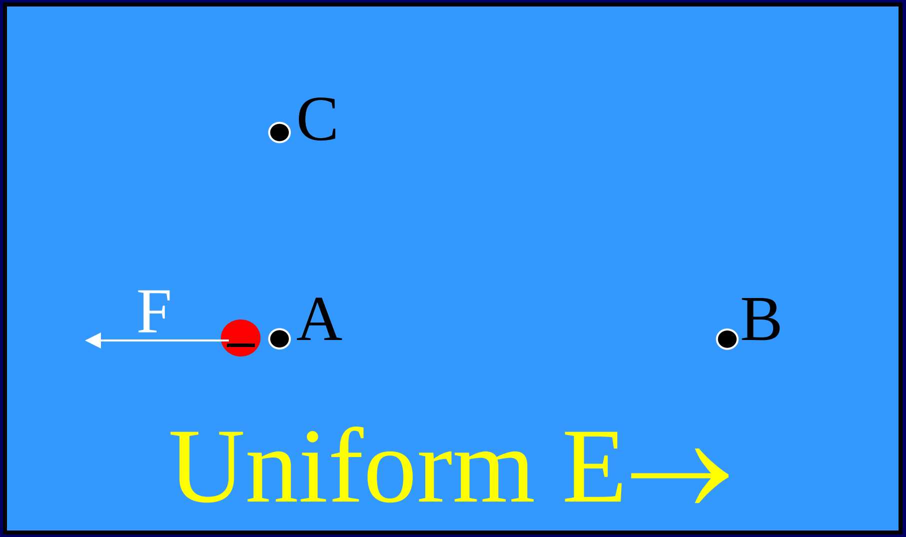


Electric

- Charge moved $x_i \rightarrow x_f$
  - $F_E = qE$ **(left)**
  - $W_E = -qEd$
  - $W_{you} = qEd$



CheckPoint 1.1



In what direction does the force on a negative charge at point A point?

65% 1) left

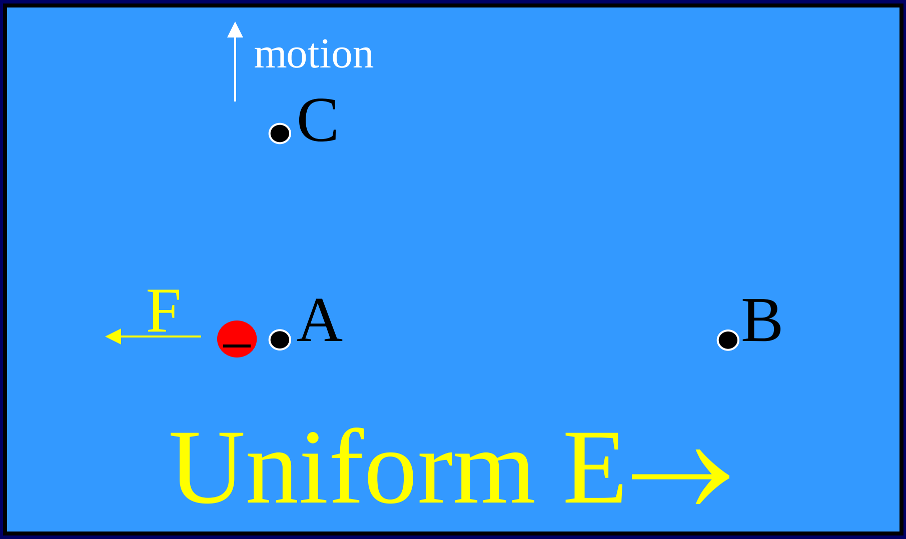
32% 2) right

3% 3) up

Electric field points in the direction a POSITIVE charge would feel force.

CheckPoint 1.2

"Force applied perpendicular to the direction of motion brings about no work"



