

PHYS 2321
Week4: Gauss's Law/Potential

Day 3 Outline

1) Hwk: Ch. 23 P. 2,3,5,9,12,15,17,21,25,28,29,35,36,43,
48,51. MCQ 1-13 odd (Due next Fri)

Next: Read Ch. 23.1-8

2) Ch. 22 Gauss's Law for E near conductors

a. Example: nested metal spherical shells.

3) Ch. 23 Electric Potential

a. Potential, V , of a point charge

b. Electric Potential energy, U , and work

c. Compare to gravitational PE, U_g

Notes: Next quiz is on Mon on Flux and Gauss's Law.

Return Ch. 21B hwk. Mean=9.54/10.

Ch. 22 PDF is my2321wk4.pdf under "NEW STUFF"

Electric Potential of a Point Charge

- Recall E field of point charge:

$$\vec{E} = \frac{kq}{r^2} \hat{r}$$

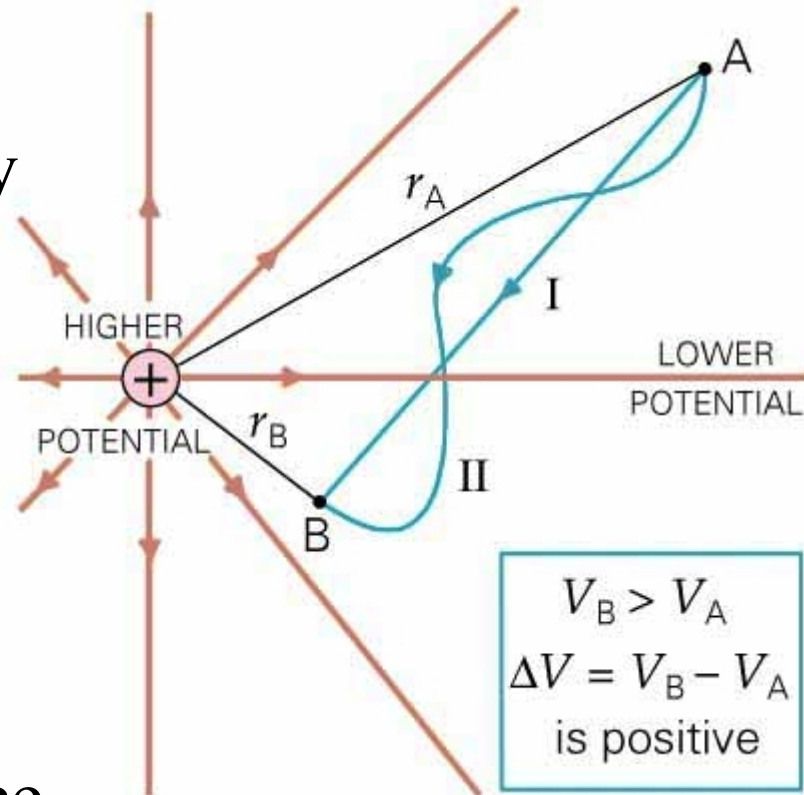
- Electric Potential at r away from a point charge

$$V = \frac{kq}{r}$$

$$V = 0 \quad \text{when} \quad r \rightarrow \infty$$

- Electric potential difference

$$\Delta V_{ab} = \frac{kq}{r_b} - \frac{kq}{r_a}$$



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Week5: Electric Potential

Day 1 Outline

1) Hwk: Ch. 23 P. 2,3,5,9,12,15,17,21,25,28,29,35,36,43, 48,51. MCQ 1-13 odd (Due this Fri)

Next: Read Ch. 23.1-8

2) Quiz 3 on Flux and Gauss's Law

3) Ch. 23 Electric Potential

- a. Relate V to U , W_{field} , F_E and E
- b. Compare to gravitational PE, U_g
- c. Examples with uniform E-fields.

Notes:

Electric Potential

- Electric Potential of a point charge (previous slide)
- Electric potential closely related to *potential energy*
 - $\Delta U = q\Delta V$
 - And to *work*: $W_{\text{byfield}} = -q\Delta V = -\Delta U$
 - Convention: both U and V = 0 at r=infinity
- Electric potential closely related to electric force
 - $\mathbf{F}_E \cdot \Delta \mathbf{r} = W_{\text{byfield}} = -q\Delta V$
- Electric potential closely related to electric field
 - $\delta V = -E\delta r$ so that potential difference is:
$$\Delta V = - \int \vec{E} \cdot d\vec{l}$$
- Electric potential is easier to work with than the E-field because it is not a vector.

