PHYS2321

Week4: (Finish Gauss' Law) and Electric Potential

Day ~~2~~ 1 Outline

1) Hwk: Ch. 22 P. 1,2,5,6,9,10,13,17,19,20,35 MCQ. 1-9 odd.
   Due <3pm
   Ch. 23 P. 2,3,5, (more to come)
   Read Ch. 23-1 to 23-8

2) Gauss' Law – find E-fields near extended charge distributions
   a. Line charge
   b. Cylindrical charge distribution
   c. Nested spherical shells

3) Electric Potential

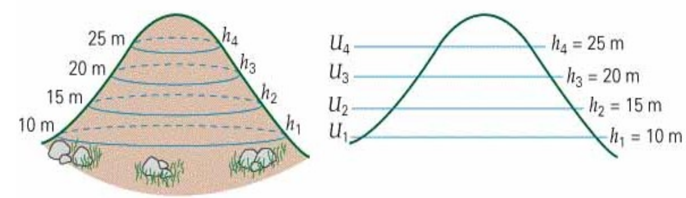
Notes: PDF version of week3 PPT was updated 9/11
   Today is last day to ~~W~~ drop

PHYS2321
Week4: (Finish Gauss' Law) and 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 Mon)
Read Ch. 23-1 to 23-8

2) Electric Potential
   Electric Potential Energy U_E
   Comparison to gravity
   Electric potential (or voltage) V
   Relation to E-field



(a)

Notes: Return Hwk 2 Mean=8.9/10. Checked #33,55.
Key to Hwk 2 online.
Quiz 2 this Friday on Gauss’s law and flux.
PDF version of this week4 PPT online.
Try “Ch. 23 Test Bank Practice” online.

Electric Potential

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

Electric Potential of Point Charges

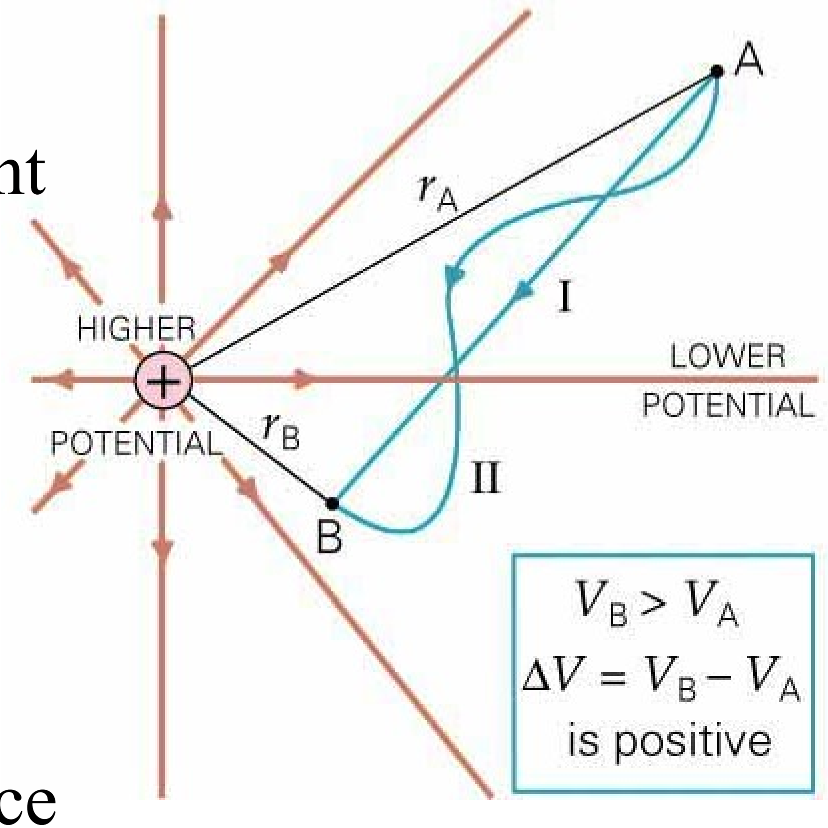
- E field

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

- Electric Potential of a point charge

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

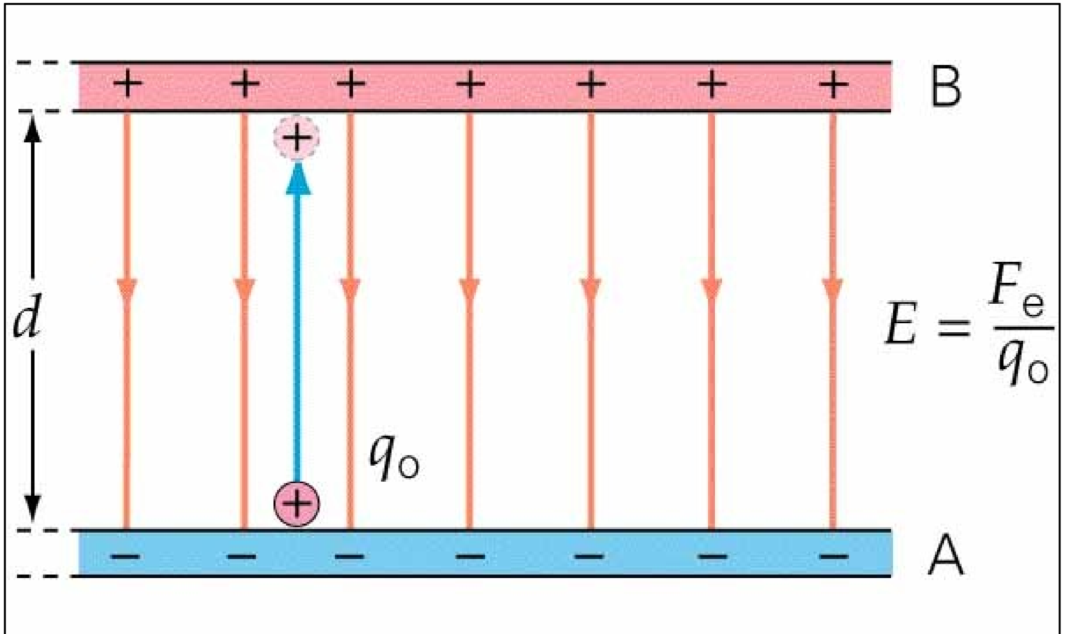
$$V = 0 \quad \text{when} \quad r \rightarrow \infty$$



