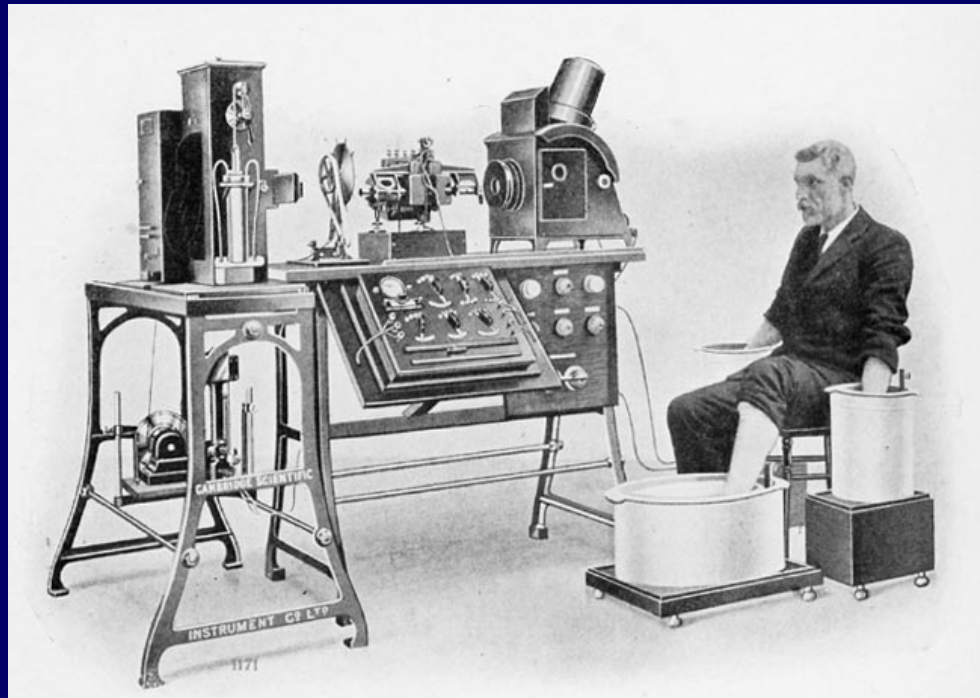


Physics 102: Lecture 3

Electric Potential Energy & Electric Potential



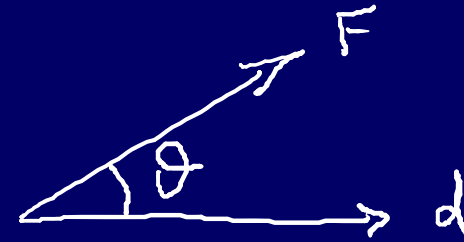
Overview for Today's Lecture

Phys. 101

- Electric Potential Energy & Work
 - Uniform fields
 - Point charges
- Electric Potential (like height)
 - Uniform fields
 - Point charges

Work

$$W_F = F d \cos(\theta)$$



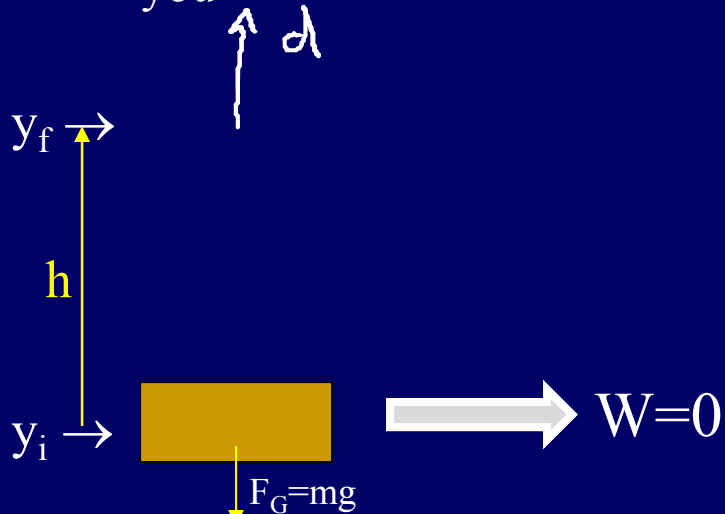
Gravity

- Brick raised $y_i \rightarrow y_f$

- $F_G = mg$ (down)

