PHYS 2321
Week4: Electric Potential

Day 1 Outline

1) Hwk: Ch. 25 P. 3,4,5,7,12,20,29,37,39,45,50 Due Fri
   Read Ch. 25.1-25.6 (skim sec 7-8)
2) Electric Potential (Ch. 25)
   a. Results from “Mapping E-fields” Lab
   b. Relate to Electric Potential Energy, $U=q_oV$
   c. Potential, $V = U/q_0$

Notes: Quiz Wednesday on Gauss’ Law.

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Week4: Electric Potential

Day 2 Outline

1) Hwk: Ch. 25 P. 3,4,5,7,12,20,29,37,39,45,50 Due Fri
   Read Ch. 25.1-25.6 (skim sec 7-8)
2) Electric Potential (Ch. 25)
   a. ΔV and ΔU in a uniform E-field
   b. The eV
   c. V and ΔV near point charges
   d. U of point charge arrangments
3) Quiz (on Gauss' Law and flux) 11:36

Notes: Tutoring Thurs 7-9 pm, my office hours.
Exam I next Wednesday on Ch. 23-25.

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Week4: Electric Potential

Day 3 Outline

1) Hwk: Ch. 25 P. 3,4,5,7,12,20,29,37,39,45,50 Due tonight
   Read Ch. 25.1-25.6 (skim sec 7-8)

2) Review Quiz

3) Electric Potential (Ch. 25)
   a. The eV
   b. V and ΔV near point charges
   c. U of point charge arrangments
   d. Finding E from V
   e. V near continuous charge distributions

Notes: Exam I next Wednesday on Ch. 23-25.

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

  $dV = -\mathbf{E}\cdot d\mathbf{s}$ (integrate to find ΔV)
- Math with electric potentials is easier than with E-fields because V is not a vector.