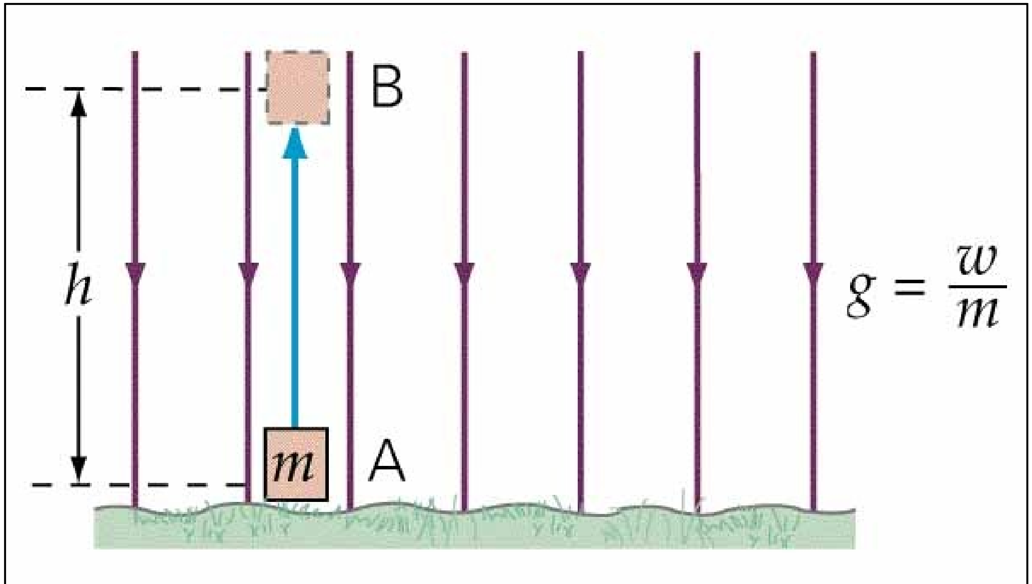
- Electric potential difference

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

Analogy with gravity



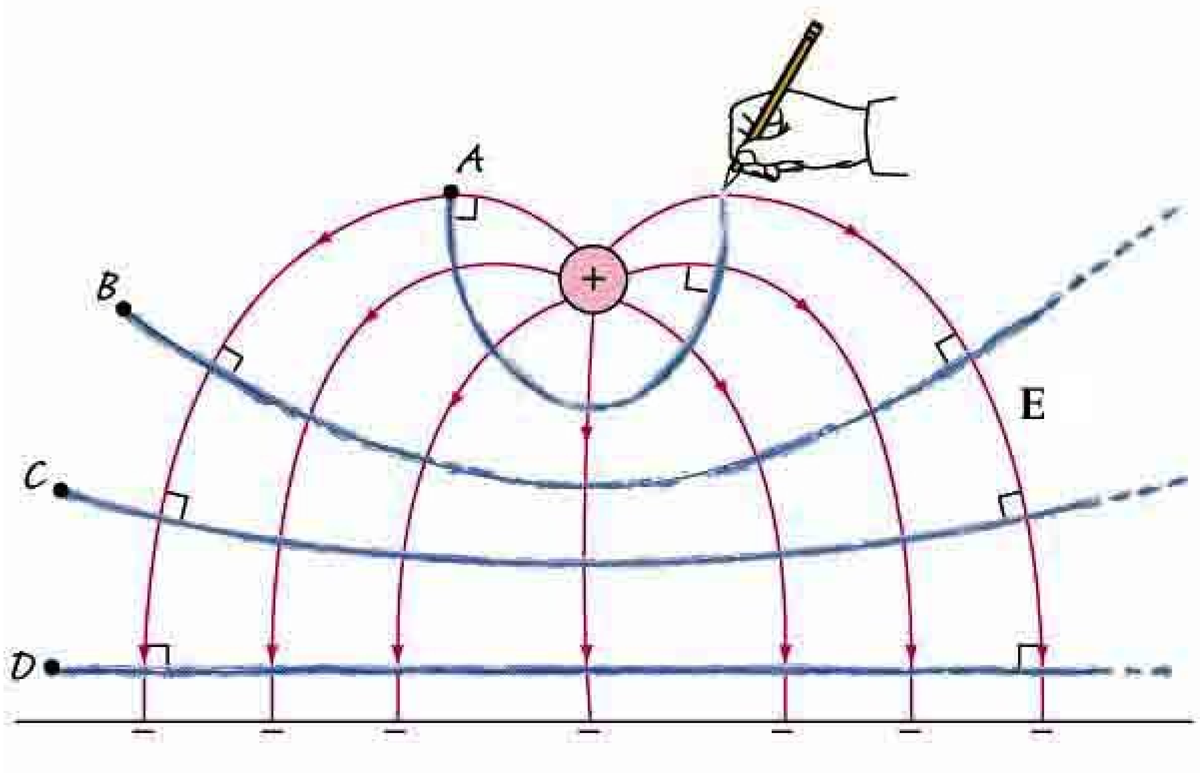
(a)



(b)

Equipotential Surfaces

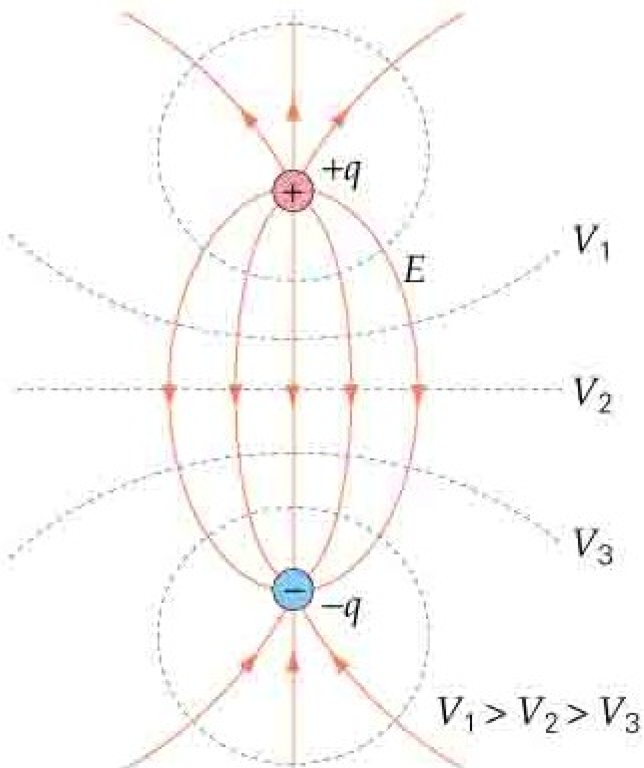
- E field is perpendicular to the equipotential surfaces
- The surface of a conductor is an equipotential surface
  - no E field parallel to the surface in *Electrostatics*
  - gradually "match" the boundaries