- $W_G = -mgh$

- $W_{\text{you}} = mgh$



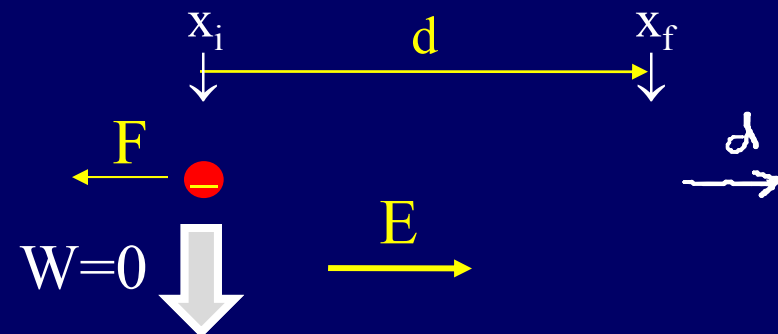
Electric

- Charge moved $x_i \rightarrow x_f$

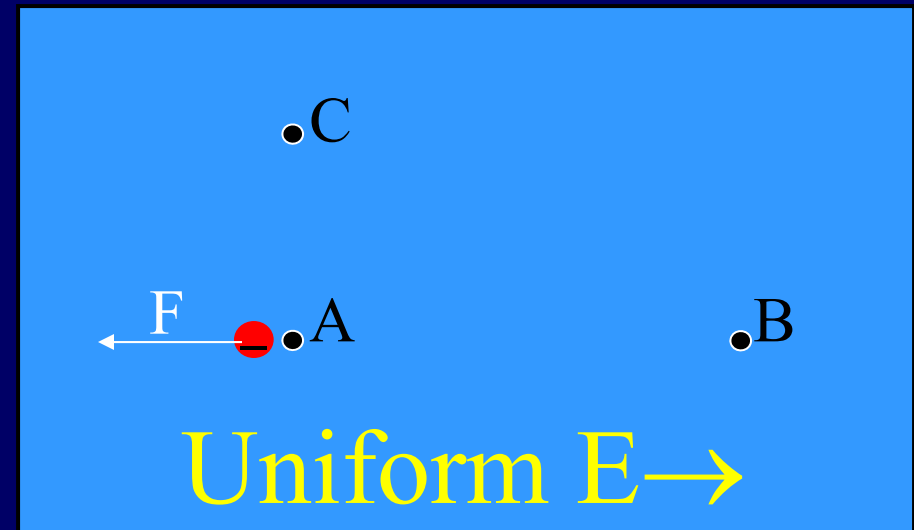
- $F_E = \{qE\}$ (left)

- $W_E = -qEd$

- $W_{\text{you}} = qEd$



CheckPoint 1.1



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

64% 1) left

33% 2) right

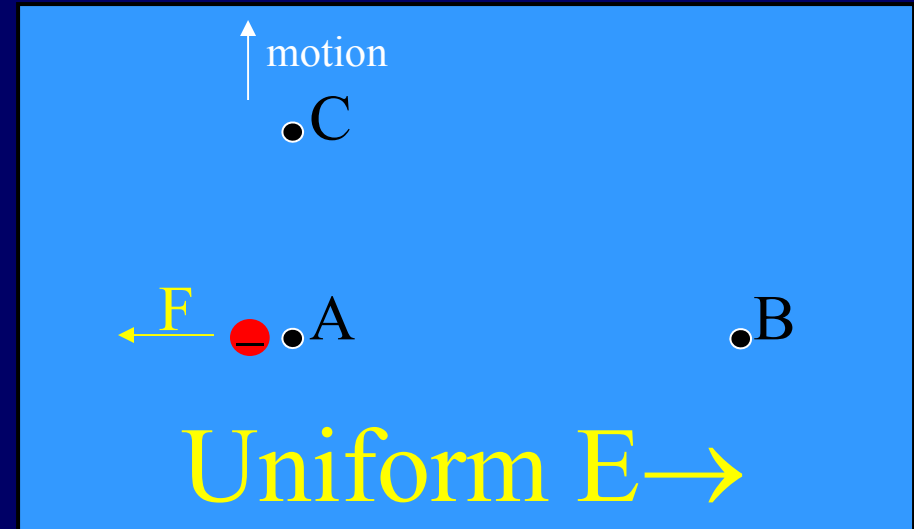
4% 3) up

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

CheckPoint 1.2

"I would say zero because the path is perpendicular to the field"

$$W_E = Fd \cos \theta \quad \theta = 90^\circ$$



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

24% 1) positive work.