When a negative charge is moved from A to C the ELECTRIC force does

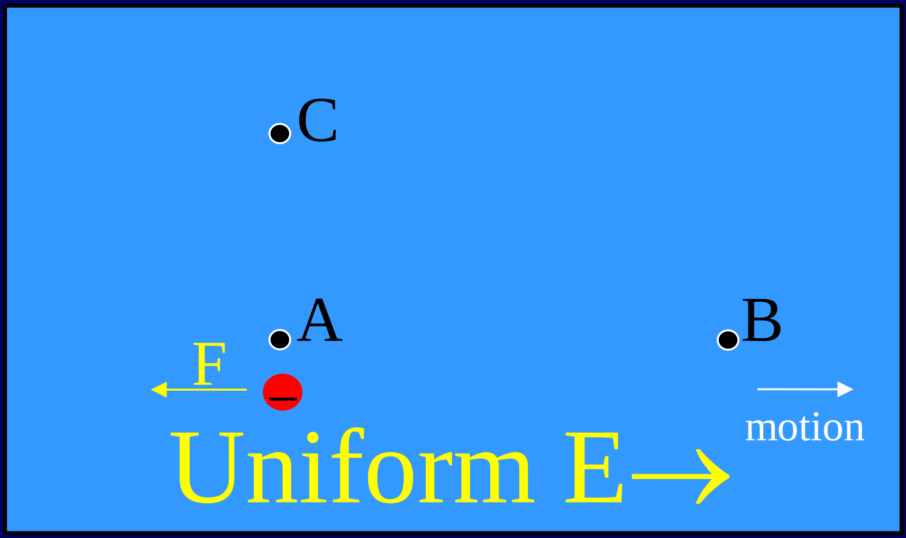
20% 1) positive work.

70% 2) zero work.

10% 3) negative work.

CheckPoint 1.3

"The work is negative because the electric force opposes the direction of motion"



When a negative charge is moved from A to B the ELECTRIC force does

48% 1) positive work.

17% 2) zero work.

35% 3) negative work.

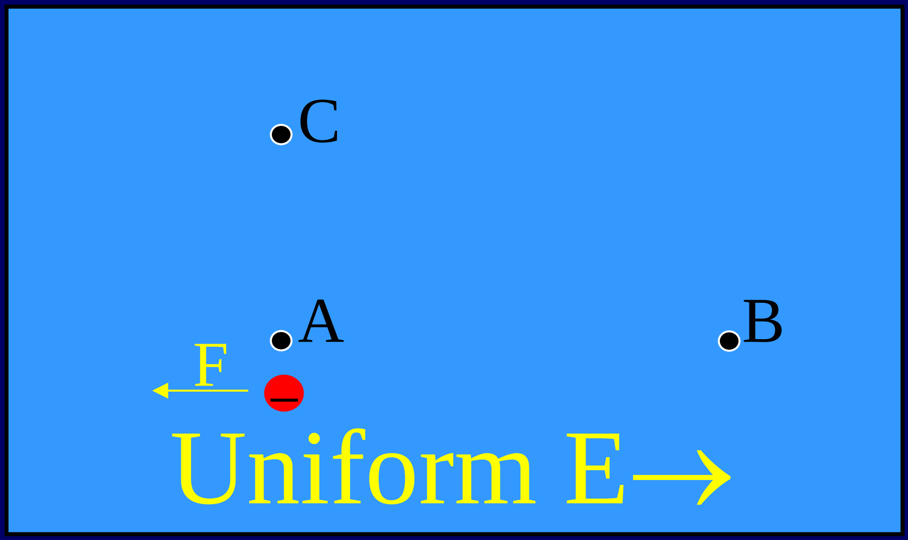
$-W_{E\ field} = +W_{You}$

Electric force did negative work

You did positive work

ACT: Work

$W_{A\text{-}B}$ = work done by F_E moving charge from A to B



The negative charge is moved from A to C to B. Is the work done by the electric force:

A) Greater than $W_{A\text{-}B}$

B) Same as $W_{A\text{-}B}$

C) Less than $W_{A\text{-}B}$

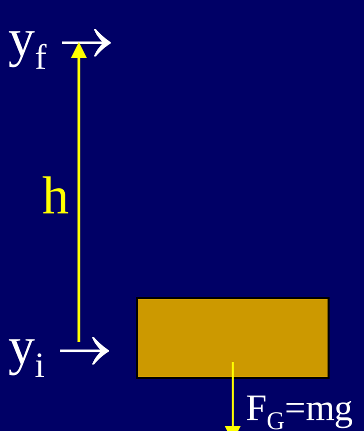
Path <u>does not</u> matter!
Only end points matter

Work and Δ Potential Energy

$$W_F = F\,d\cos(\theta) = -\Delta U$$

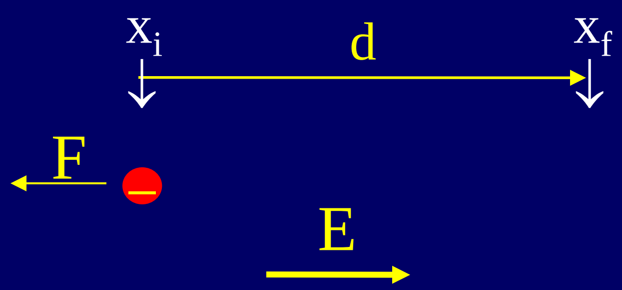
Gravity

- Brick raised $y_i \rightarrow y_f$
  - $F_G = mg$ **(down)**
  - $W_G = -mgh$
  - $\Delta U_G = +mgh$