Electric Potential of Point Charges

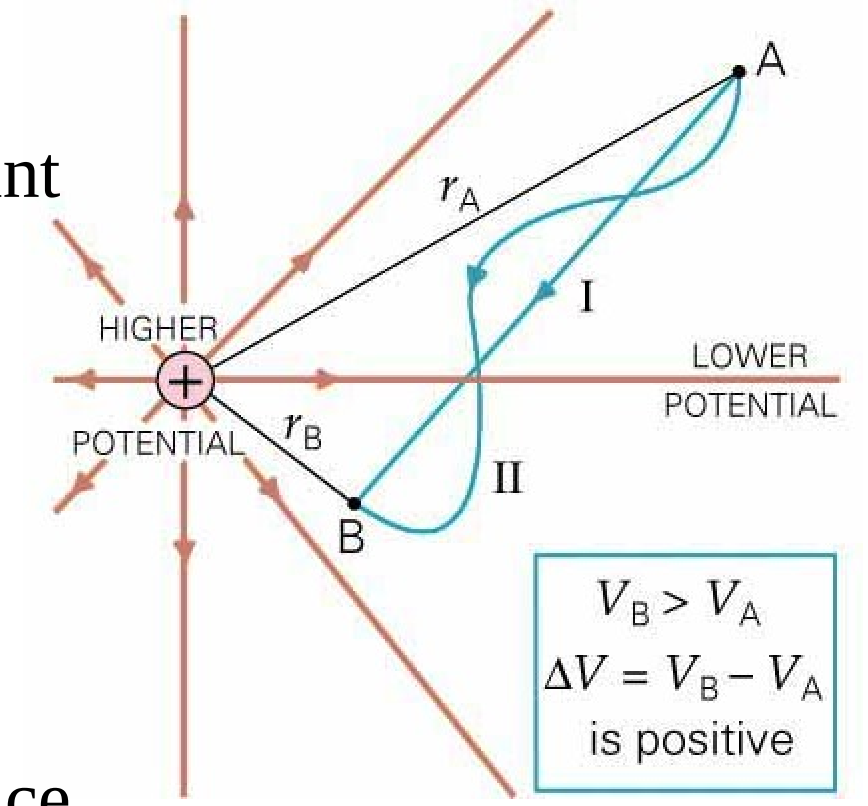
- E field of a point charge

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

- Electric Potential of a point charge

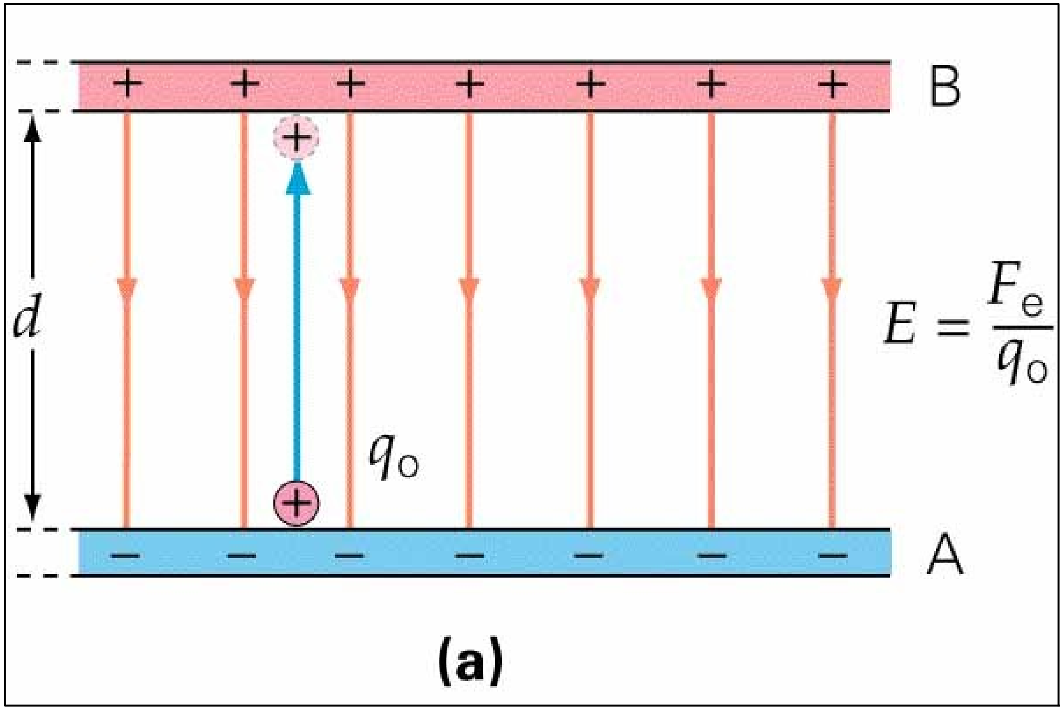
$$V = \frac{kq}{r}$$

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



- Electric potential difference

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

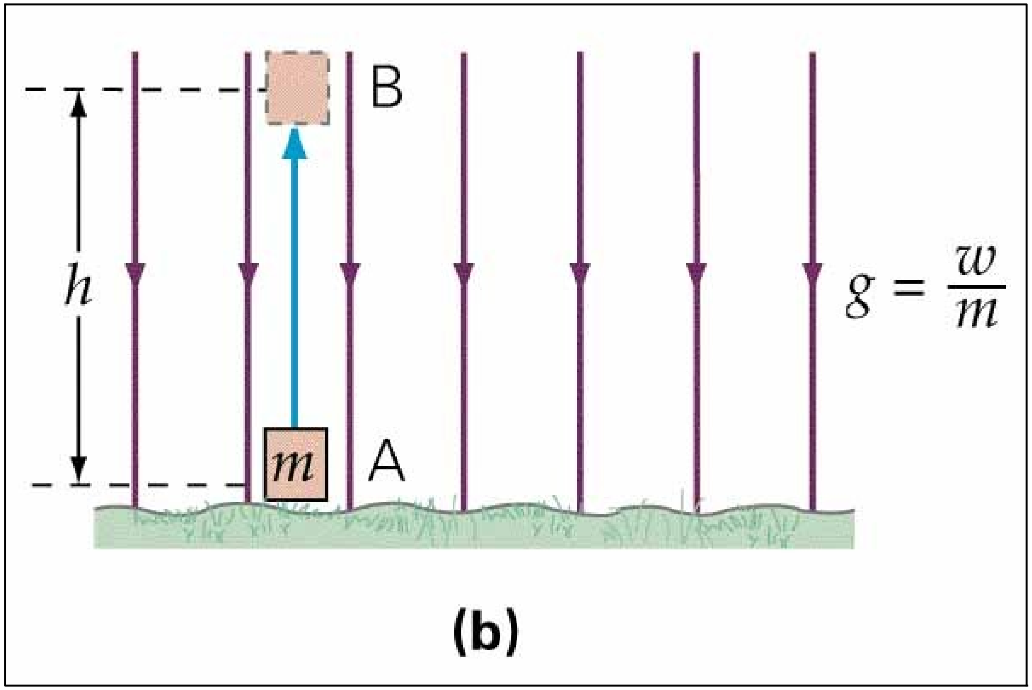


U_E depends on height of point charge, q_o.

+ charge is at a higher U_E when it is near the top plate.
(- charge is at a lower U_E when it is near the top plate.)
$\Delta U_E = -W_{\text{by E-field}}$

Analogy with gravity

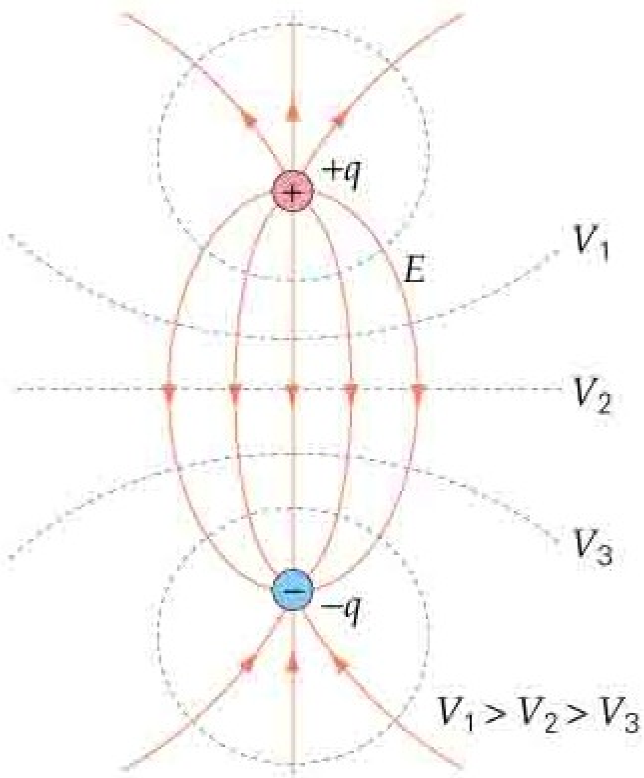
Mass is at a higher Ug when it is higher above the ground.
$\Delta U_{grav} = -W_{\text{by grav}}$

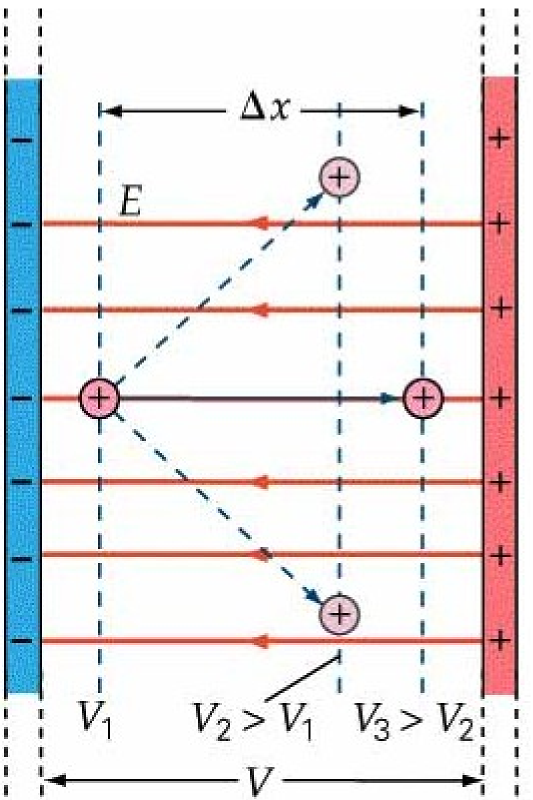


Equipotential Surfaces

Equipotential = a line of constant potential
Equipotential surface = a surface of constant potential