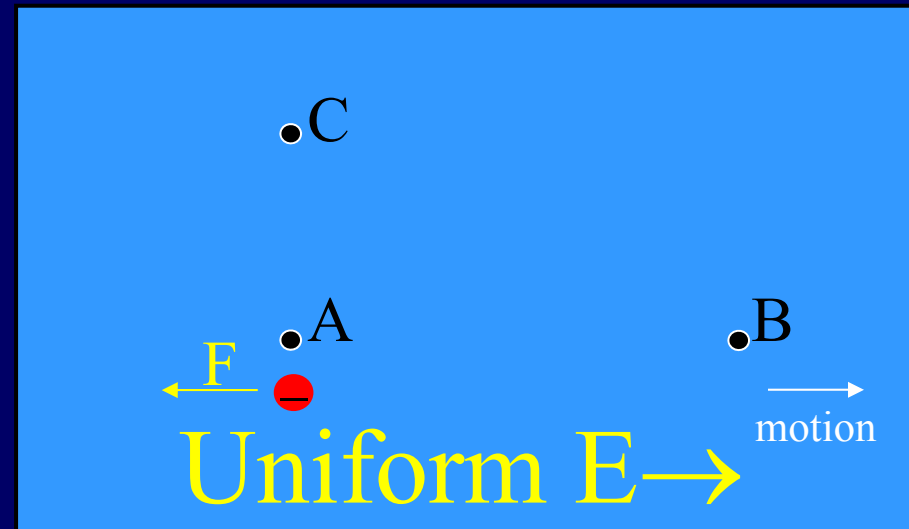
64% 2) zero work.

12% 3) negative work.

CheckPoint 1.3

"because the direction of the displacement is 180 degrees from direction of the force "

$$W_E = Fd \cos \theta \quad \theta = 180^\circ$$



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

47% 1) positive work.

18% 2) zero work.

35% 3) negative work.

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

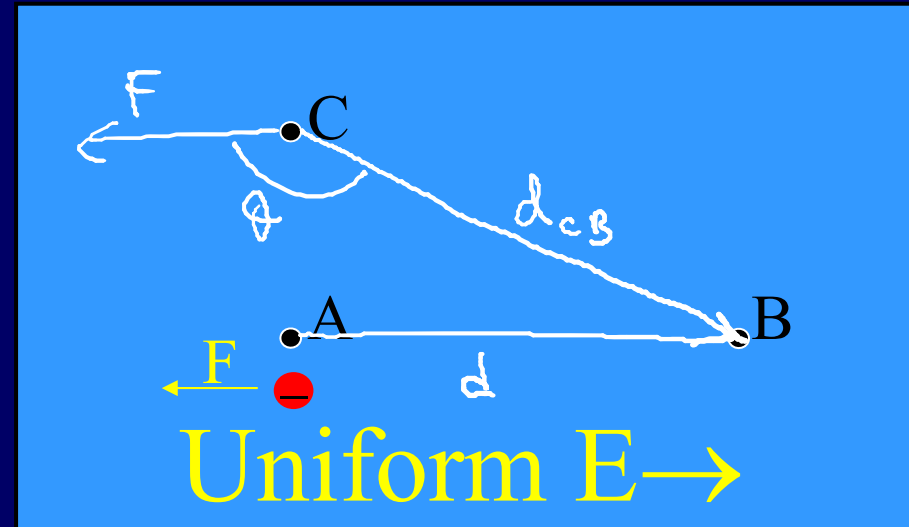
Electric force did negative work

You did positive work



ACT: Work

W_{A-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-B}

B) Same as W_{A-B}

C) Less than W_{A-B}

$$W_{A-C} + W_{C-B}$$
$$qEd_{CB}\cos\theta = -qEd$$

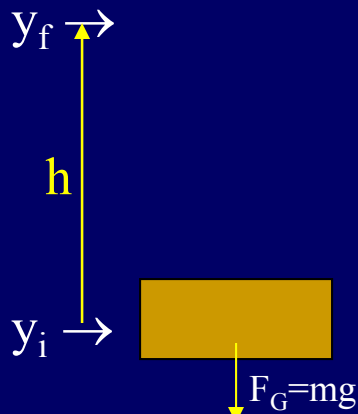
**Path does not matter!
Only end points matter**

Work and Δ Potential Energy

$$W_F = F d \cos(\theta) = -\Delta U = -W_{\text{you}}$$

Gravity

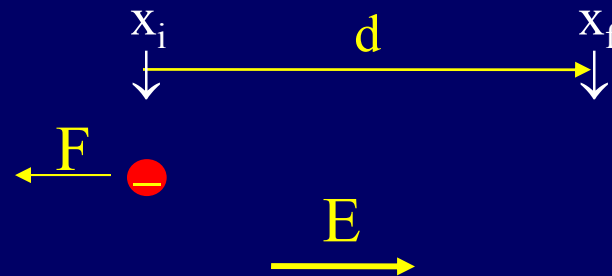
- Brick raised $y_i \rightarrow y_f$
 - $F_G = mg$ (down)
 - $W_G = -mgh = -W_{\text{you}}$
 - $\Delta U_G = +mgh$