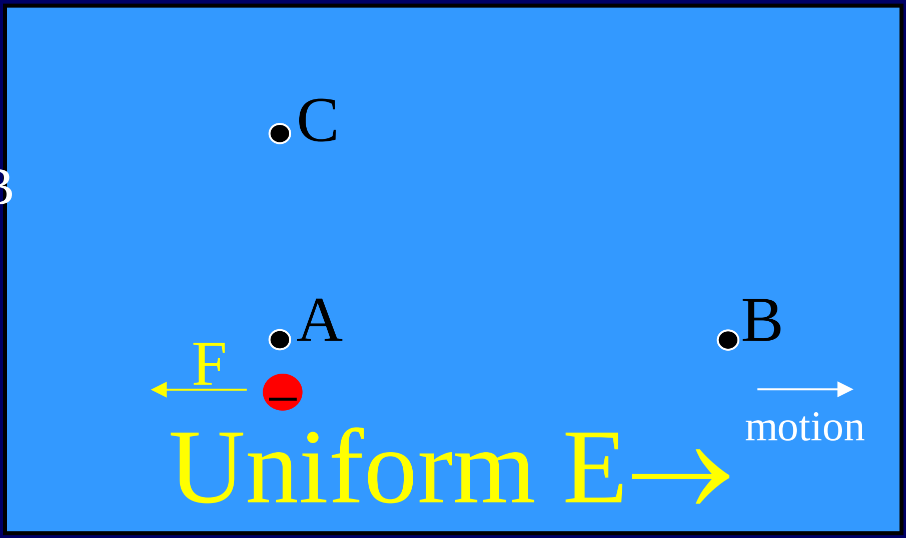
Electric

- Charge moved $x_i \rightarrow x_f$
  - $F_E = qE$ **(left)**
  - $W_E = -qEd$
  - $\Delta U_E = +qEd$



CheckPoint 1.5

"The movement of an electron from A to B requires energy from an outside source. The energy put in will be released when the electron moves from B to A."



When a negative charge is moved from A to B the potential energy of the charge

45% 1) increases.

23% 2) remains the same.

32% 3) decreases.

$-W_{E\ field} = +W_{You}$

Electric force did negative work

You did positive work

E.P.E. for point charges

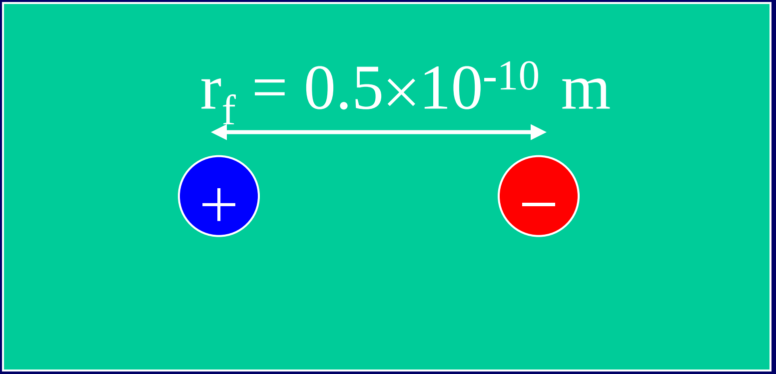
E.P.E. of two charges q_1 and q_2 separated a distance r:

Example

$$U_E = k\frac{q_1 q_2}{r}$$

What is the electric potential energy of an electron a distance $r = 0.53\times10^{-10}$ m from a proton (H atom)?