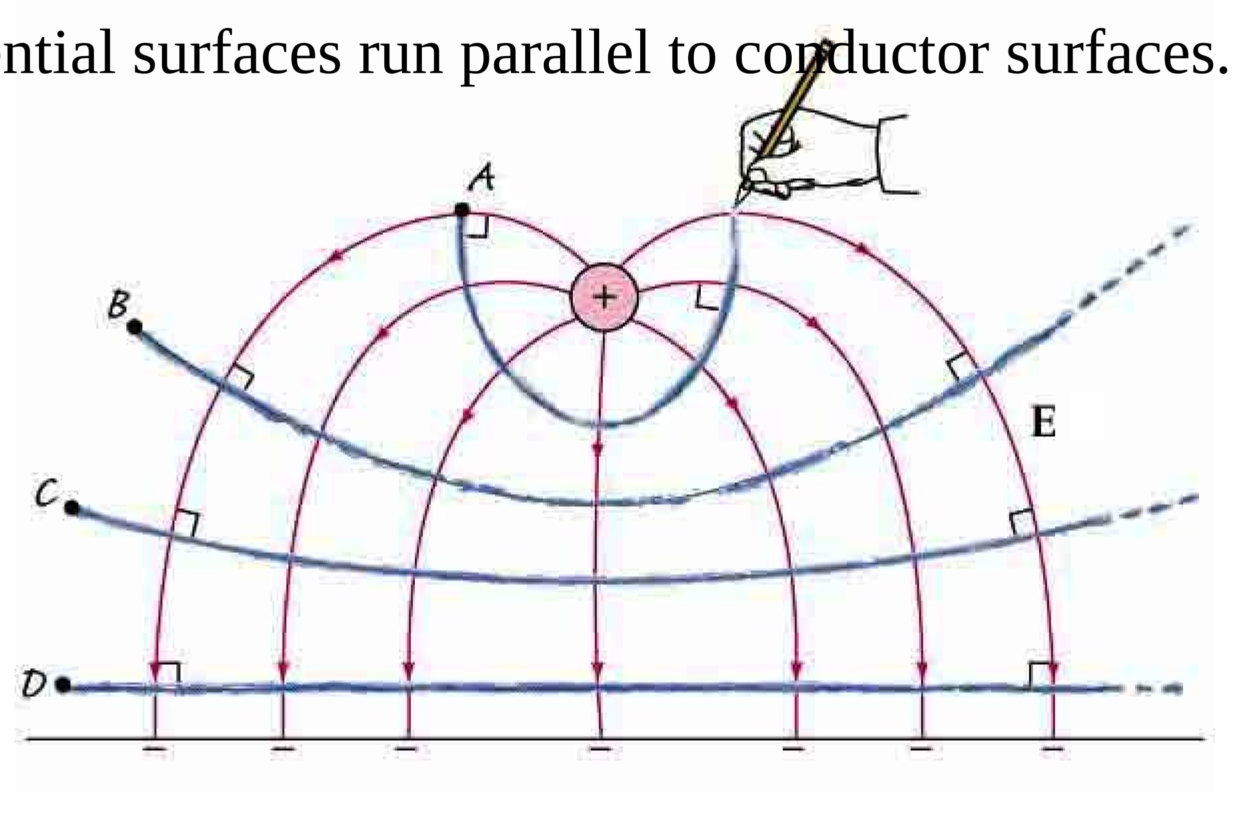
E field points "down hill" (from high potential to low potential) and runs perpendicular to the equipotential surfaces.





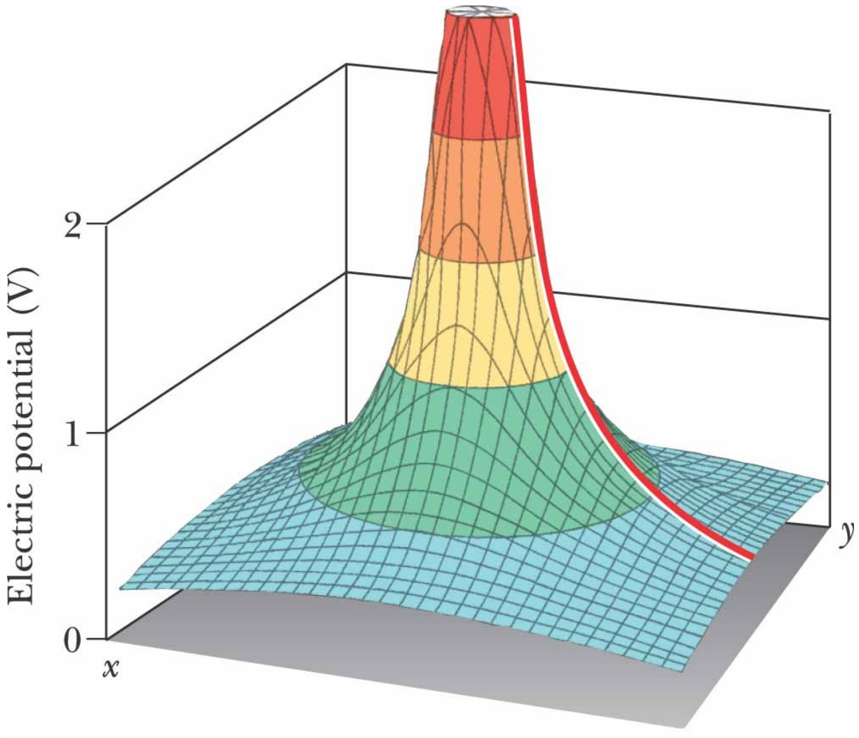
Equipotential Surfaces

- E-field lines (purple) are perpendicular to the equipotential surfaces (blue).
- The surface of a conductor is an equipotential surface
  - The entire chunk of a conductor is at the same potential.
  - Equipotential surfaces run parallel to conductor surfaces.