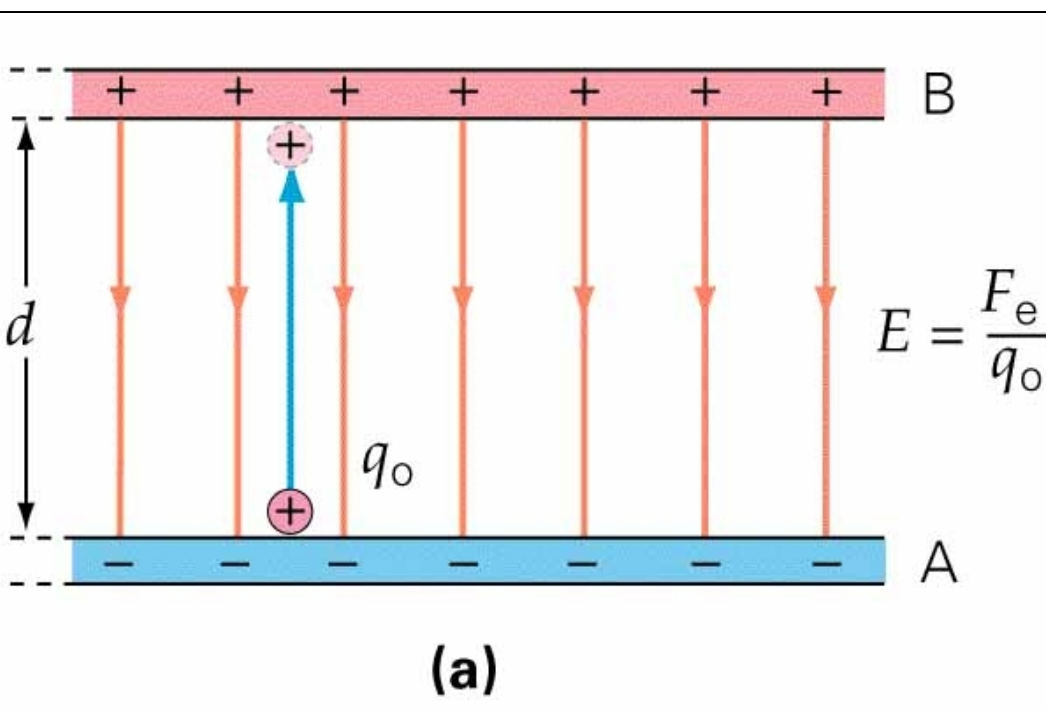
Analogy with gravity

F_E on q_0 is down

$$W_{E\text{field}} = -|F_E|d \quad (F_E = q_0 E)$$

$$\Delta U = -W_{E\text{field}} = |F_E|d$$

$$\Delta V = \Delta U / q_0$$

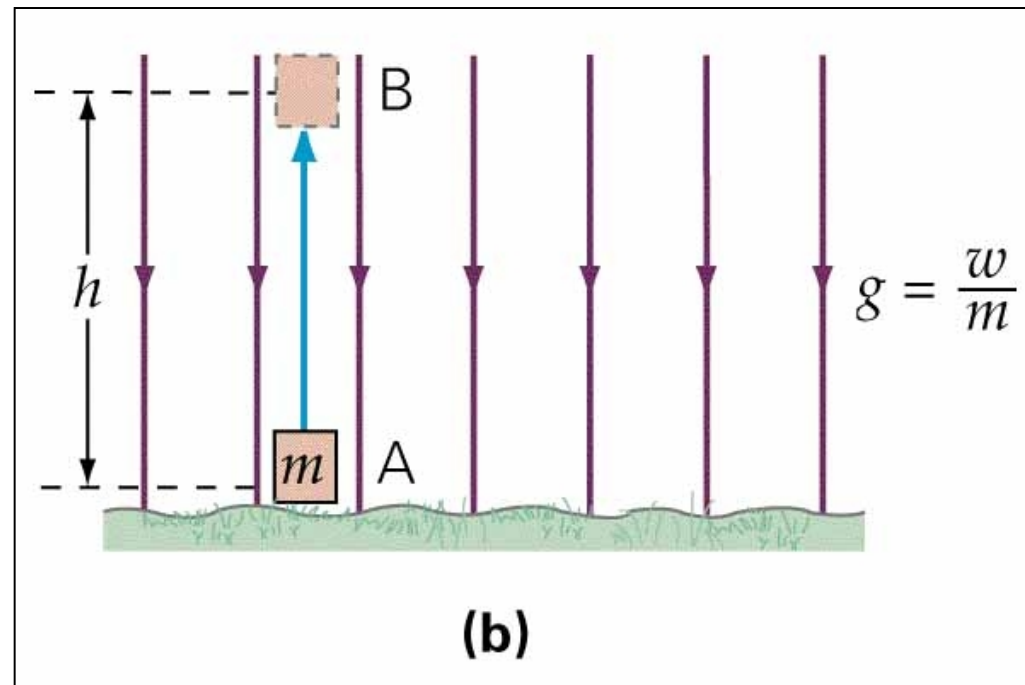


F_g on m is down

$$W_{G\text{field}} = -|F_g|h \quad (F_g = mg)$$

$$\Delta U_G = -W_{G\text{field}} = |F_g|h$$

$$\Delta V_G = \Delta U_G / m$$



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Week5: Electric Potential

Day 2 Outline

1) Hwk: Ch. 23 P. 2,3,5,9,12,15,17,21,25,28,29,35,36,43, 48,51. MCQ 1-13 odd (Due this Fri)

Next: Read Ch. 23.1-8

2) Return Quiz 3. Mean=3.3/8

3) Ch. 23 Electric Potential

a. Examples involving charges in uniform E-fields.

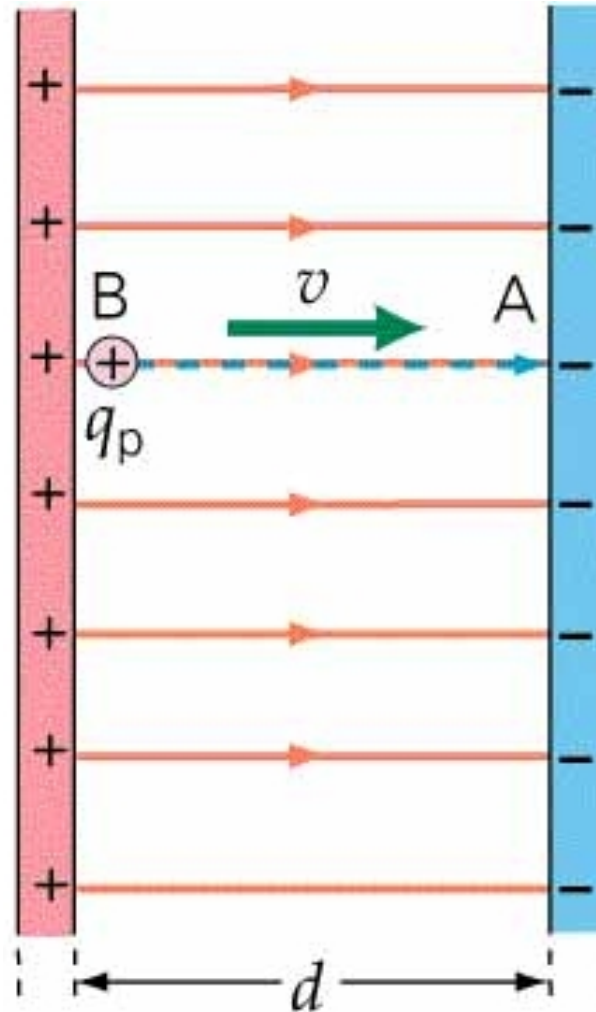
b. Potential and Potential Energy of point charge systems

Notes:

Parallel Plates

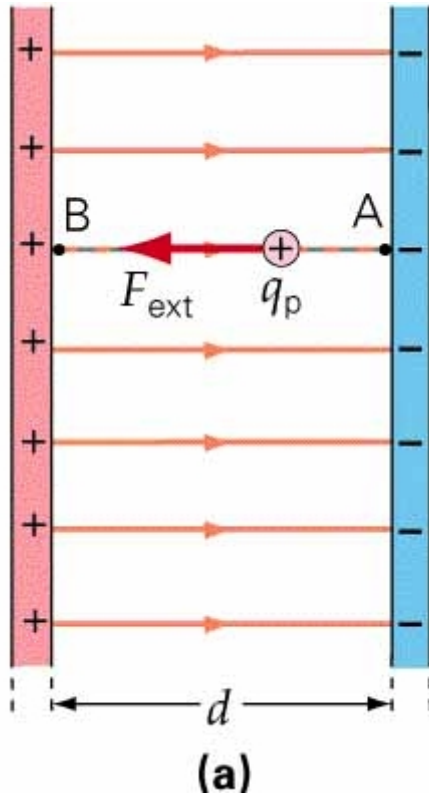
- Releasing a positive test charge from rest at point B...

Find expression
for v at A given
uniform \mathbf{E} and
plate separation d .

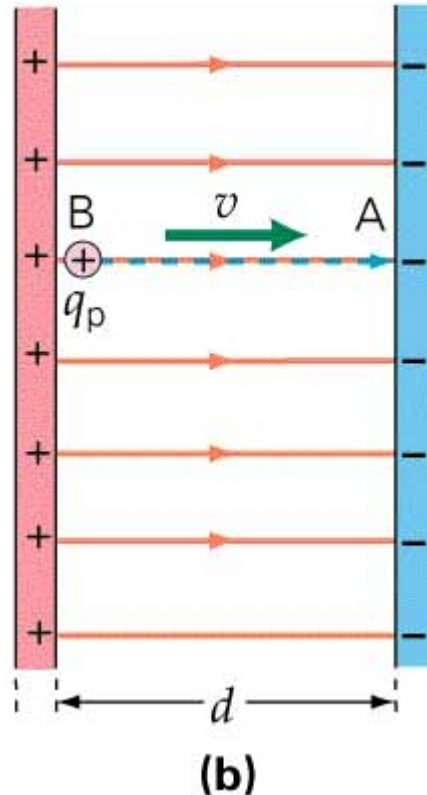


(b)

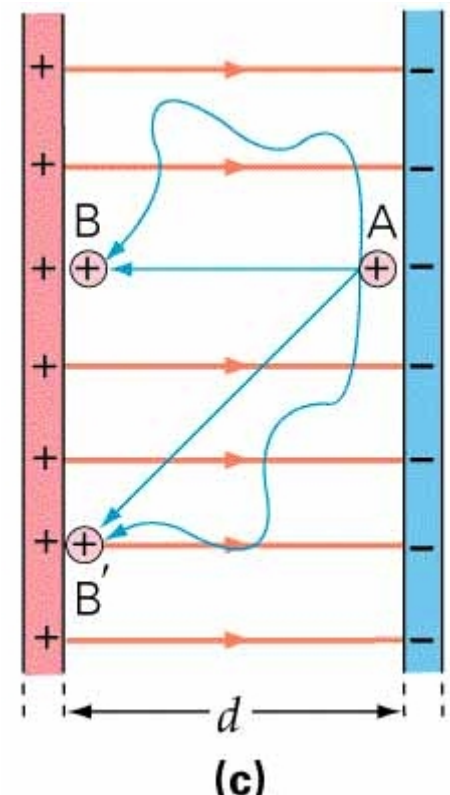
Electric Potential Energy (conservation of energy ideas)



Work is done by “the hand”, so we store potential energy, U_E



Charge is released and energy is converted from U_E to KE



Only the displacement in the direction of the E field matters
(ΔU_E independent of path)

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Week5: Electric Potential

Day 3 Outline

1) Hwk: Ch. 23 P. 2,3,5,9,12,15,17,21,25,28,29,35,36,43,
48,51. MCQ 1-13 odd (Due this ~~Fri~~->Mon)

Next: Read Ch. 23.1-8

2) Ch. 23 Electric Potential

- a. Potential and Potential Energy of point charge systems
- b. Potential due to extended charge distributions
- c. How to find E_x, E_y, E_z from $V(x,y,z)$

Notes: Exam I on Wednesday, Ch. 21-23.

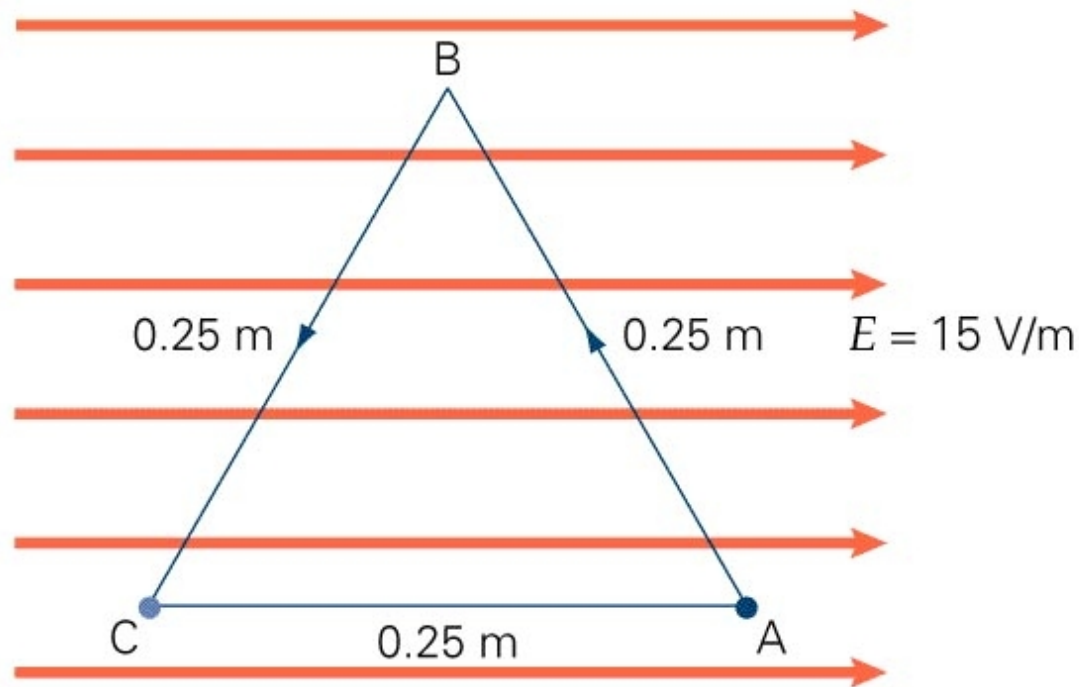
See online “Review for Exam I” (equations)