$U_E = (9\times10^{9})(+1.6\times10^{-19})(-1.6\times10^{-19})/0.53\times10^{-10} = -4.35\times10^{-18}$J



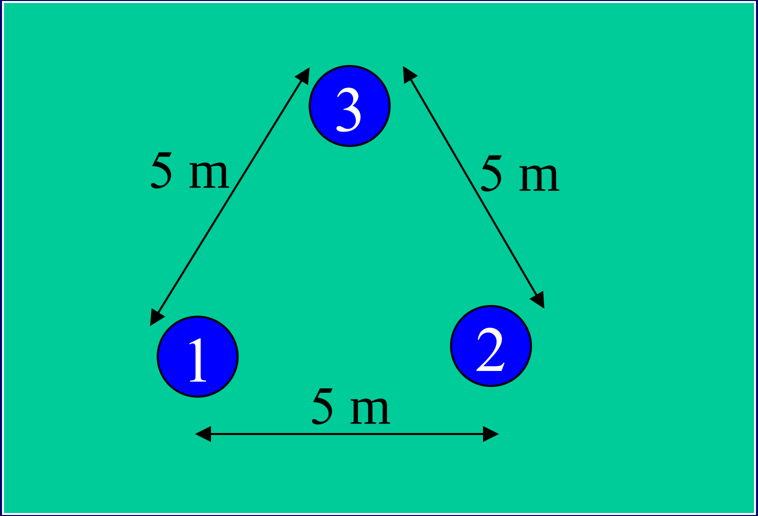
Work done by YOU to assemble 3 + charges

Example

- $W_1 = 0$
- $W_2 = k\ q_1\ q_2\ /r$ $=(9\times10^9)(1\times10^{-6})(2\times10^{-6})/5$ $=3.6$ mJ
- $W_3 = k\ q_1\ q_3/r + k\ q_2\ q_3/r$
  $(9\times10^9)(1\times10^{-6})(3\times10^{-6})/5 + (9\times10^9)(2\times10^{-6})(3\times10^{-6})/5$ $=16.2$ mJ

- $W_{total} = +19.8$ mJ
- $W_E = -19.8$ mJ
- $\Delta U_E = +19.8$ mJ

(watch signs!)

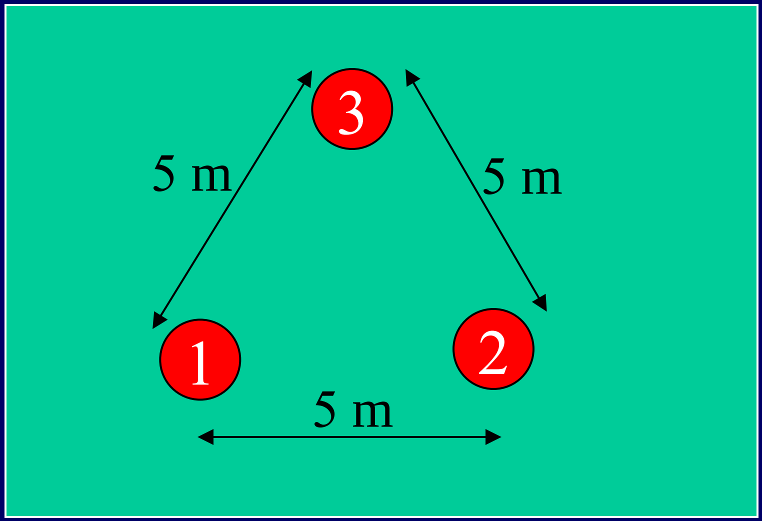


ACT: Work done by YOU to assemble 3 negative charges

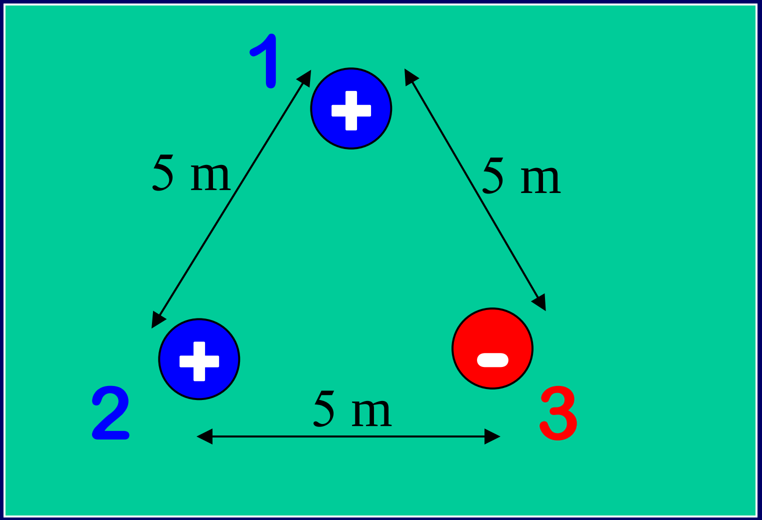
How much work would it take YOU to assemble 3 negative charges?

Likes repel, so YOU will still do positive work!