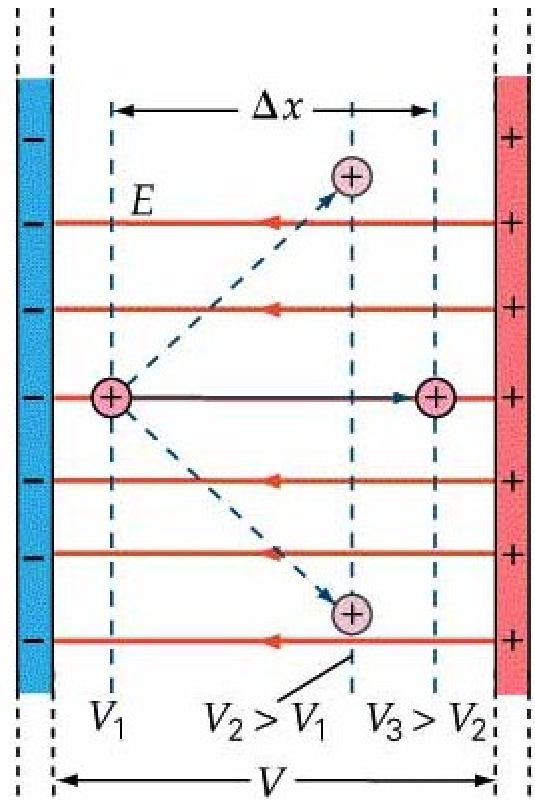


Equipotential Surfaces

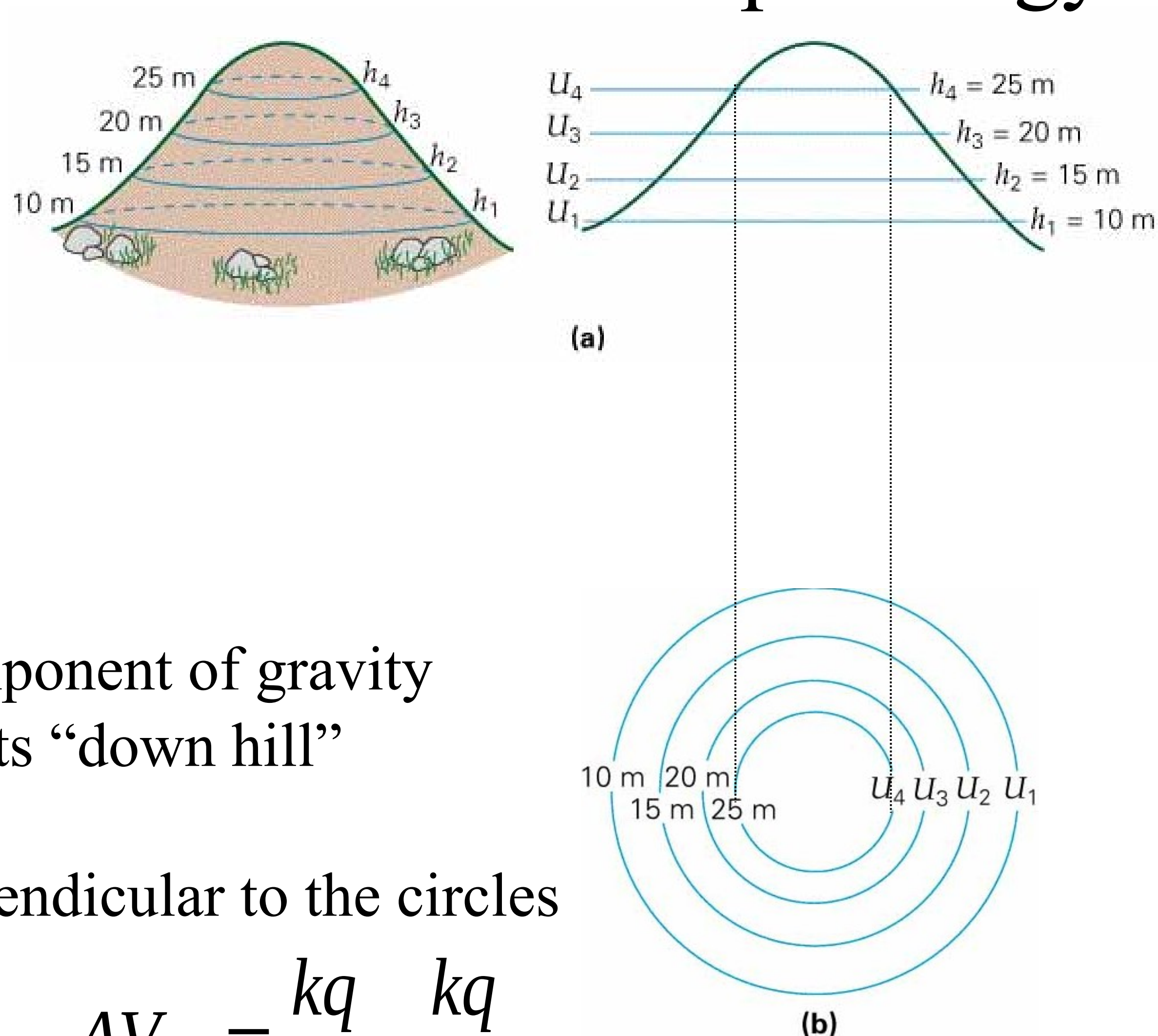
E field points “down hill”

perpendicular to the equipotential surfaces





Contours of a map analogy



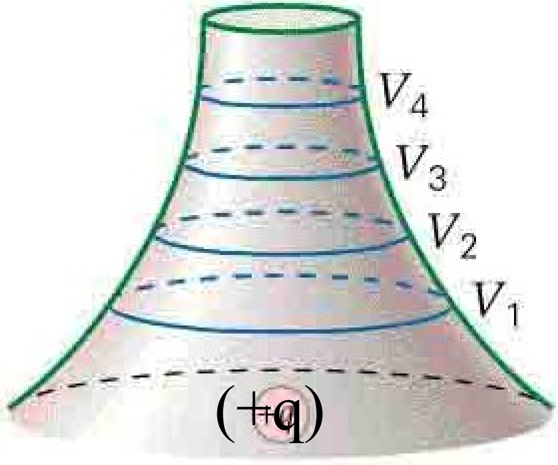
Component of gravity points "down hill"