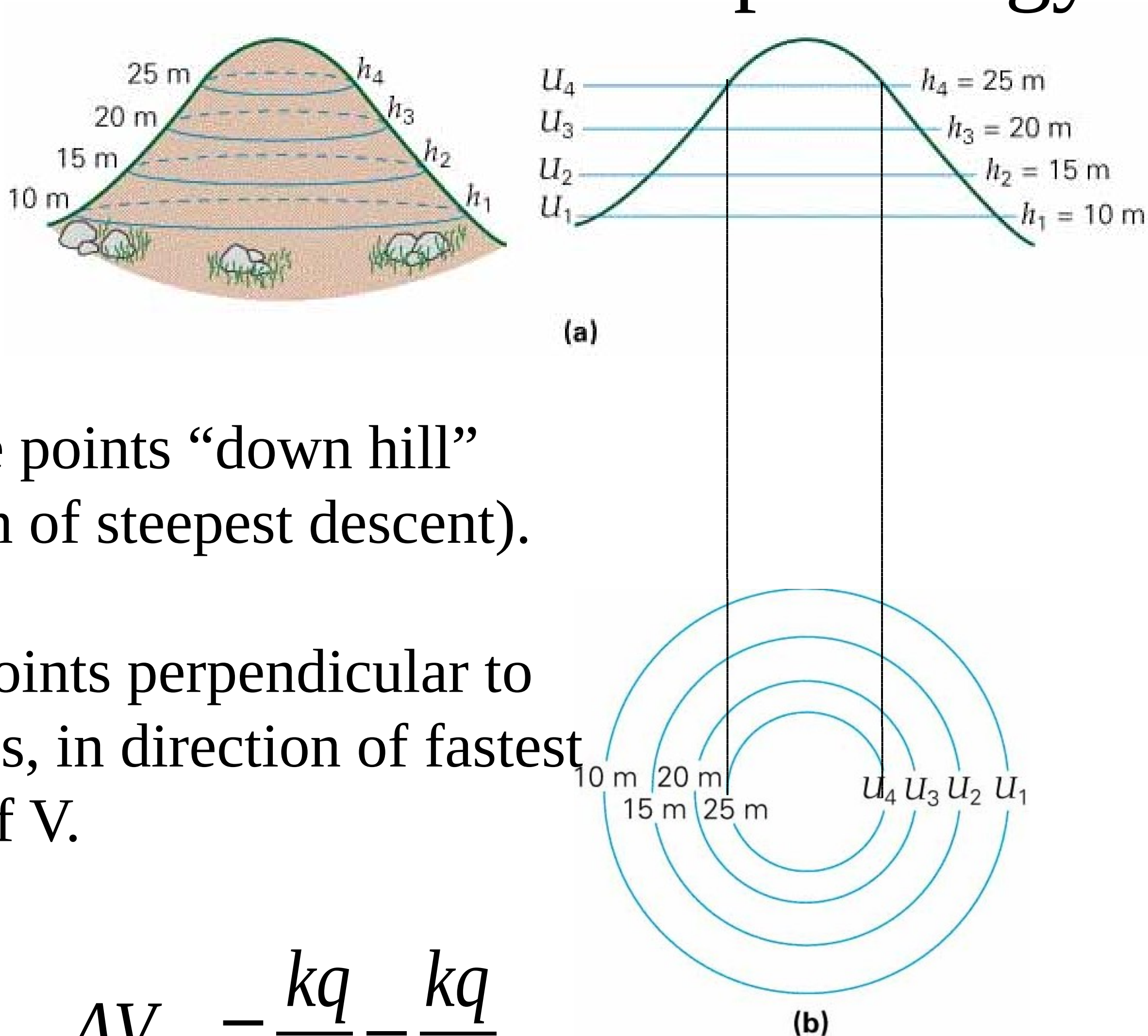


Electric Potential of a Point Charge

- The electric potential in the plane around a single point charge is shown
- The red line shows the $1/r$ nature of the potential



Contours of a map analogy



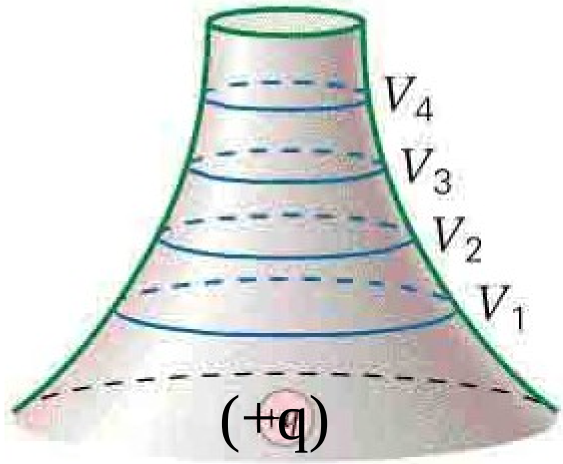
Net force points "down hill" (direction of steepest descent).

E-field points perpendicular to the circles, in direction of fastest change of V.

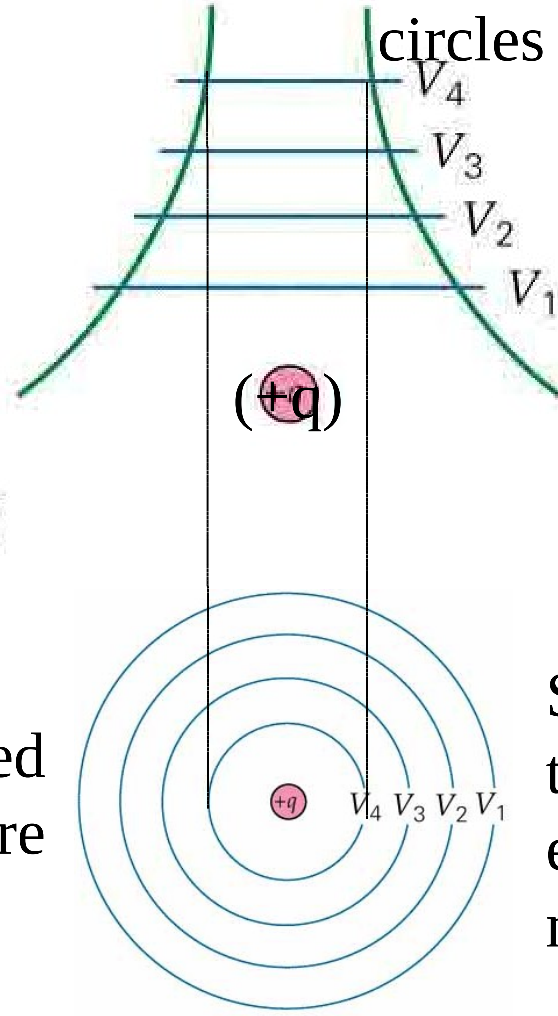
$$\Delta V_{ab} = \frac{kq}{r_b} - \frac{kq}{r_a}$$

Analogy with Gravity and hills

E field points “down hill” perpendicular to the circles



(c)



(d)

V = kq/r for a point charge.