A) W = +19.8 mJ
B) W = 0 mJ
C) W = -19.8 mJ



CheckPoint 2.1



The total work required by you to assemble this set of charges is:

57%	(1)	positive
14%	(2)	zero
28%	(3)	negative

Bring in (1): zero work

Bring in (2): positive work

Bring in (3): negative work x 2

Electric Potential

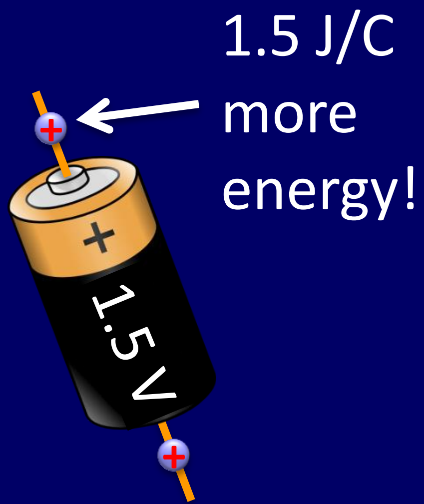
$$V \equiv U_E/q$$

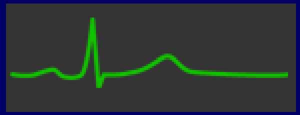
Electric potential energy per charge

- Units:

  Joules/Coulomb ≡ Volts

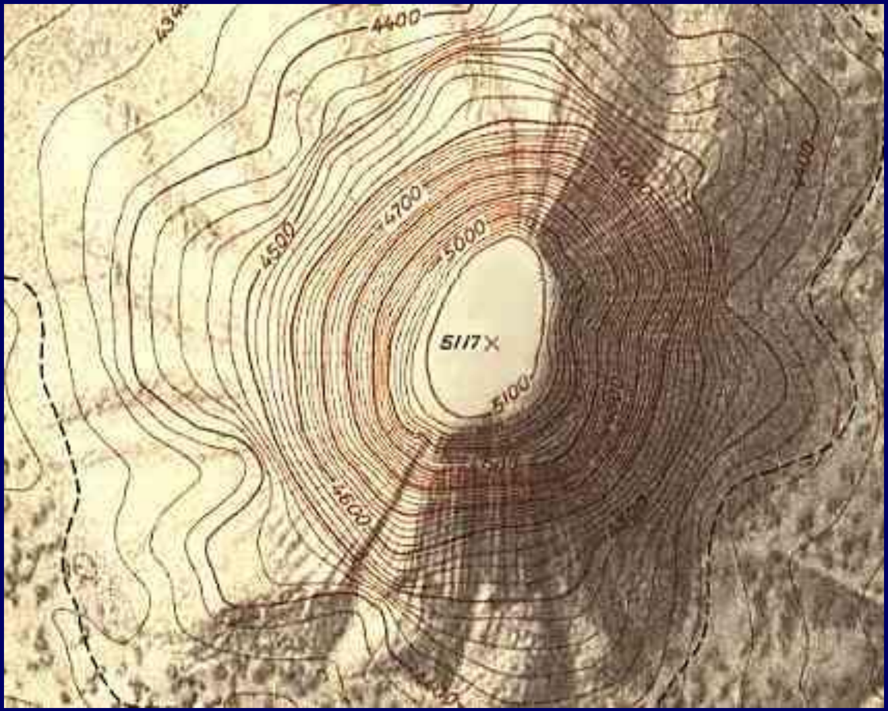
- Examples:
  - Batteries
  - EKG
- Only potential differences matter