Review on Monday

Observatory event 8:30-10:30

Problem: closed loop path, ABCA

- Work done is path independent (\mathbf{F}_E is conservative!)
 - Only the initial and final position matter (for $\Delta U, \Delta V, W_{\text{field}}$)
 - Look for an easy solution!
 - True even if E is non-uniform!



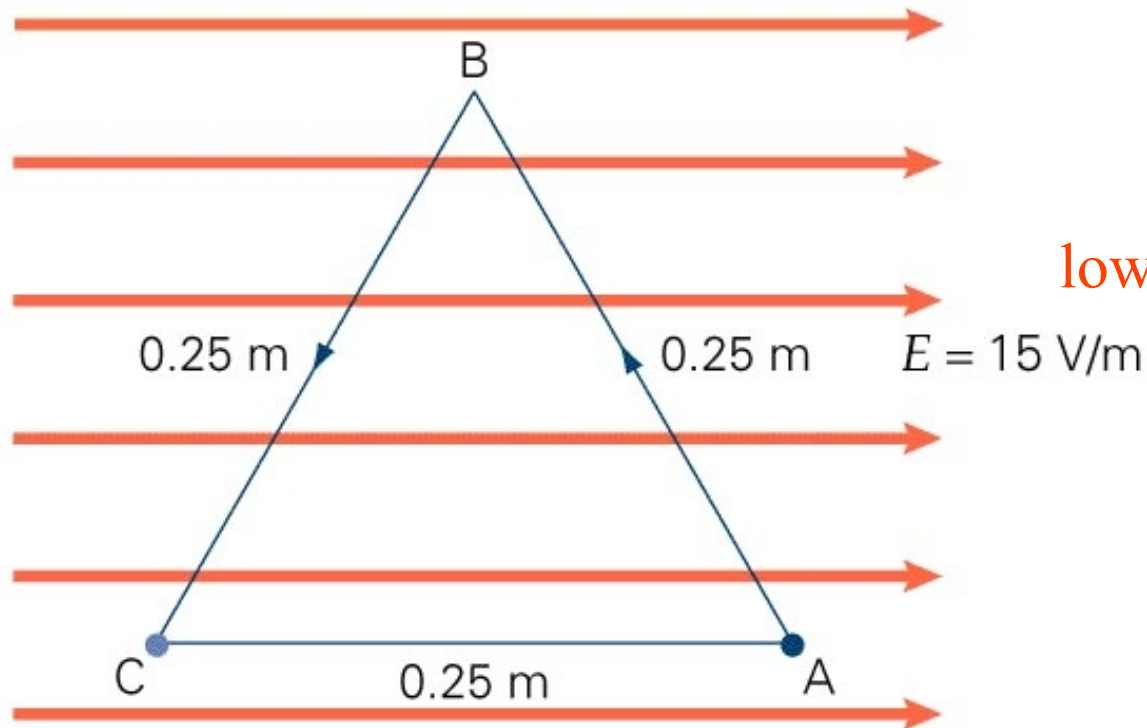
Problem: find ΔV and ΔU along path ABC

Higher V

lower V

Most general:

$$\Delta V = - \int \vec{E} \cdot d\vec{R}$$



$$\Delta V_{ABC} = \Delta V_{AC} = -Ed \cos 180 = \left(15 \frac{\text{V}}{\text{m}}\right)(0.25 \text{ m}) = 3.75 \text{ V}$$

If $q = -e$:

$$\Delta U = q\Delta V = (-1.6 \times 10^{-19} \text{ C})(3.75 \text{ V}) = -6 \times 10^{-19} \text{ J}$$

Problem: find V 's on equipotentials if $V_A = 0$.