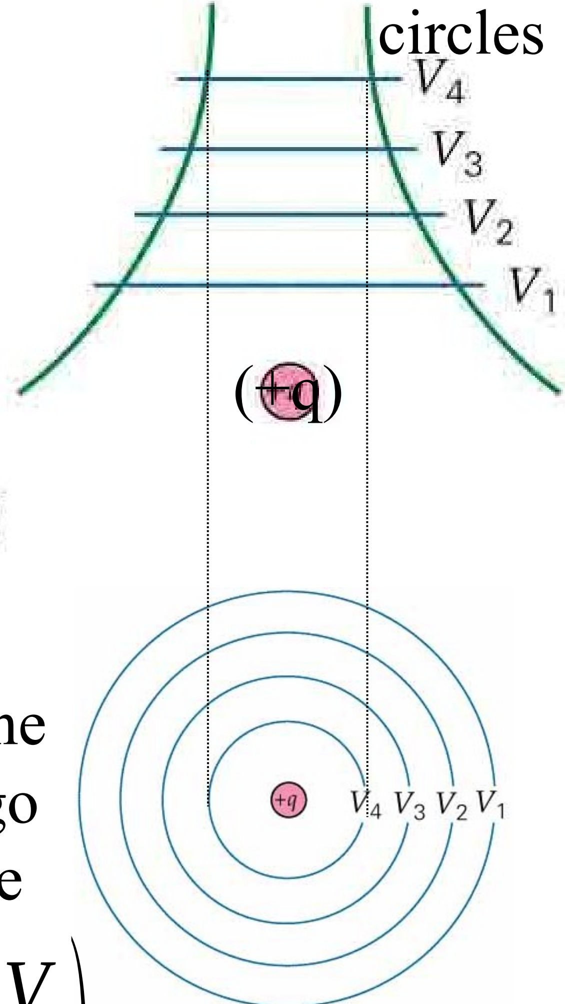
perpendicular to the circles

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

Analogy with Gravity and hills

E field points "down hill" perpendicular to the circles





(c)

(d)

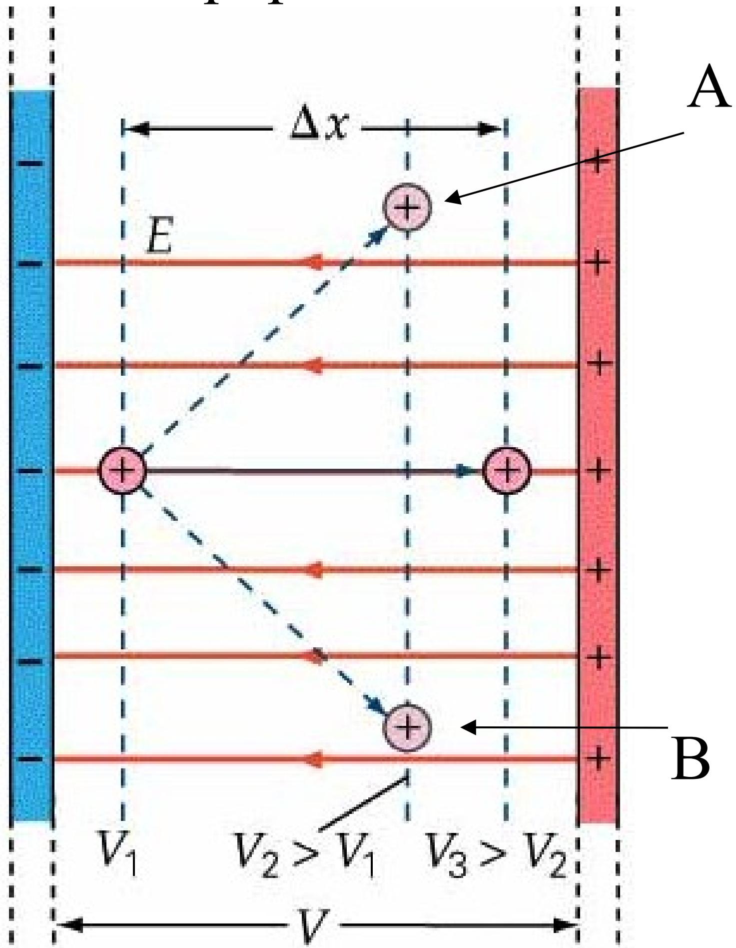
Field gets stronger closer to the point charge. Don't have to go as far to have the same change in electric potential

$$\Delta E = -\left(\frac{\Delta V}{\Delta x}\right)_{\max}$$

Slightly misleading

Equipotential Surfaces

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



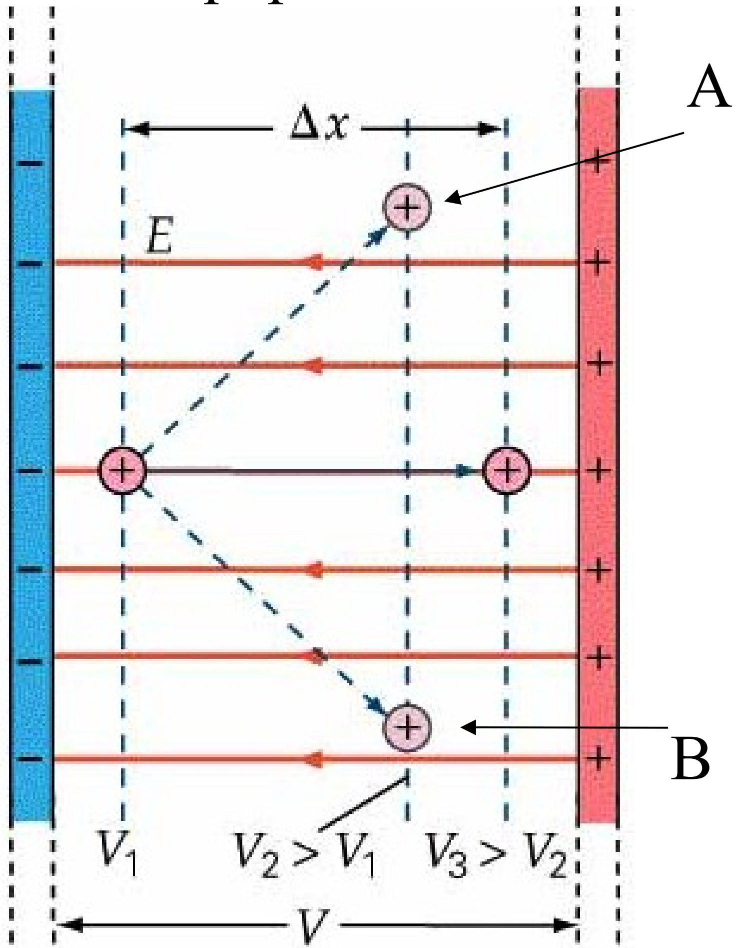
If a charge moves from A to B along an equipotential surface, then