Physics 102: Lecture 2, Slide 8

Electric

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



$$W_E = Fd \cos \theta$$

E.P.E. for point charges

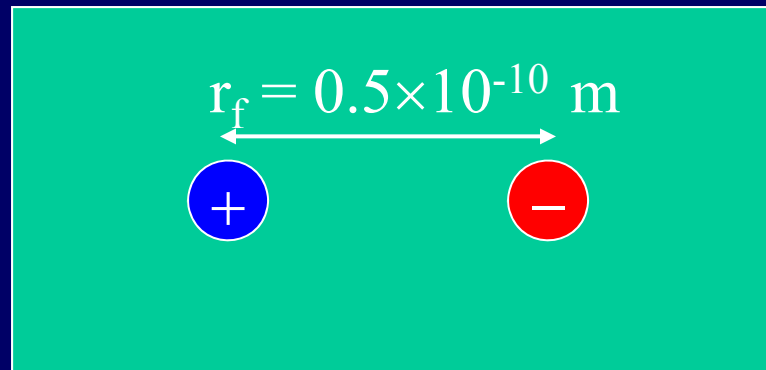
E.P.E. of two charges q_1 and q_2 separated a distance r :

Example

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

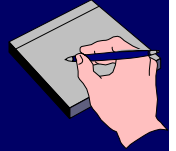
What is the electric potential energy of an electron a distance $r = 0.53 \times 10^{-10}$ m from a proton (H atom)?

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

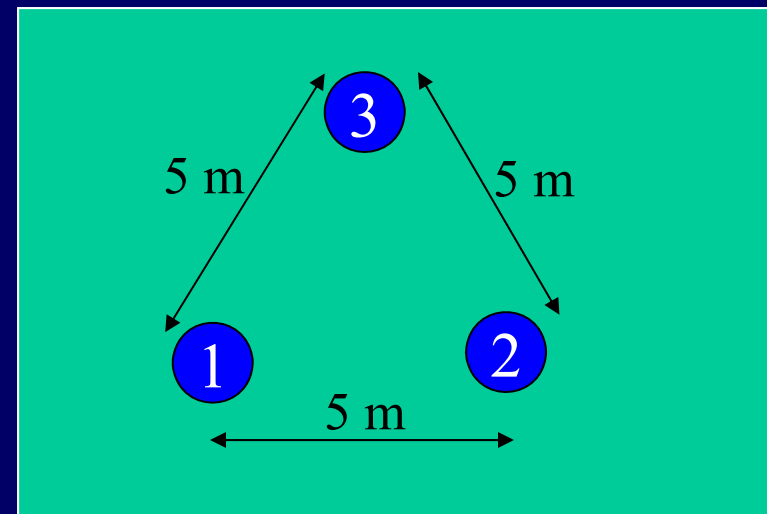


Example

Work done by YOU to assemble 3 + charges



- $W_1 = 0$
- $W_2 = k q_1 q_2 / r = (9 \times 10^9)(1 \times 10^{-6})(2 \times 10^{-6})/5 = 3.6 \text{ mJ}$
- $W_3 = k q_1 q_3 / r + k q_2 q_3 / r$
 $(9 \times 10^9)(1 \times 10^{-6})(3 \times 10^{-6})/5 + (9 \times 10^9)(2 \times 10^{-6})(3 \times 10^{-6})/5 = 16.2 \text{ mJ}$
- $W_{\text{total}} = +19.8 \text{ mJ}$
- $W_E = -19.8 \text{ mJ}$
- $\Delta U_E = +19.8 \text{ mJ}$
(watch signs!)