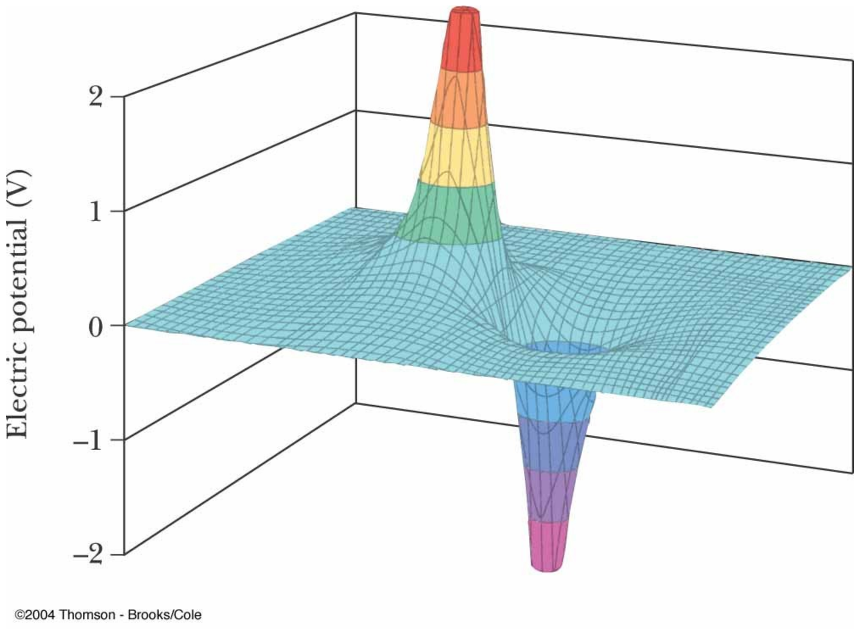
If contours were evenly spaced in voltage, they would be more crowded towards the center!

Slightly misleading – these contours are equally spaced in r, not V.

Electric Potential of a Dipole

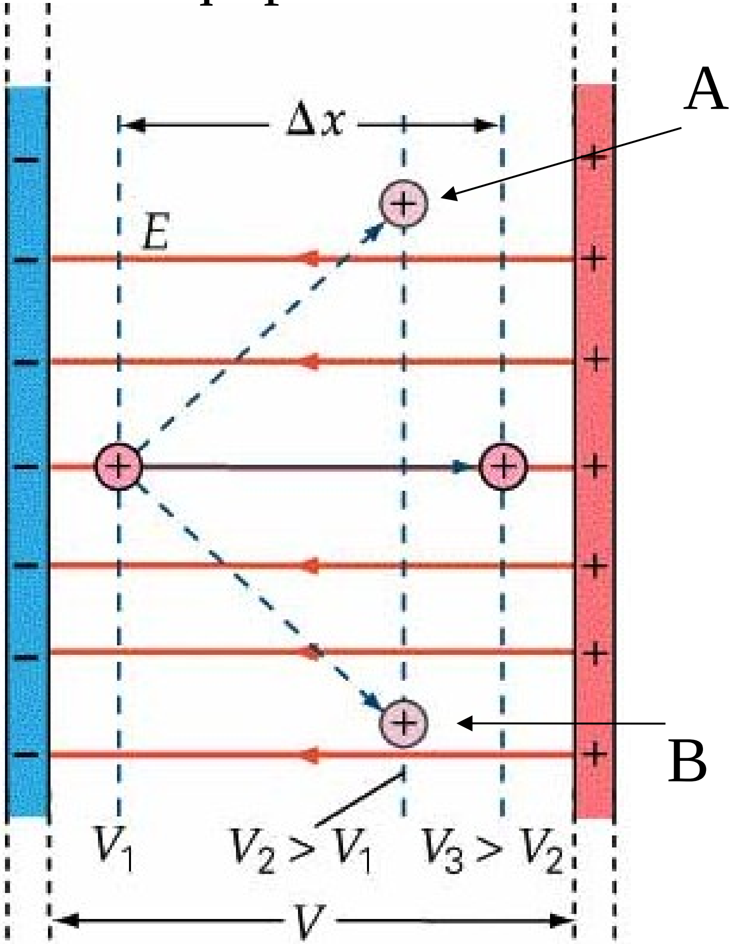
The graph shows the potential (y-axis) of an electric dipole

The steep slope between the charges represents the strong electric field in this region



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



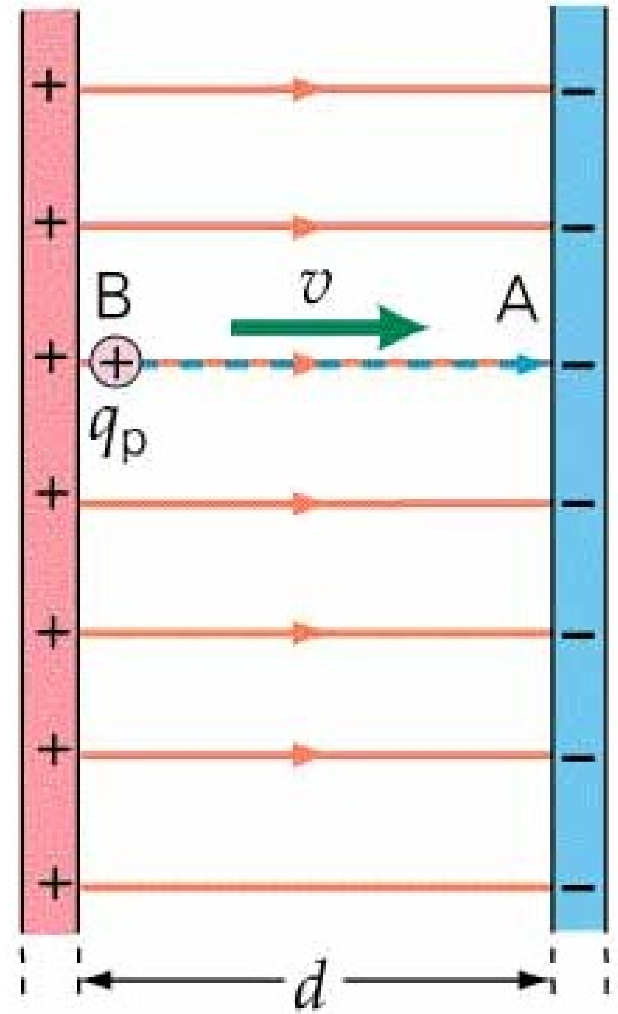
If a charge moves from A to B along an equipotential surface, then

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

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

Parallel Plates

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



(b)

Charged Particle in a Uniform Field

Ex) Oppositely charged plates (assume no gravity).