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

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

Equipotential Surfaces

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



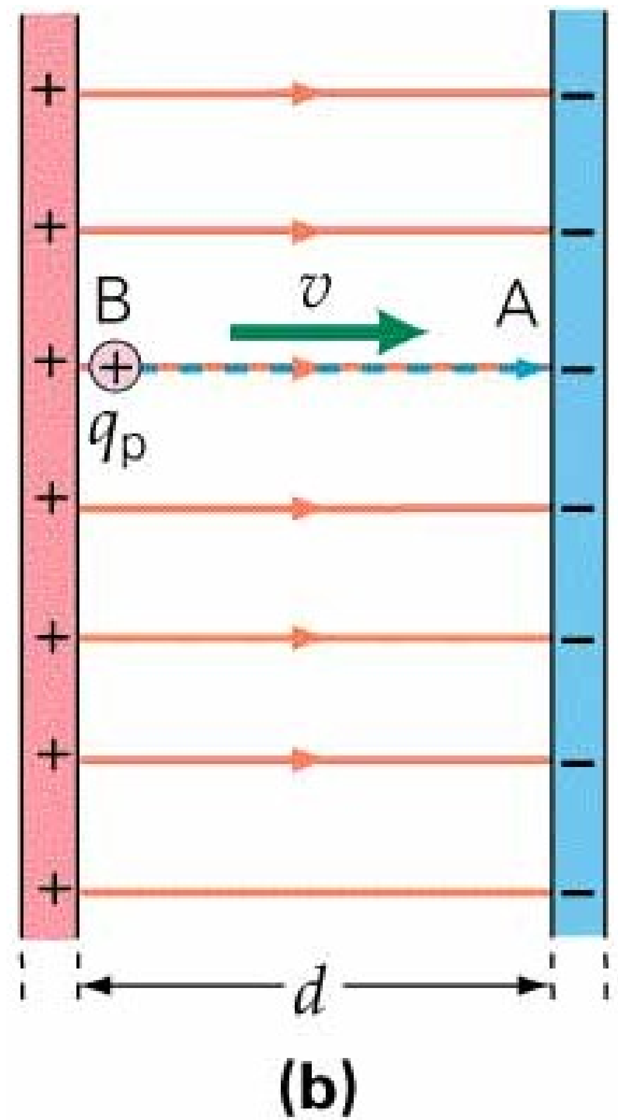
If a charge moves from A to B along an equipotential surface, then

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

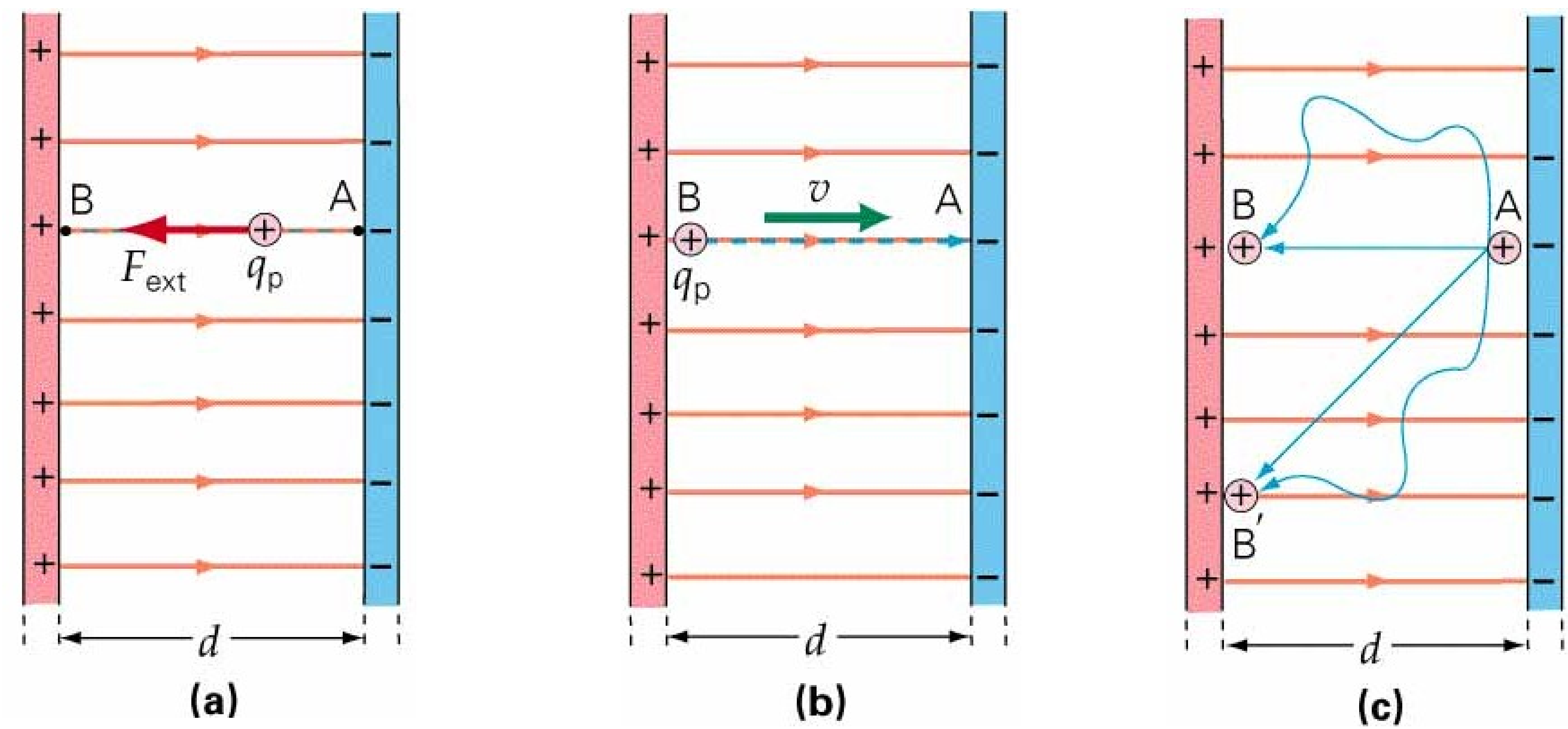
$$\Delta U_{AB} = q\Delta V_{AB} = 0$$

Parallel Plates

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



Electric Potential Energy (conservation of energy ideas)