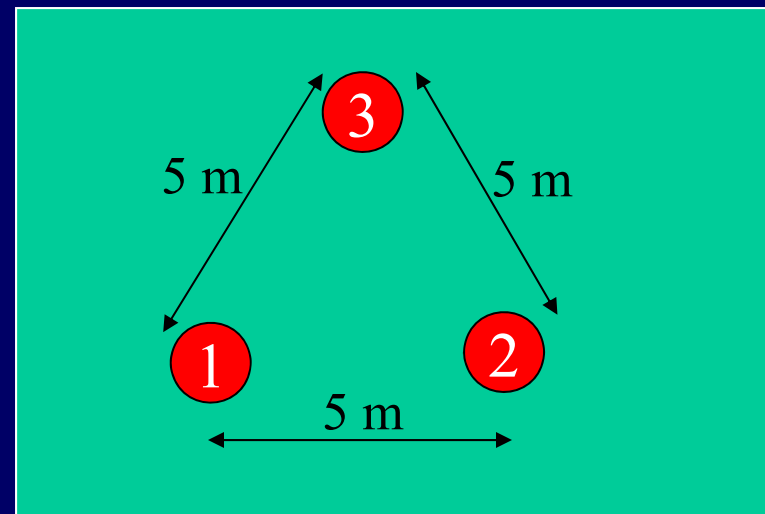


ACT: Work done by YOU to assemble 3 negative charges

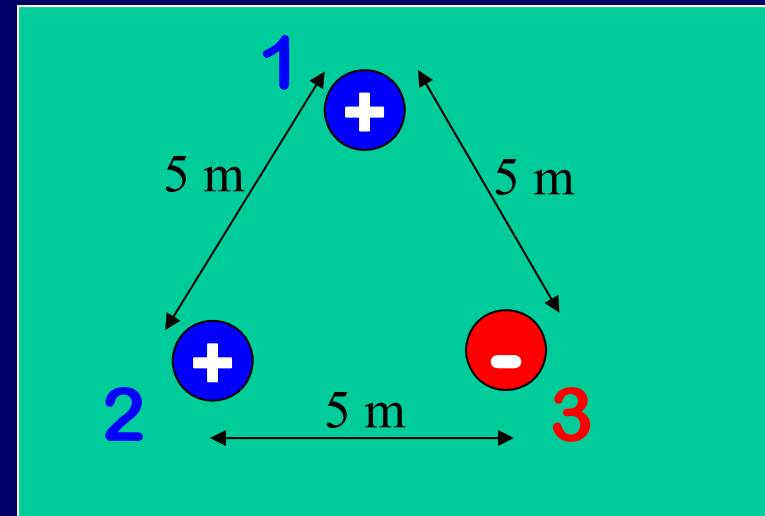
How much work would it take YOU to assemble 3 negative charges?

Likes repel, so YOU will still do positive work!

- A) $W = +19.8 \text{ mJ}$
- B) $W = 0 \text{ mJ}$
- C) $W = -19.8 \text{ mJ}$



CheckPoint 2.1



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

57% (1) positive

14% (2) zero

29% (3) negative

Bring in (1): zero work

Bring in (2): positive work

Bring in (3): negative work x 2

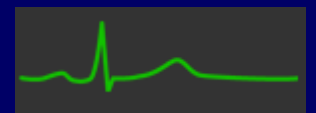
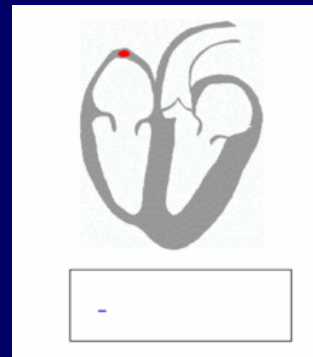
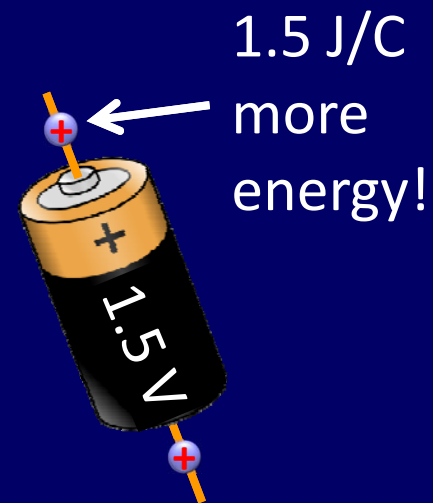
Electric Potential

$$\rightarrow V \equiv U_E/q$$

Defined at a location

Electric potential
energy per charge

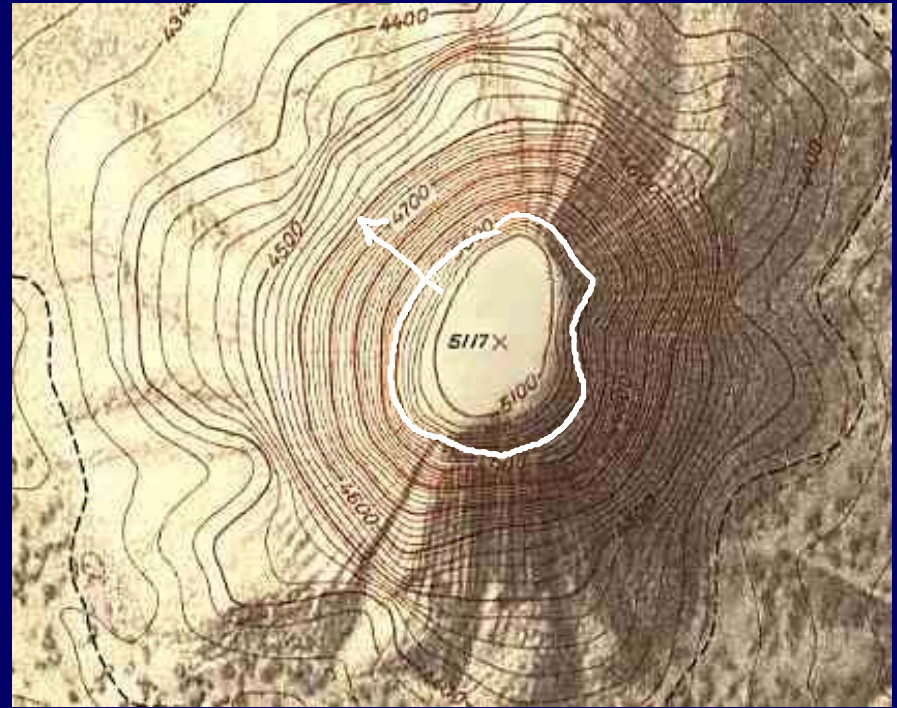
- Units:
Joules/Coulomb \equiv Volts
- Examples:
 - Batteries
 - EKG
- Only potential differences matter