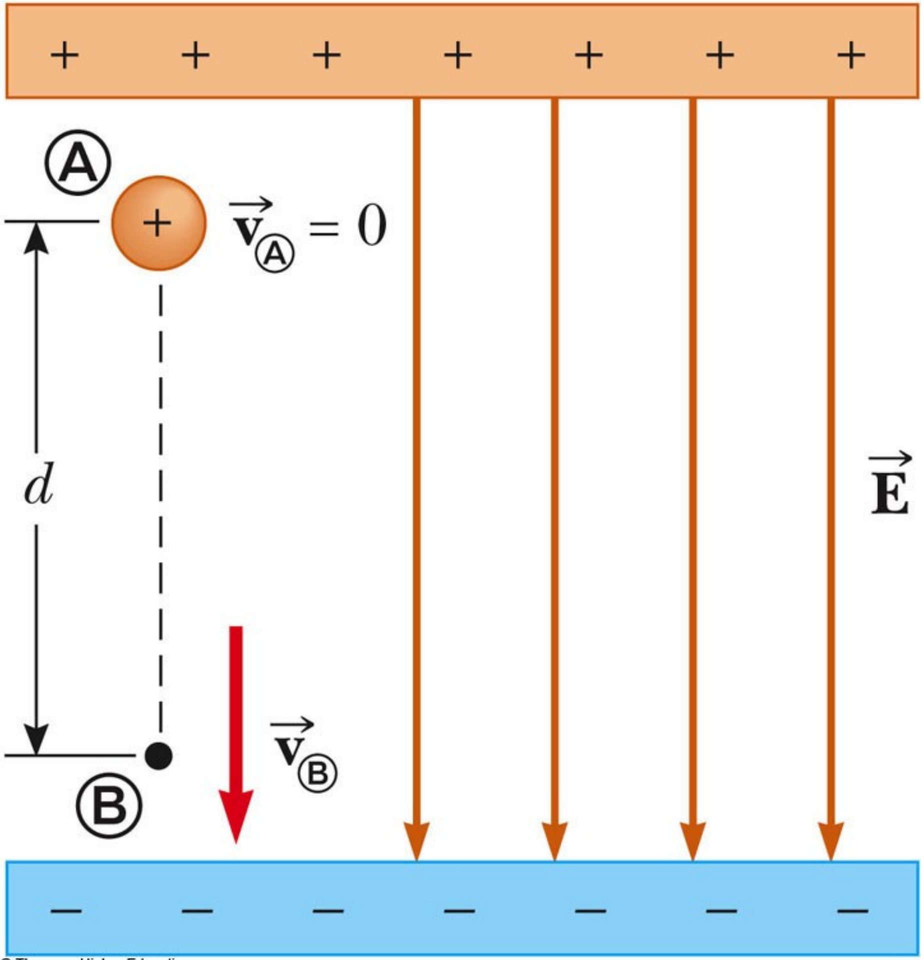
A positive charge released from rest at A moves in the direction of the electric field.

The change in potential from A to B is negative. $\Delta V<0$

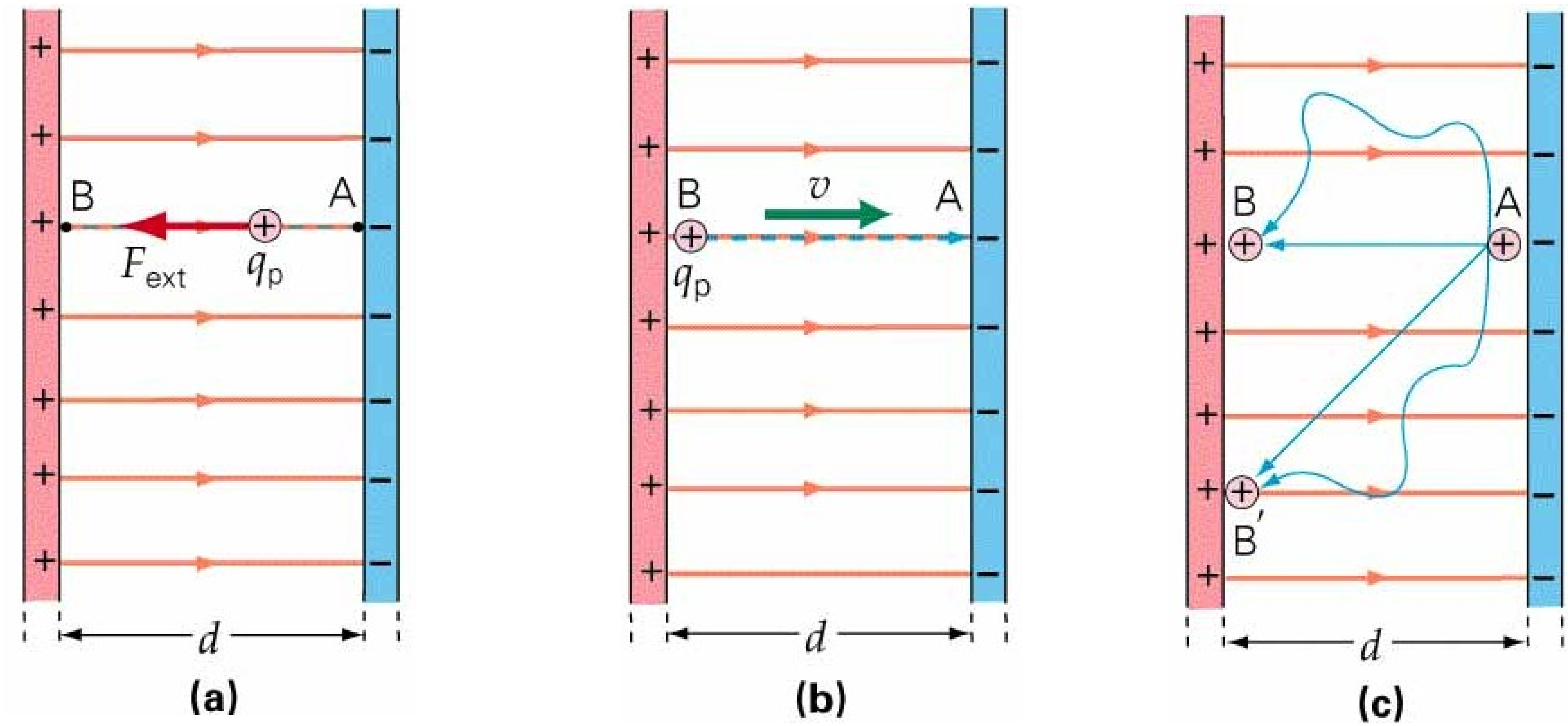
The change in potential energy is negative. $\Delta U<0$

The force and acceleration are in the direction of the field.