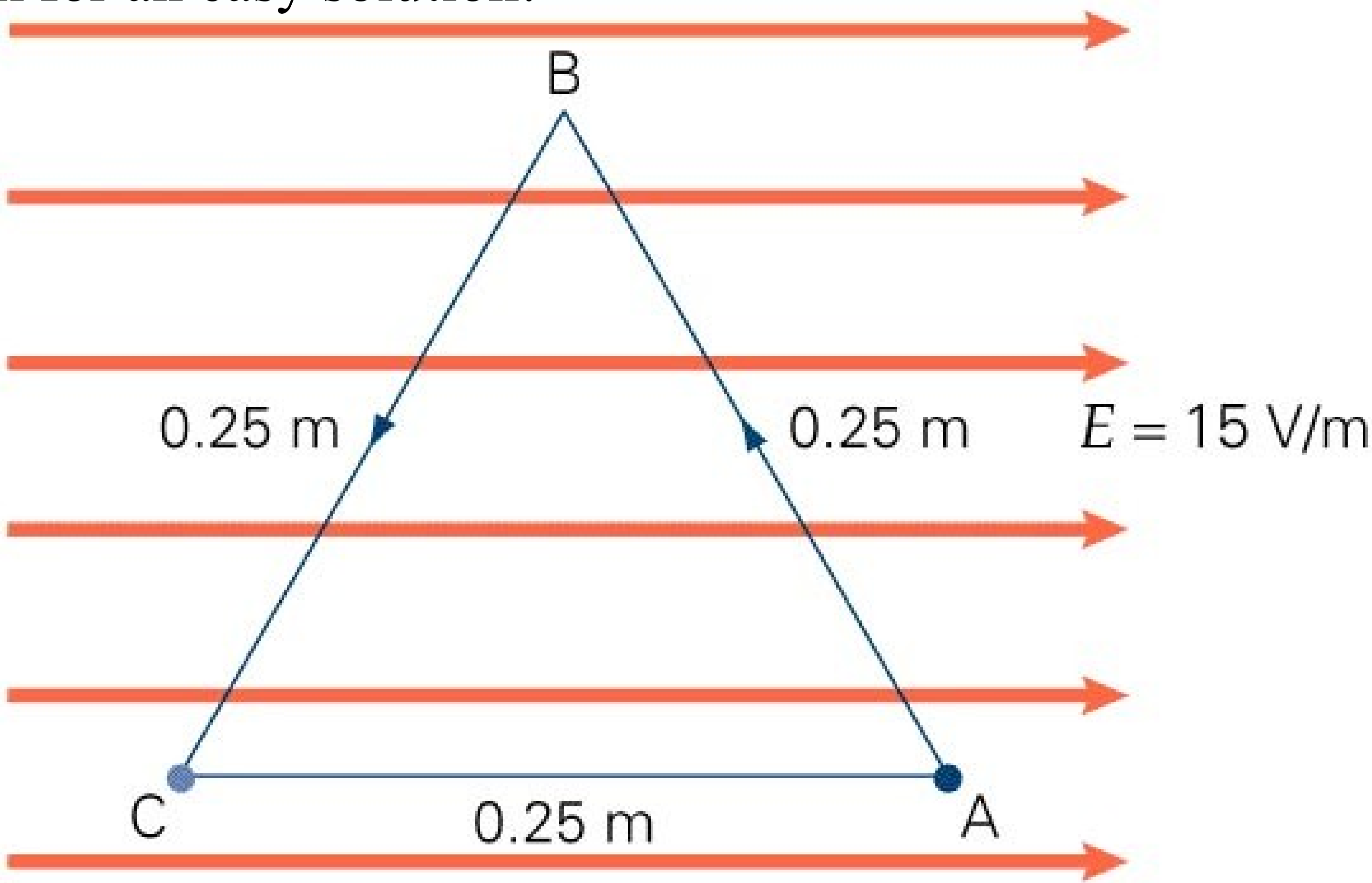
Work is done to move the charge, so we store potential energy

Charge is released and energy is converted from electric PE to KE

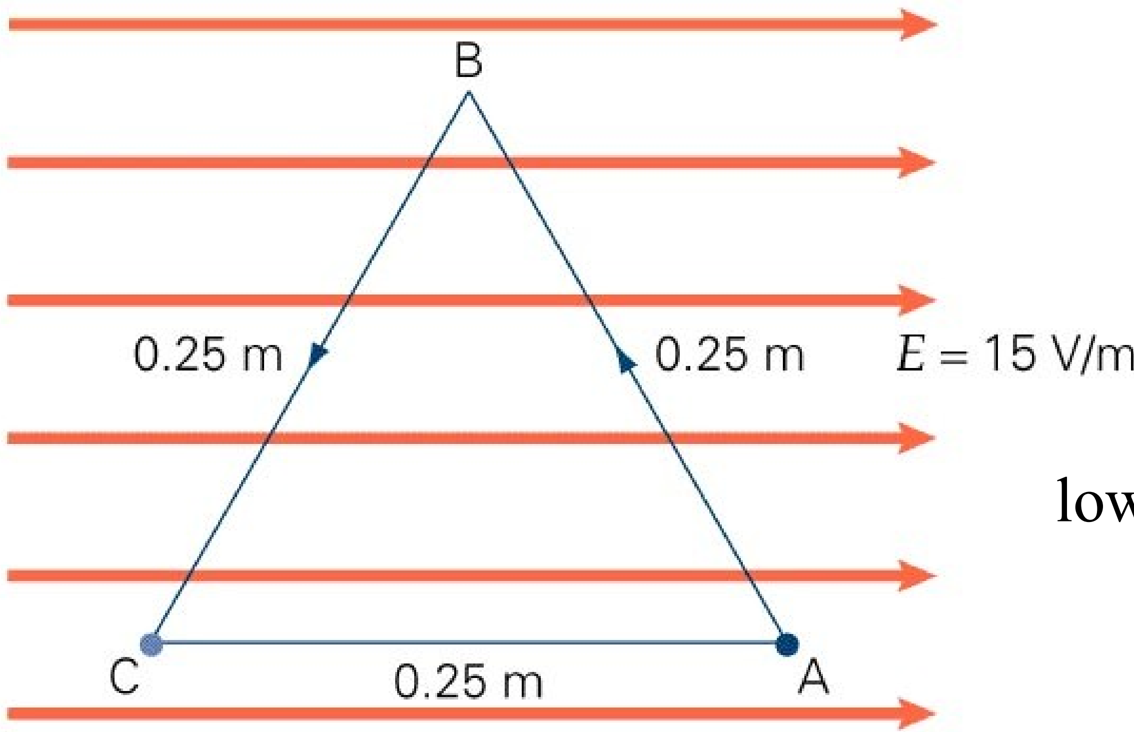
Only the displacement in the direction of the E field matters (independent of path)

Problem: closed loop path, ABCA

- Work done is path independent
  - Only the initial and final position matter
  - Look for an easy solution!