Electric Potential: like height



Devil's Tower

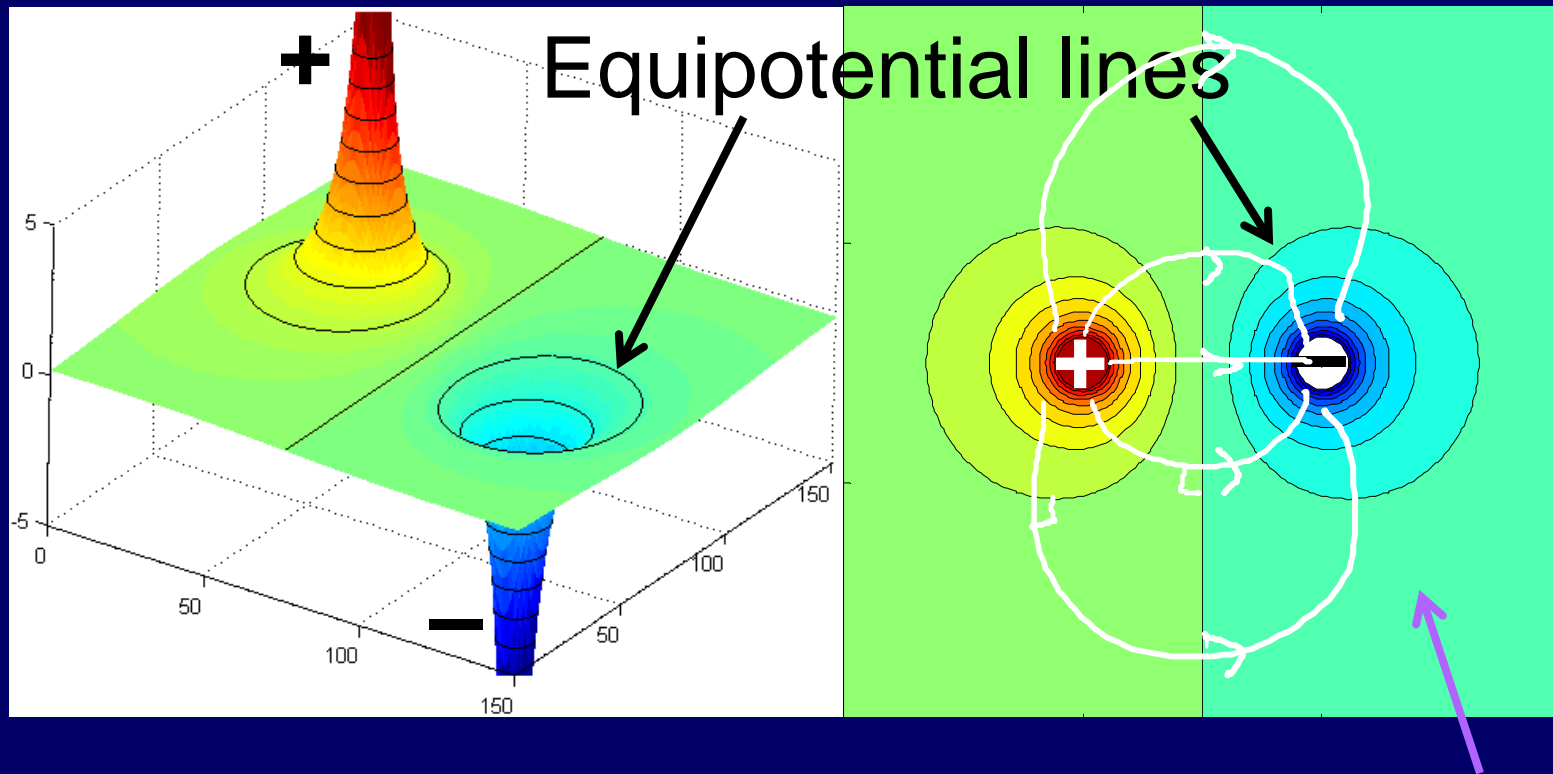


Topographical map

Moving to higher potential \Leftrightarrow moving uphill

Demo: electric potential

Recall electric dipole

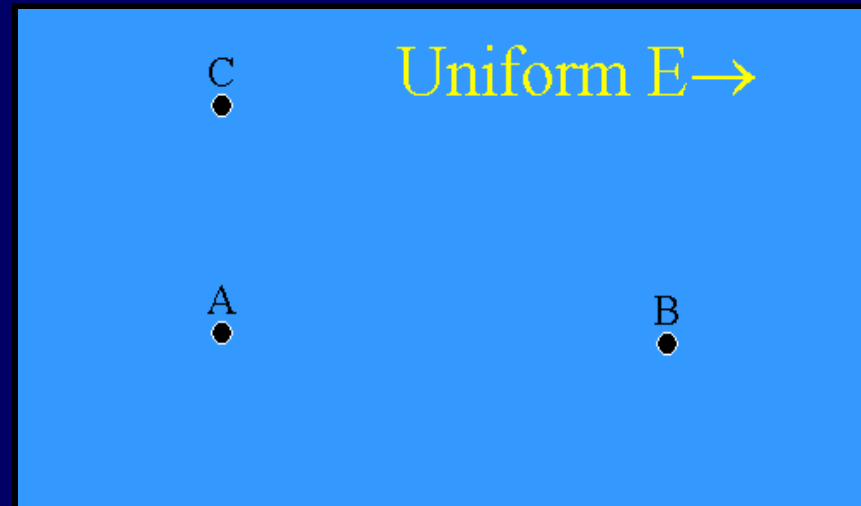


- + (-) charge has high (low) potential
- Equipotential lines at same “height”
- Electric field lines point “downhill”

Electric field

CheckPoint 1.7

Electric field Points from greater potential to lower potential



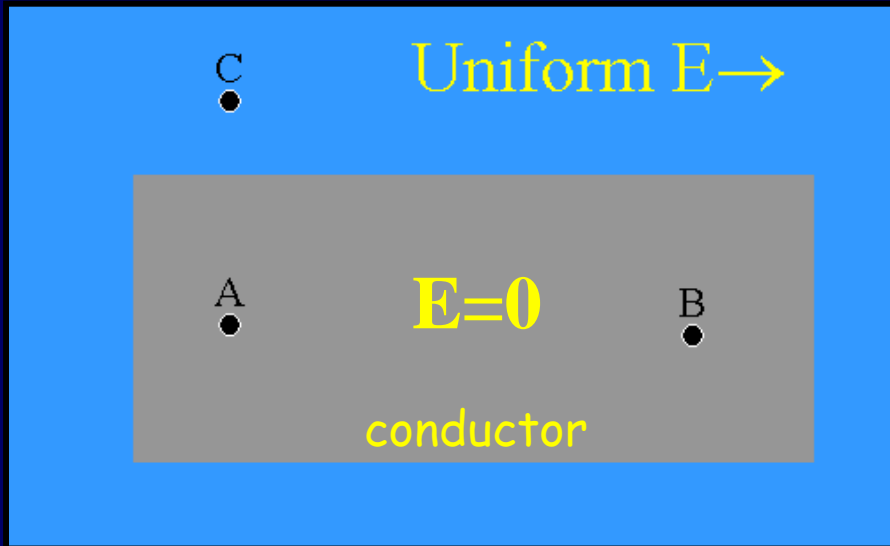
The electric potential at point A is _____ at point B