$$V_1 - V_5 = 3.75 \text{ V}$$

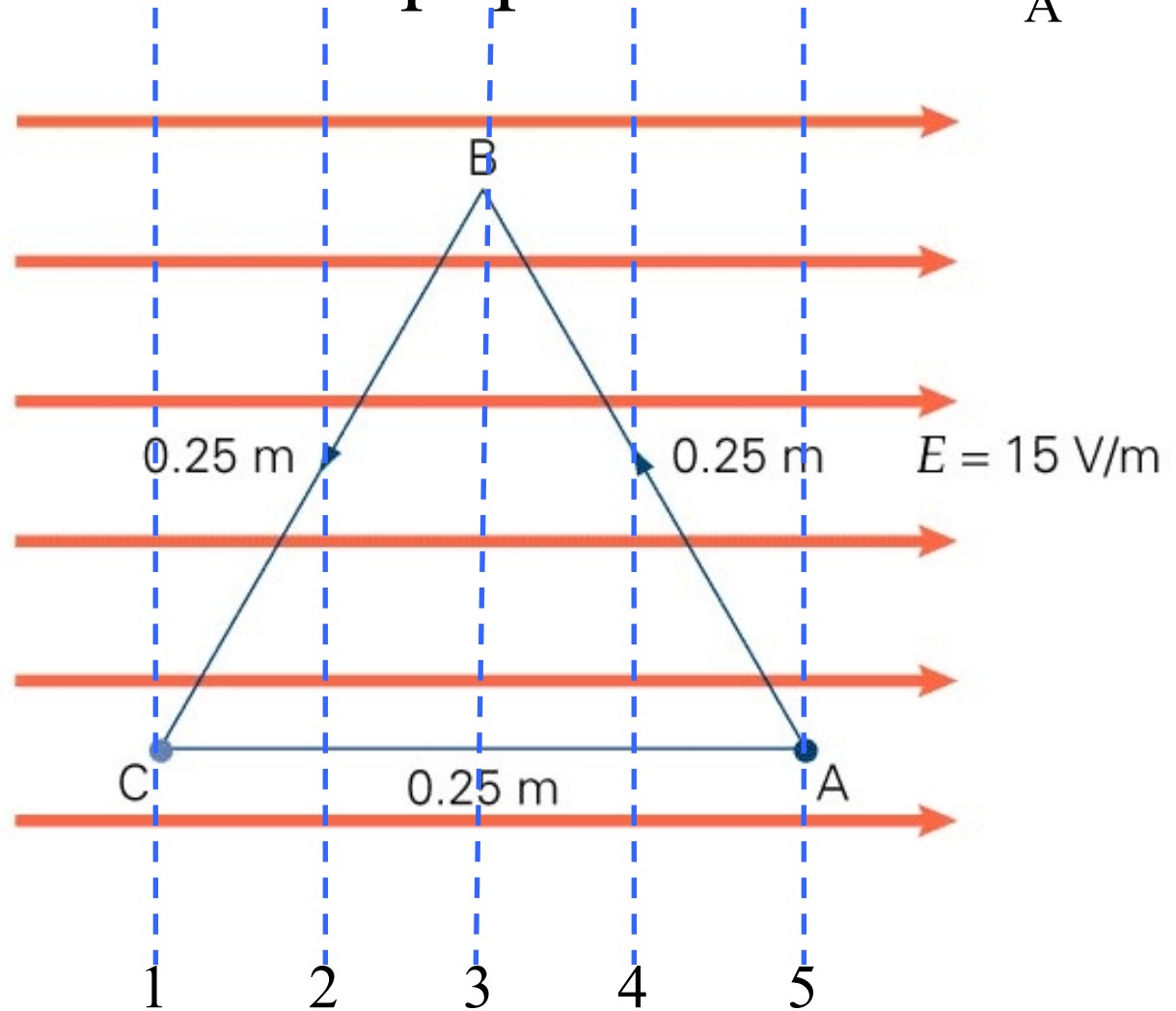
$$V_1 = 3.75 \text{ V}$$

$$V_2 = 2.8125 \text{ V}$$

$$V_3 = 1.875 \text{ V}$$

$$V_4 = 0.9375 \text{ V}$$

$$V_5 = 0 \text{ V}$$



Electric Potential Energy U_E

- Building up arrangements of charge
 - Energy required to “build” = ΔU
- Bring a point charge in from infinity
 - like charges requires energy
 - repulsive forces
 - unlike charges give up energy
 - attractive forces

$$W = Fd = qEd$$

$$\text{and } E = \frac{kq}{r^2}$$

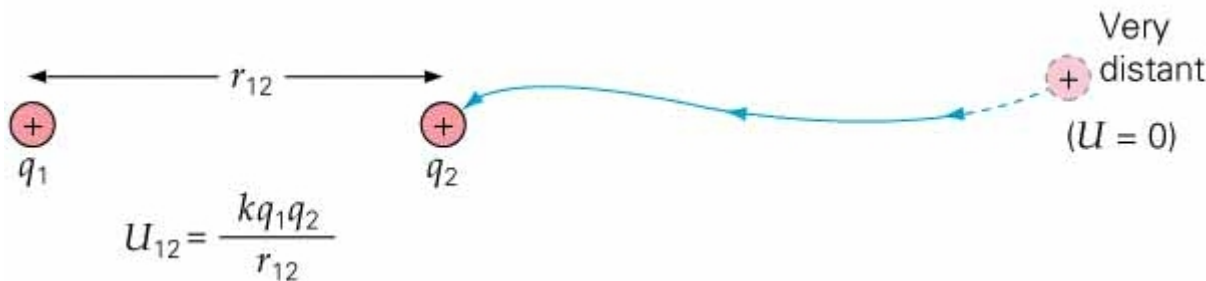
...are difficult to use
since E is not a
constant.

Can use:

$$U_{12} = \Delta U_{12} = q_2 \Delta V_{\infty 1}$$

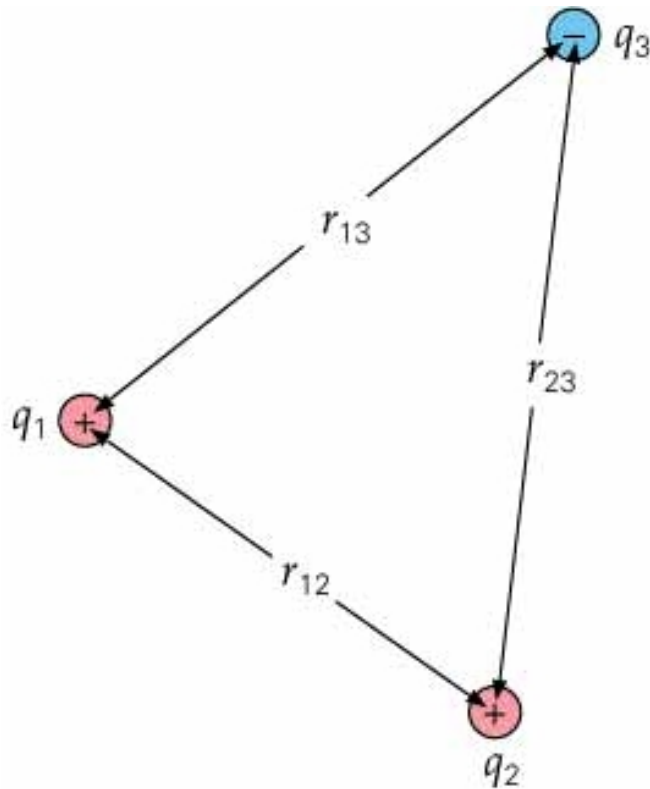
$$V_{\infty} = 0$$

$$V_1 = k \frac{q_1}{r_{12}}$$



U_E for more than two charges

- Don't double count
- Bring each one in from “infinity”
- Bringing together like charges requires energy (force them together)
- Bringing together un-like charges gives up energy (fall together naturally)



$$U_{\text{total}} = U_{12} + U_{23} + U_{13}$$

(b)