Electric Potential: like height

Devil's Tower

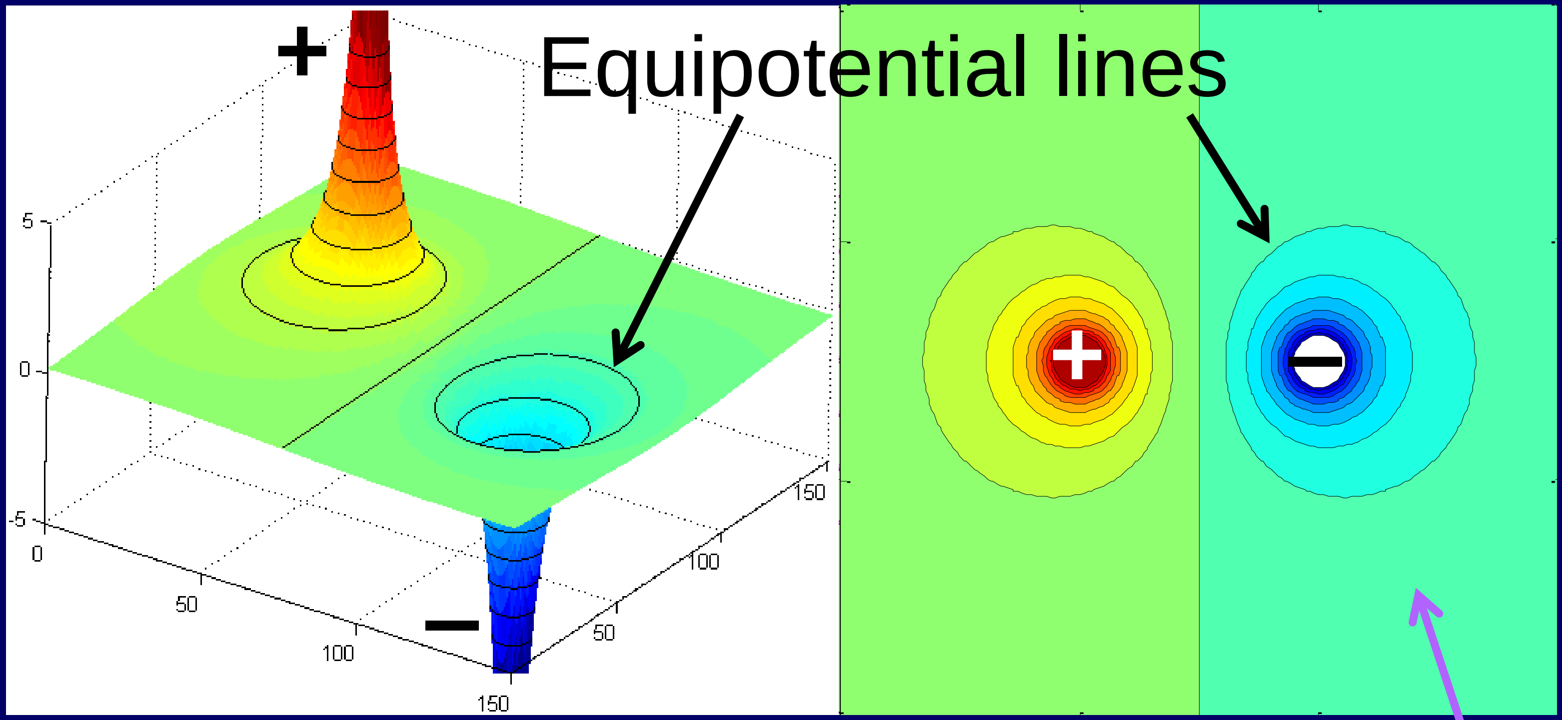


Topographical map

Moving to higher potential ⇔ moving uphill

Demo: electric potential

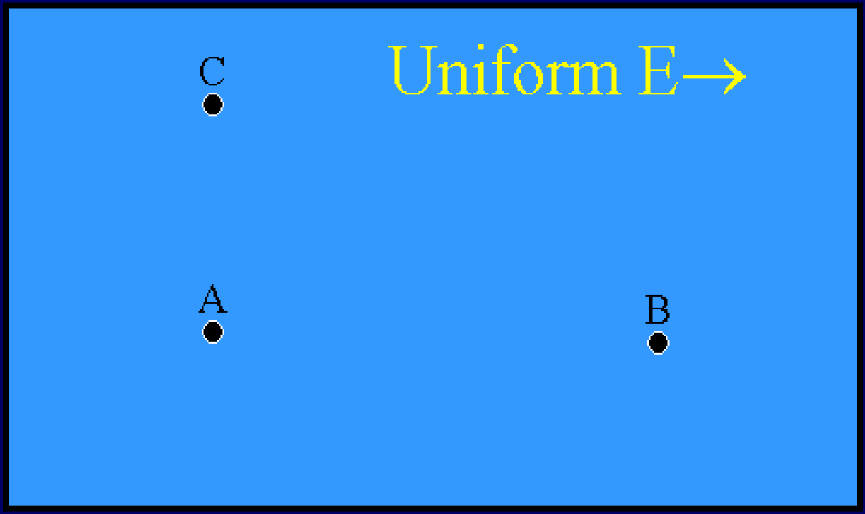
Recall electric dipole



- + (–) charge has high (low) potential
- Equipotential lines at same “height”
- Electric field lines point “downhill”

CheckPoint 1.7

To go from B to A, a positive charge must climb “up hill” – increases potential energy. Hence A is at higher potential than B.