Problem: find V's and ΔV's



Higher V

lower V

$$E=\frac{\Delta V}{d}\Rightarrow \Delta V=Ed=\left(15\frac{V}{m}\right)(0.25\,m)=3.75\,V$$

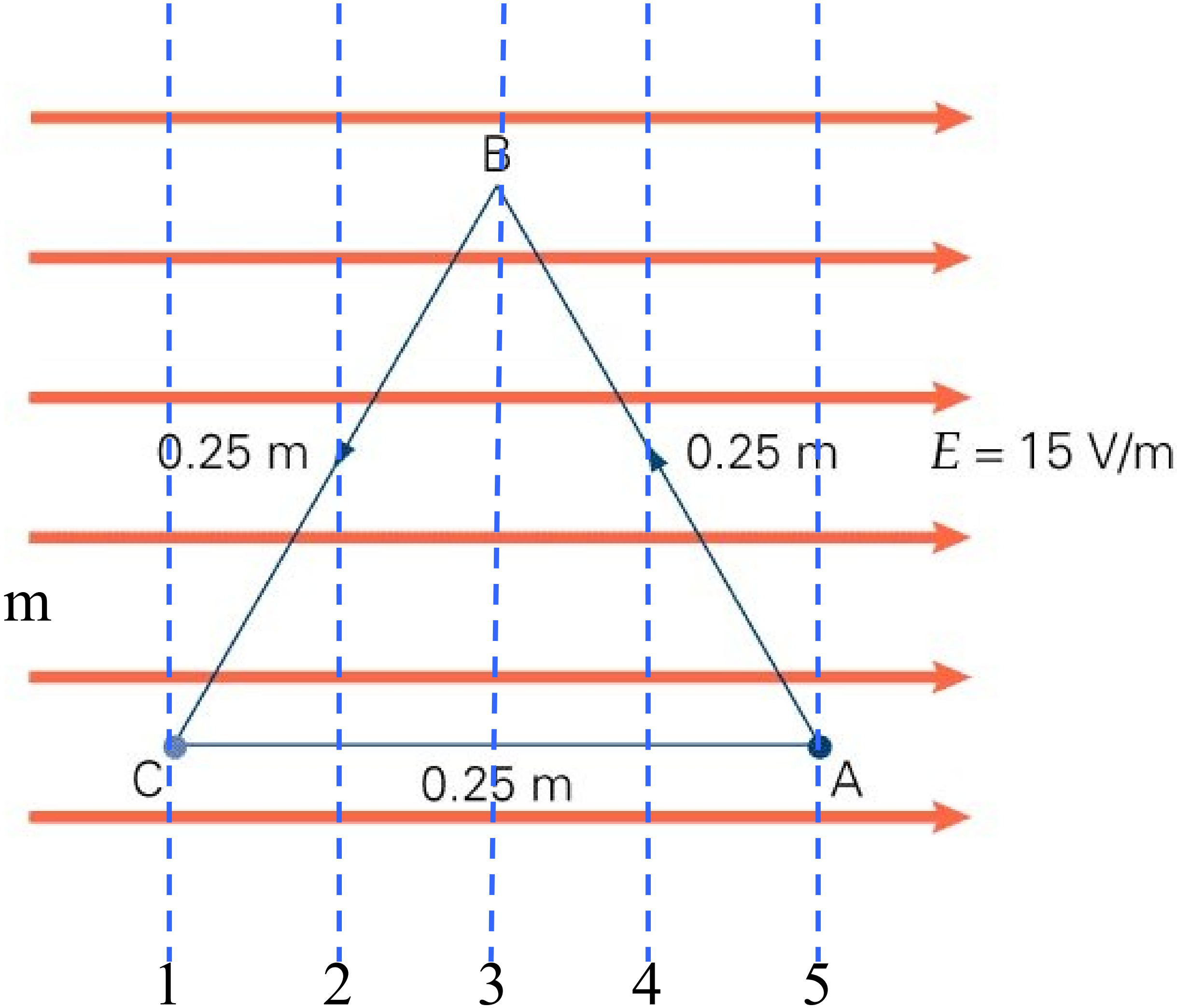
$$\Delta U=q\Delta V=\left(-1.6\times 10^{-19}C\right)(3.75\,V)=-6\times 10^{-19}J$$