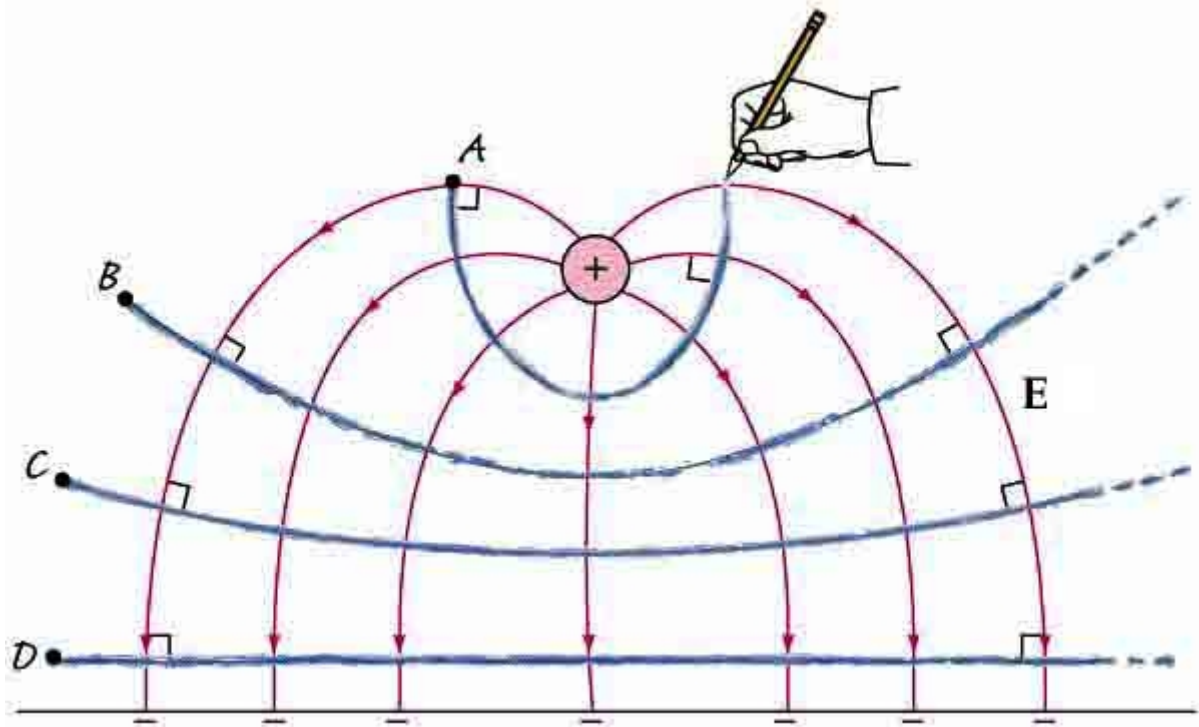
$$U_{12} = k \frac{q_1 q_2}{r_{12}}$$

$$U_{23} = k \frac{q_2 q_3}{r_{23}}$$

$$U_{13} = k \frac{q_1 q_3}{r_{13}}$$

Equipotential Surfaces

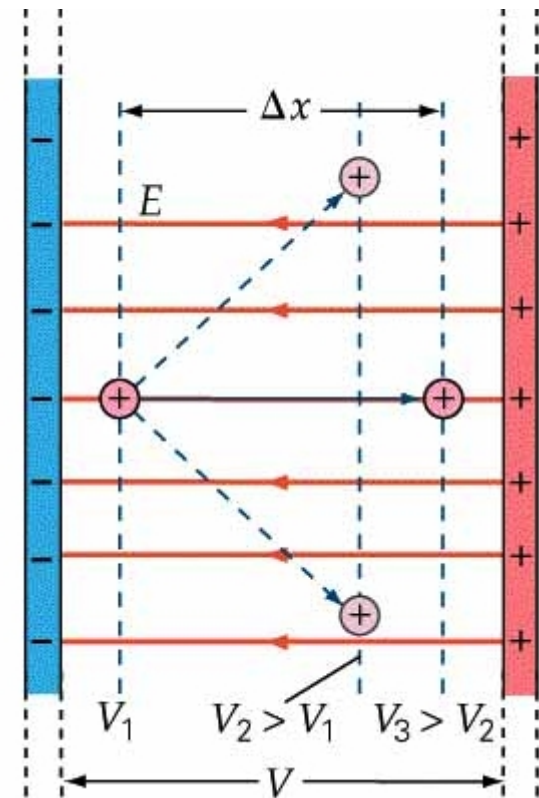
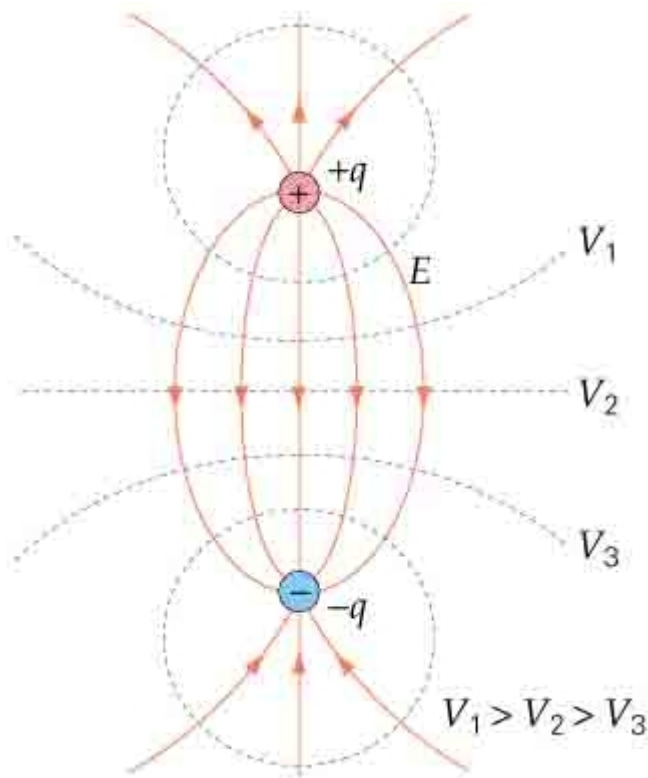
- E field is perpendicular to the equipotential surfaces
- The surface of a conductor is an equipotential surface
 - no E field parallel to the surface in *Electrostatics*
 - gradually “match” the boundaries