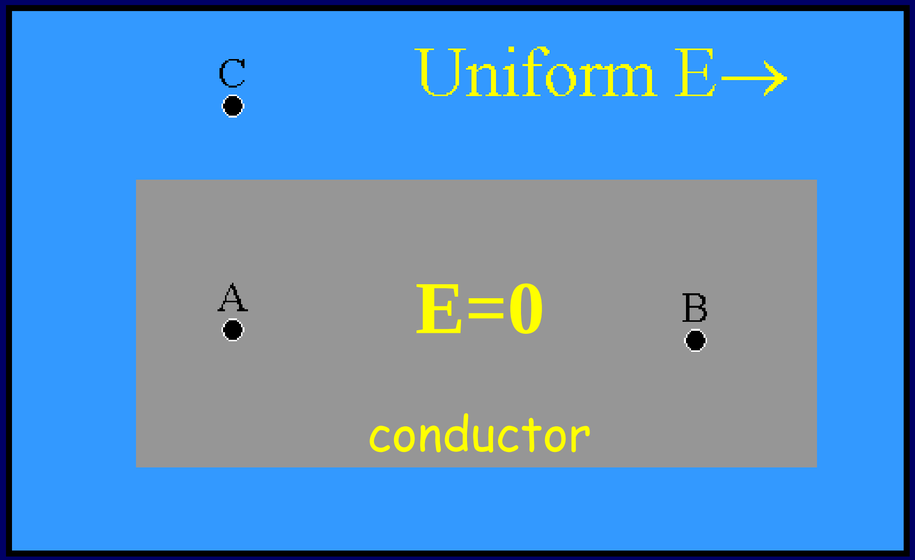
The electric potential at point A is _______ at point B

46% 1) greater than

32% 2) equal to

22% 3) less than

ACT



Now points A and B lie inside a conductor…

The electric potential at point A is ________ at point B

A) greater than

B) equal to

C) less than

The electric field points toward lower potential, but the electric field is zero inside a conductor…so the potential is equal everywhere!

Potential for Point charges

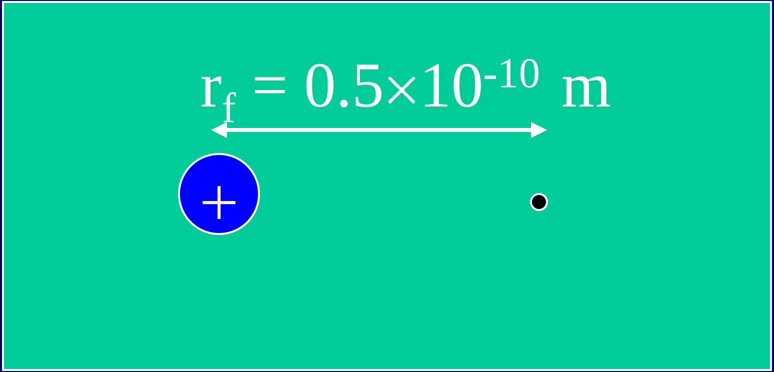
Electric potential a distance r from a charge q:

$$V \equiv U_E/q \qquad V = k\frac{q}{r}$$

Example

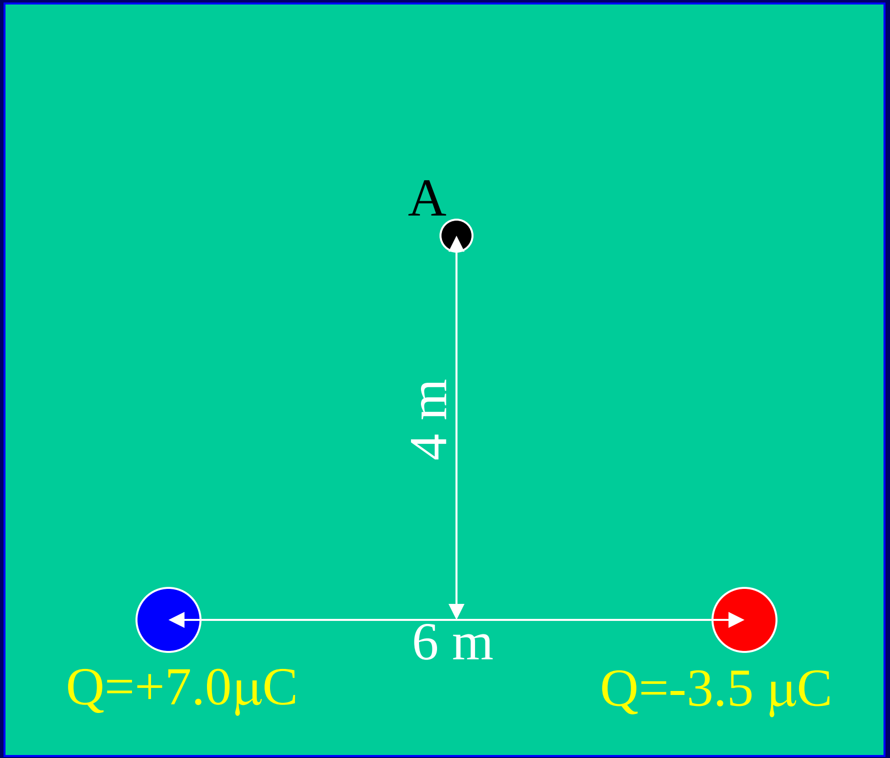
What is the electric potential a distance $r = 0.53\times10^{-10}$ m from a proton? $(V(\infty)=0)$