Problem: find V's and ΔV's

$V_1 - V_5 = 3.75$ V

Let $V_1 = 3.75$ V
and $V_5 = 0$ V

Distance between surfaces is
(0.25 m)/4 =0.0625 m



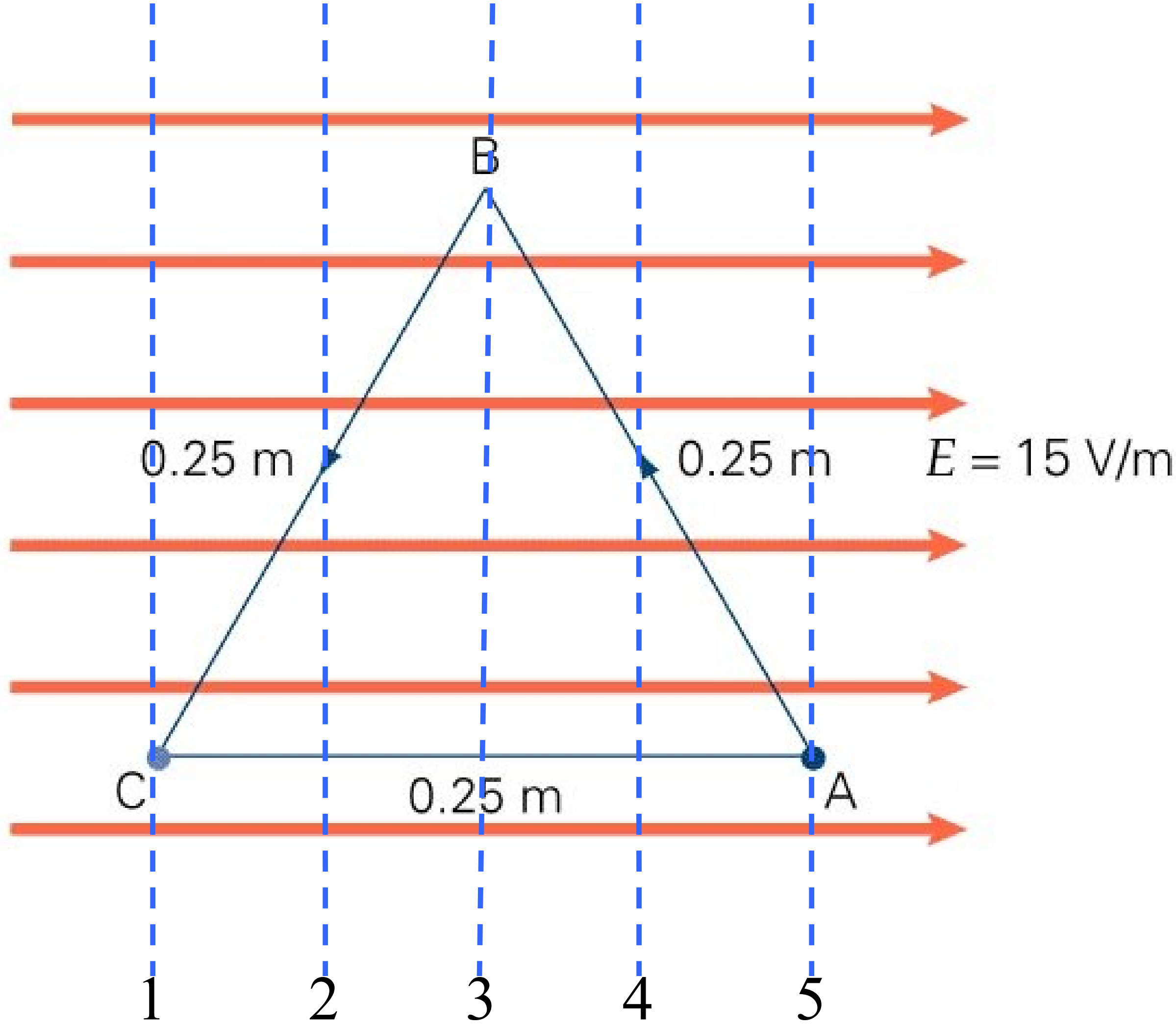
$$\Delta V_{12} = V_1 - V_2 = Ed = \left(15\frac{V}{m}\right)(0.0625\,m) = 0.9375\,V$$

$$V_2 = V_1 - \Delta V_{12} = 3.75\,V - 0.9375\,V = 2.8125\,V$$

Problem: find V and ΔV

$V_1 - V_5 = 3.75$ V

$V_1 = 3.75$ V
$V_2 = 2.8125$ V
$V_3 = 1.875$ V
$V_4 = 0.9375$ V
$V_5 = 0$ V



Electric Potential Energy

- 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

$$W = Fd = qEd$$

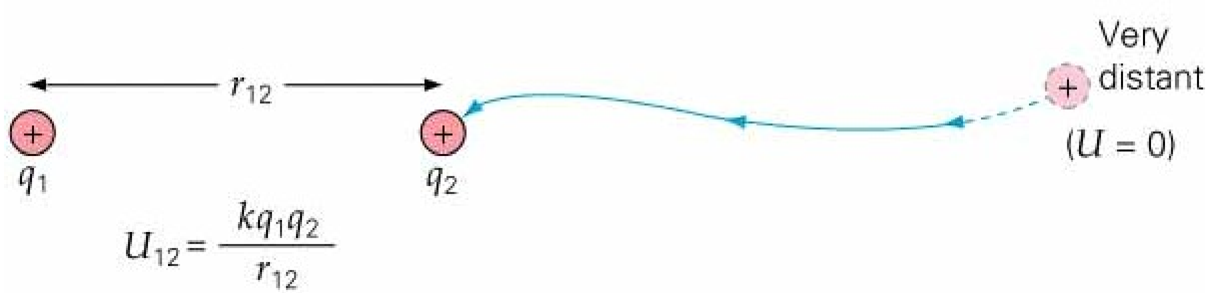
and $E = \dfrac{kq}{r^2}$

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

Can use:

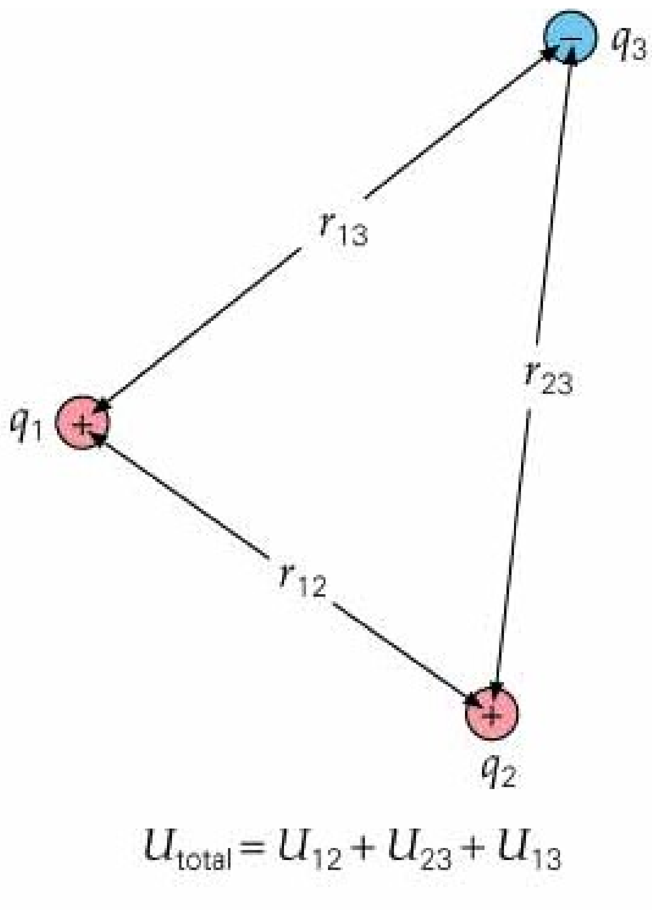
$$\Delta U_{12} = q\Delta V_{12}$$

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



More than two charges

- Don't double count
- Bring each one in from "infinity"



(b)

- Bringing together like charges requires energy (force them together)
- Bringing together un-like charges gives up energy (fall together naturally)