Conservation of Energy can be used to find its speed.



Electric Potential Energy (conservation of energy ideas)



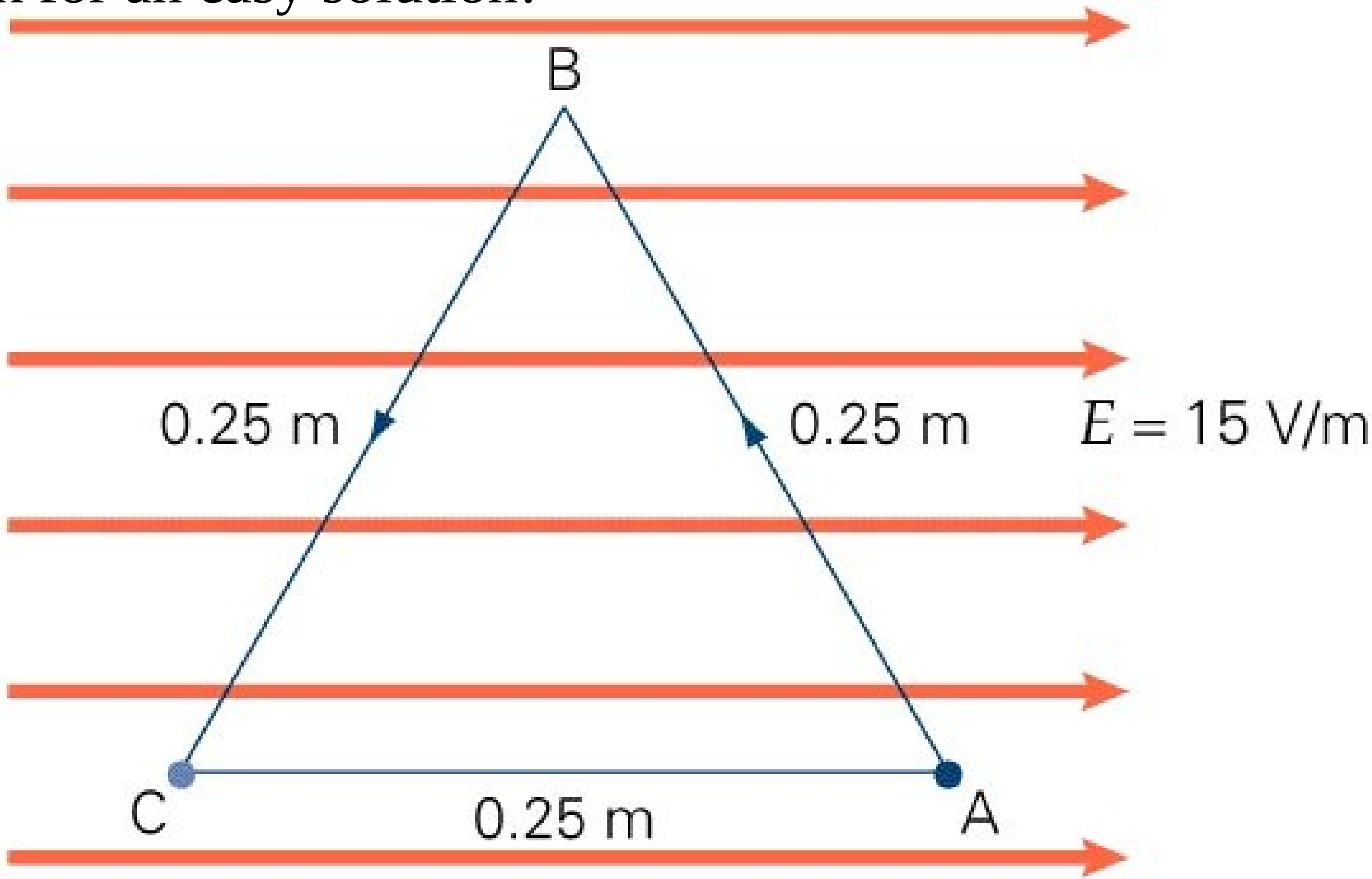
Work is done by extern. force to move the charge. This increases the electric PE.

Charge is released and electric PE is converted into KE

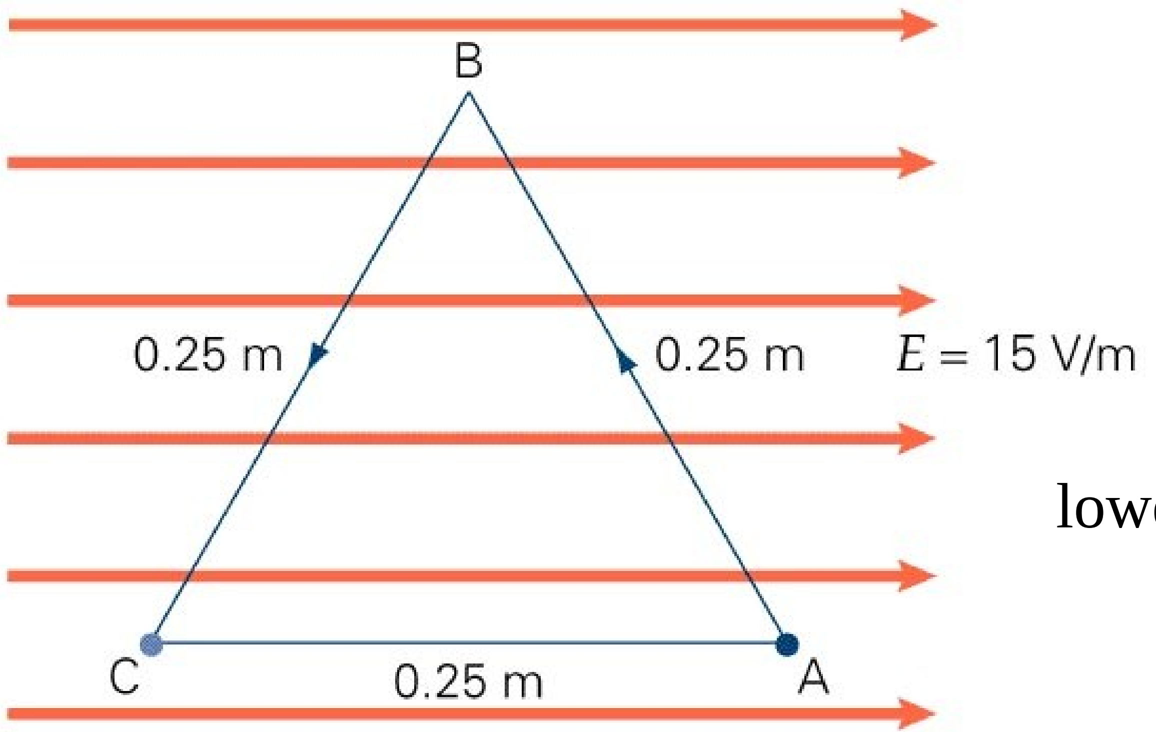
Only the displacement in the direction of the E field matters (independent of path)