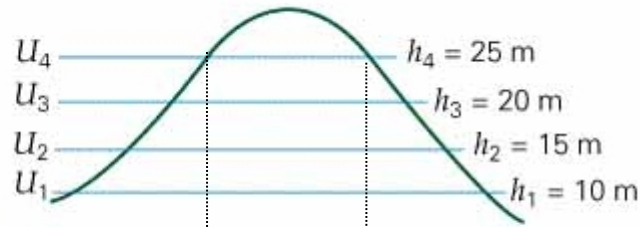
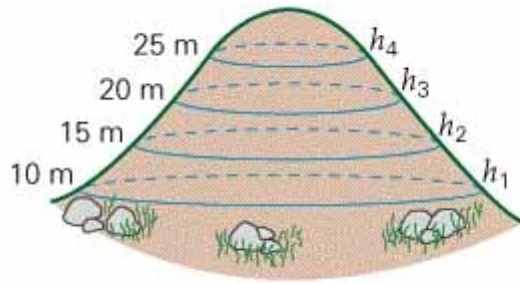
Equipotential Surfaces

Equipotentials are perpendicular to the E-field lines.

E field points “down hill”



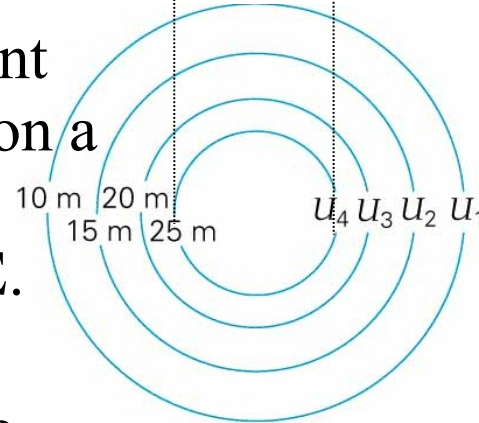
Contours of a map analogy



(a)

Lines of equal altitude are lines of equal gravitational potential energy. This is *like* lines of equal potential.

The net force on a boulder will point downhill. Similarly, the net force on a positive test charge will point “down hill” in direction of \mathbf{F} and \mathbf{E} .

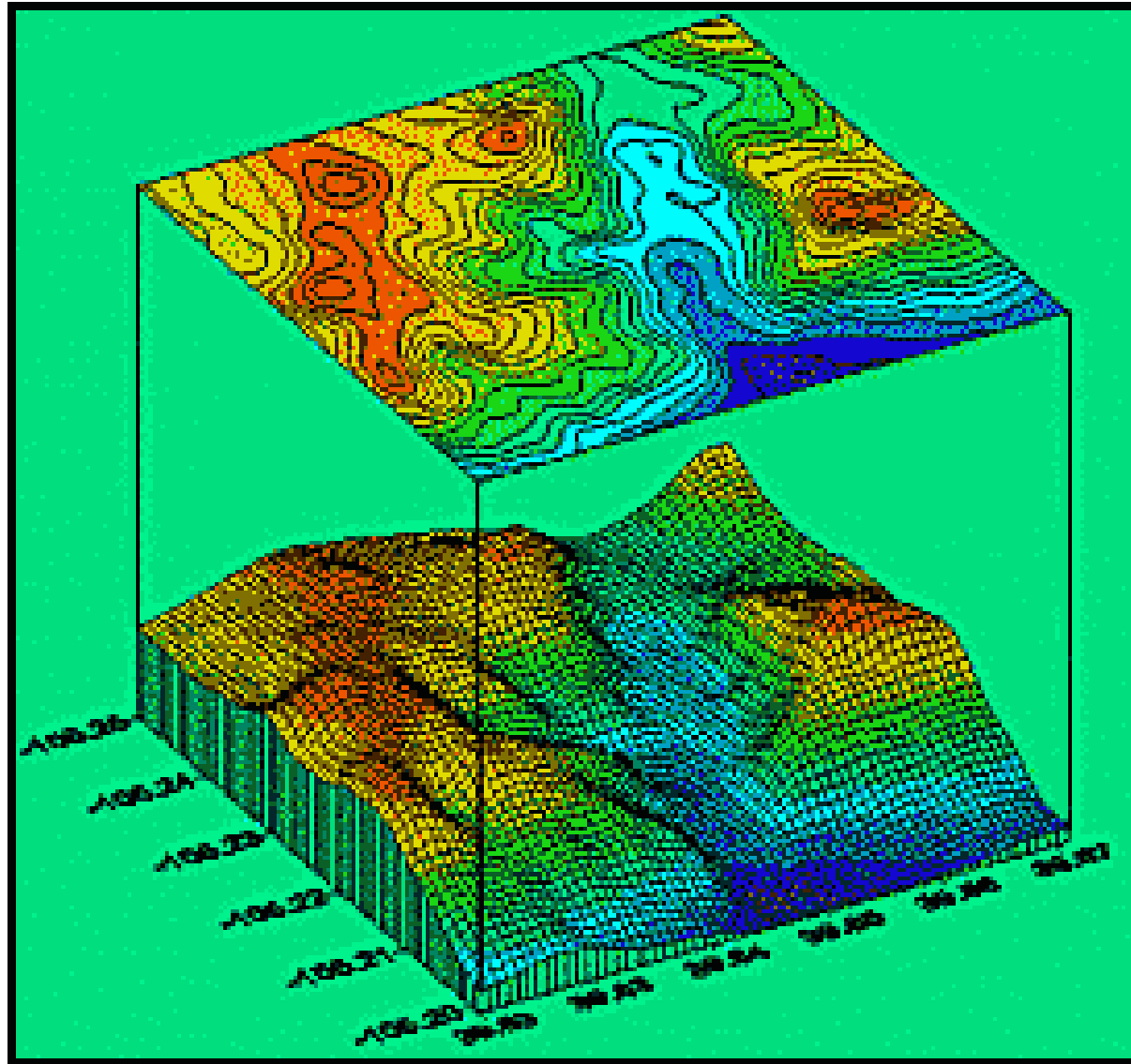


(b)

The steeper the hill the stronger the forces and fields!