43% 1) greater than

31% 2) equal to

26% 3) less than

ACT



Now points A and B lie inside a conductor...

*V is constant
Not necessarily = 0*

$$\Delta V = 0$$

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

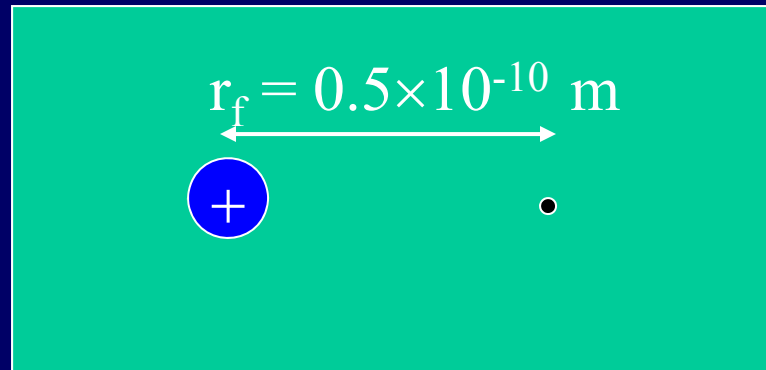
Electric potential a distance r from a charge q :

Example

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

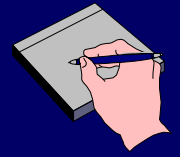
What is the electric potential a distance $r = 0.53 \times 10^{-10} \text{ m}$ from a proton? ($V(\infty)=0$)