$V = U_E/q = k\,q/r = (9\times10^{9})(1.6\times10^{-19})/0.53\times10^{-10} = 27.2$ Volts



Two Charges

- Calculate electric potential at point A due to charges
  - Calculate V from +7μC charge
  - Calculate V from –3.5μC charge
  - Add (EASY! NO VECTORS)



$V = kq/r$

$V_7 = (9\times10^9)(7\times10^{-6})/5 = 12.6\times10^3 V$

$V_3 = (9\times10^9)(-3.5\times10^{-6})/5 = -6.3\times10^3 V$

$V_{total} = V_7 + V_3 = +6.3\times10^3 V$

How much work do you have to do to bring a 2 μC charge from far away to point A?

$W = \Delta U = Vq$

$= (+6.3\times10^3 V)(2\mu C)$

$= +12.6$ mJ

Comparison:
Electric *Potential Energy* vs. Electric *Potential*

- Electric Potential Energy (U) - the energy of a charge at some location.
- Electric Potential (V) - found for a location only – tells what the EPE *would be* if a charge were located there (usually talk about potential differences between two locations):

$$U = Vq$$

- Neither has direction, just value.

  Sign matters!

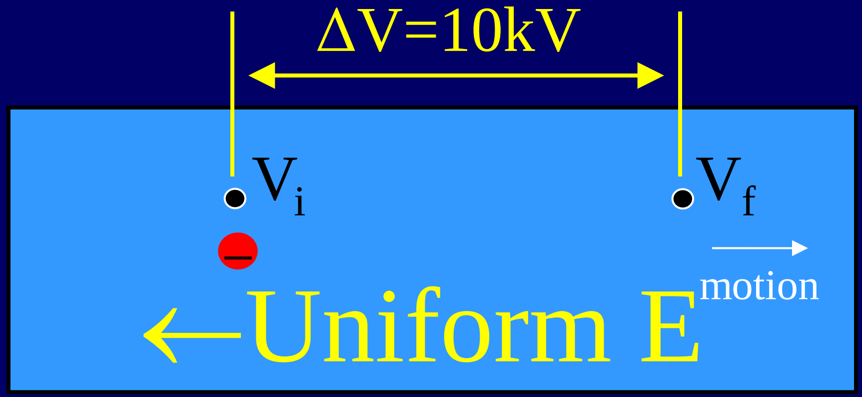
Relationship between F, E, U_E, V

	Vector	Number ("scalar")
Property of interacting charges	**F** [N] Ex: $F = k\frac{q_1 q_2}{r^2}$	**U_E** [J] Ex: $U_E = k\frac{q_1 q_2}{r}$
Property of point in space	**E** [N/C]=[V/m] $E \equiv F/q$ Ex: $E = k\frac{q}{r^2}$	**V** [J/C]=[V] $V \equiv U_E/q$ Ex: $V = k\frac{q}{r}$

Why so many ways to describe electric force?

Example

Electron microscope



- What is the final velocity of the electron?
- Solve by conservation of energy:

$$K.E._i + P.E._i = K.E._f + P.E._f$$

$$0 + -eV_i = \tfrac{1}{2}mv^2 + -eV_f$$

$$v = \sqrt{\frac{2e\Delta V}{m}} = \sqrt{\frac{2(1.6\times10^{-19})(1\times10^{4})}{9.1\times10^{-31}}}$$

$$= 5.9\times10^{7}\,m/s$$

Could solve this using F=ma & kinematic equations (Phys 101) TRY AT HOME! (HARDER)

See you Monday!