Expect $\Delta V / \Delta r \sim E$ and F

A topographical map of land.



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Week5: Electric Potential

Day 6 Outline

1) Hwk: Ch. 23 P. 2,3,5,9,12,15,17,21,25,28,29,35,36,43,
48,51. MCQ 1-13 odd (Due today <2:30pm)

Study for Exam!

Next: Read Ch. 24.1-5

2) Return Hwk Ch. 22, mean=9.6/10. Checked P.10,20

3) Ch. 23 Electric Potential

a. How to find E_x, E_y, E_z from $V(x,y,z)$

4) Exam I description.

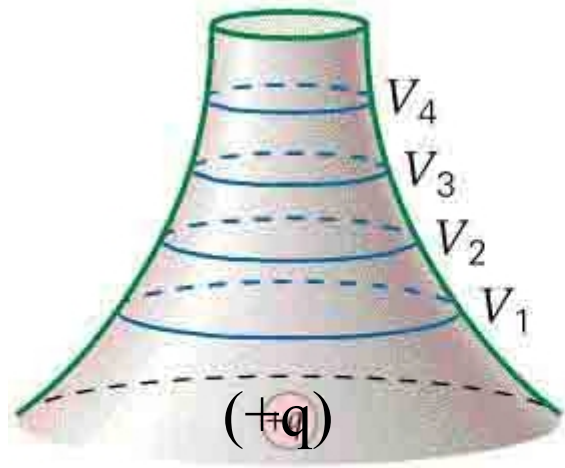
a. Review problems.

Notes: Exam I on Wednesday, Ch. 21-23.

See online “Review for Exam I” (equations)

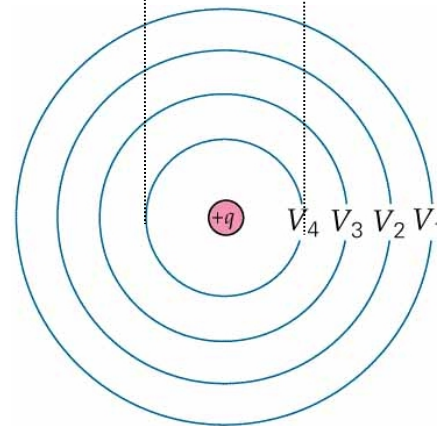
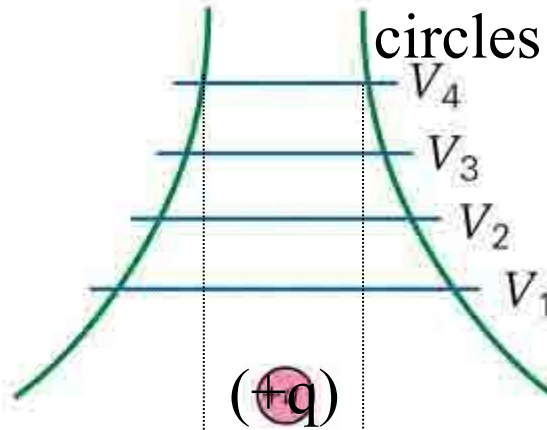
See key for Ch. 23 hwk (and others)

Analogy with Gravity and hills



(c)

E field points “down hill”
perpendicular to the
circles



(d)

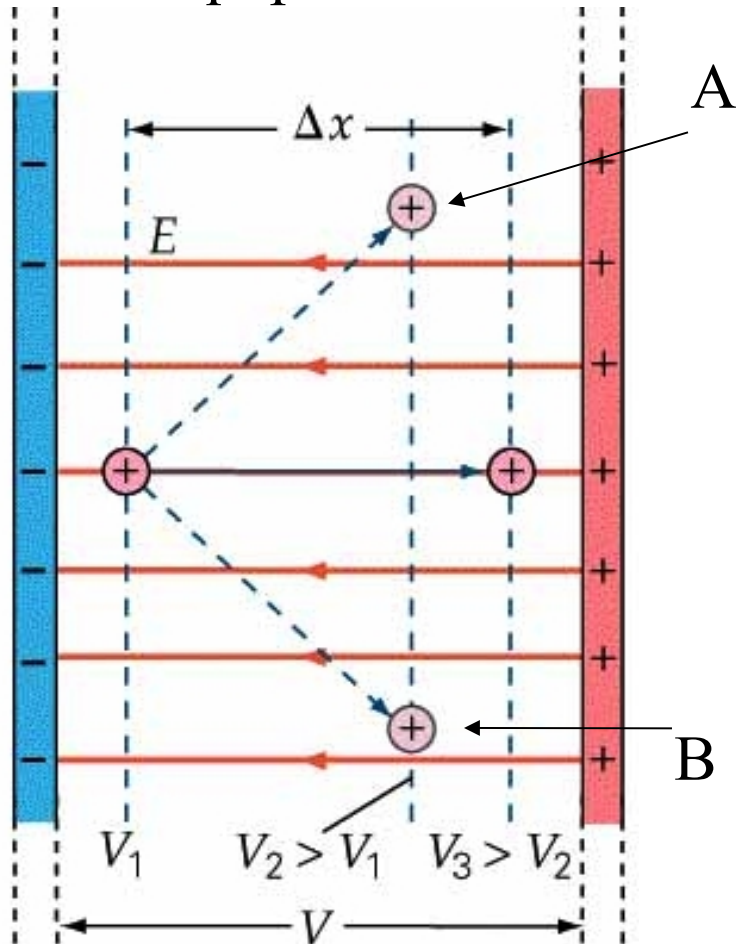
Field gets stronger closer to the
point charge. Don't have to go
as far to have the same change
in electric potential

$$E_r = - \left(\frac{dV}{dr} \right)$$

Slightly
misleading (circles
would not be evenly
spaced for $V \sim 1/r$)

Equipotential Surfaces

- Imaginary or real surfaces of constant voltage
 - The surfaces of a conductor are equipotential surfaces
- E field and equipotential surfaces are perpendicular to each other



If a charge moves from A to B along an equipotential surface, then

$$\Delta V_{AB} = 0$$

$$\Delta U_{AB} = q\Delta V_{AB} = 0$$