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



Example

Two Charges



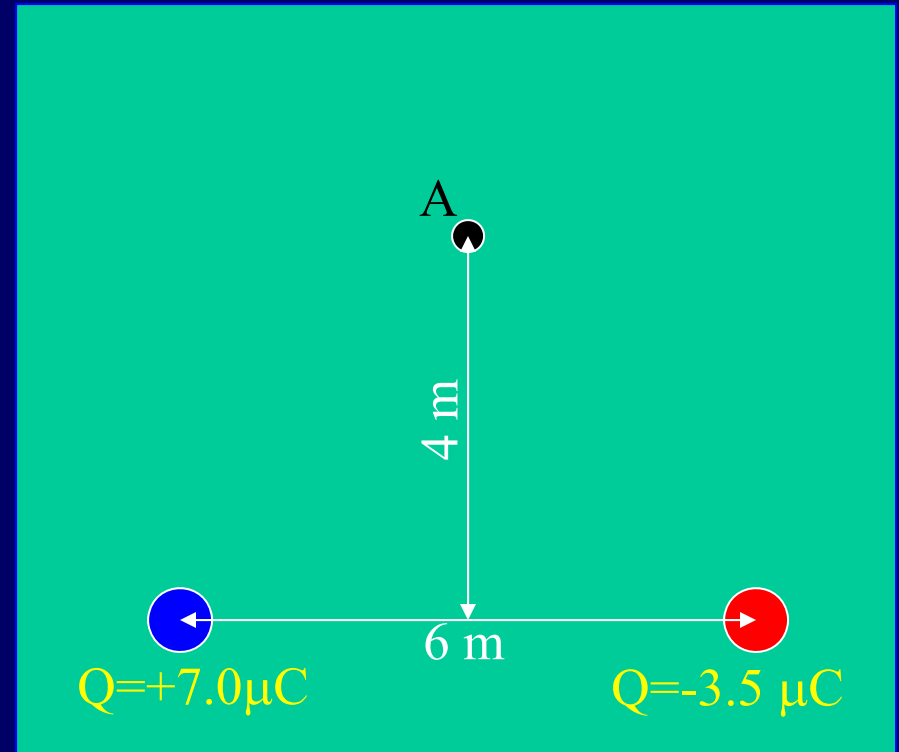
- Calculate electric potential at point A due to charges
 - Calculate V from $+7\mu\text{C}$ charge
 - Calculate V from $-3.5\mu\text{C}$ charge
 - Add (EASY! NO VECTORS)

$$V = kq/r$$

$$V_7 = (9 \times 10^9)(7 \times 10^{-6})/5 = 12.6 \times 10^3 \text{V}$$

$$V_3 = (9 \times 10^9)(-3.5 \times 10^{-6})/5 = -6.3 \times 10^3 \text{V}$$

$$V_{\text{total}} = V_7 + V_3 = +6.3 \times 10^3 \text{V}$$



How much work do you have to do to bring a $2\mu\text{C}$ charge from far away to point A?

$$\begin{aligned} W &= \Delta U = Vq \\ &= (+6.3 \times 10^3 \text{V})(2\mu\text{C}) \\ &= +12.6 \text{ mJ} \end{aligned}$$

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!

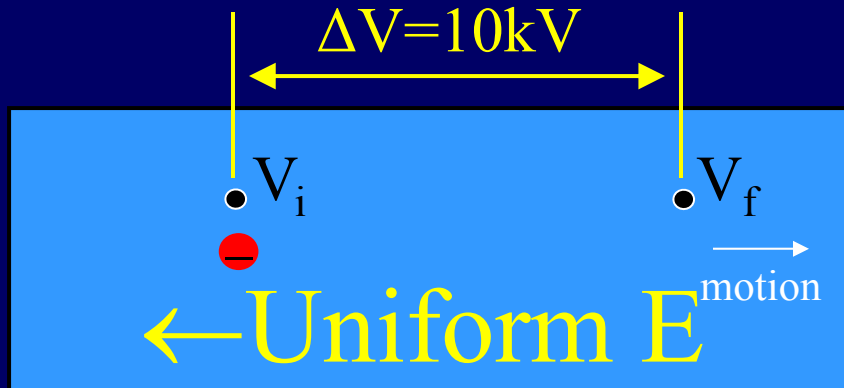
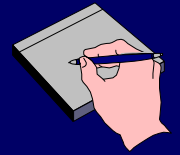
Relationship between F , E , U_E , V

	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:

$$\text{K.E.}_i + \text{P.E.}_i = \text{K.E.}_f + \text{P.E.}_f$$

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

$$v = \sqrt{\frac{2e\Delta V}{m}} = \sqrt{\frac{2(1.6 \times 10^{-19})(1 \times 10^4)}{9.1 \times 10^{-31}}} \\ = 5.9 \times 10^7 \text{ m/s}$$

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

See everyone Monday!