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

$$\Delta V_{AC} = -\vec{E}\cdot\vec{d} = Ed = 15\frac{V}{m}(0.25\,m) = 3.75\,V$$

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

Problem: find V and ΔV

$V_1 - V_5 = 3.75$ V

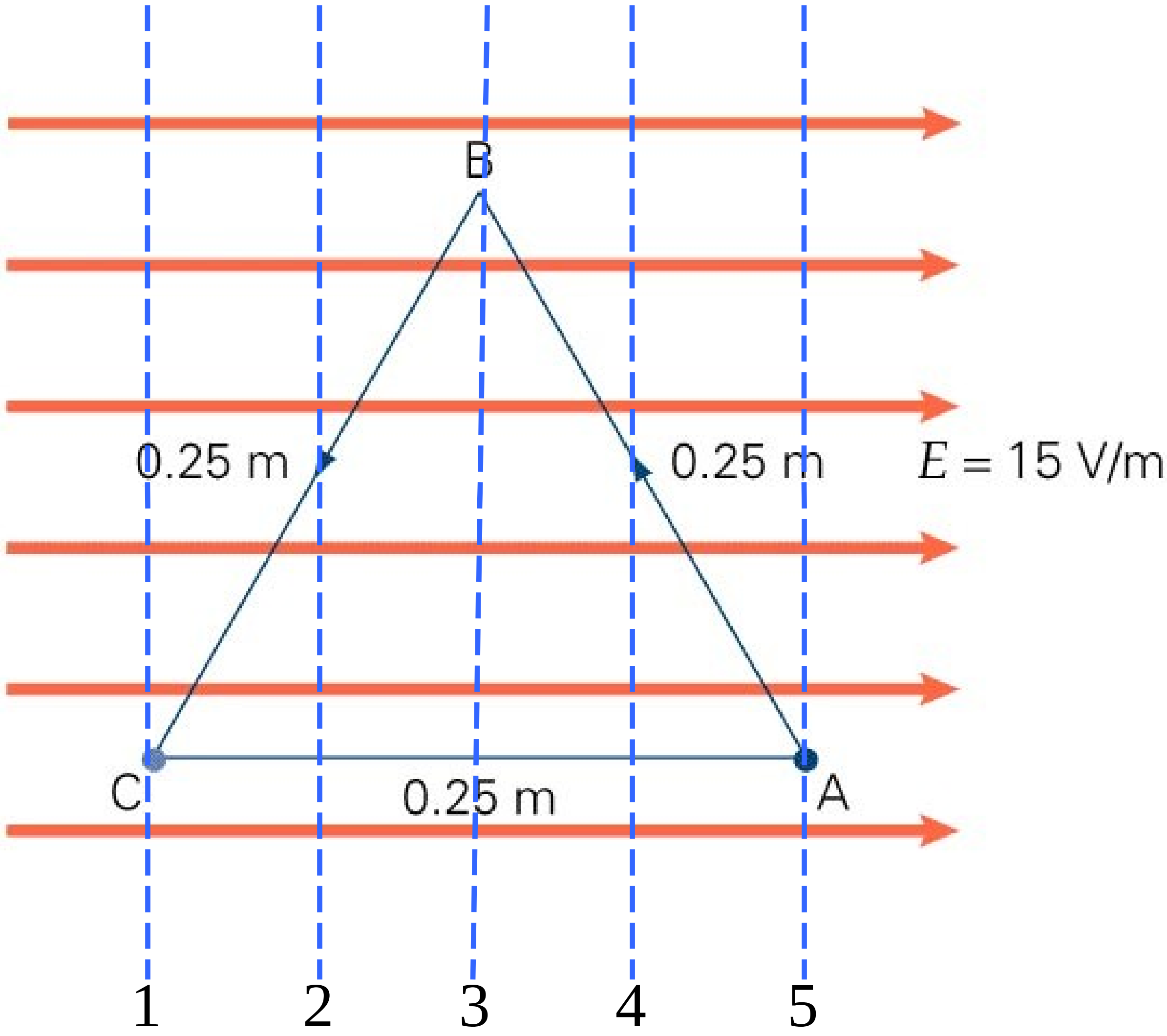
$V_1 = 3.75$ V

$V_2 = 2.8125$ V

$V_3 = 1.875$ V

$V_4 = 0.9375$ V

$V_5 = 0$ V



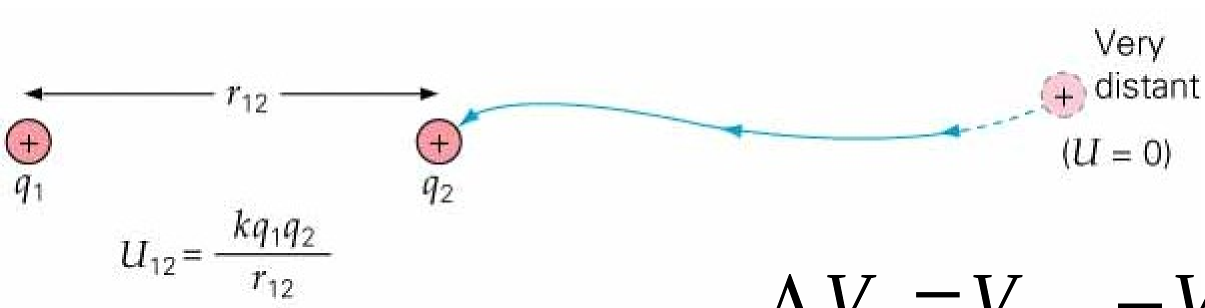
Electric Potential Energy

- 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

$-\Delta U = W = Fd = qEd$ is not valid since $E = kq/r^2$ is not a constant.

But you CAN use:

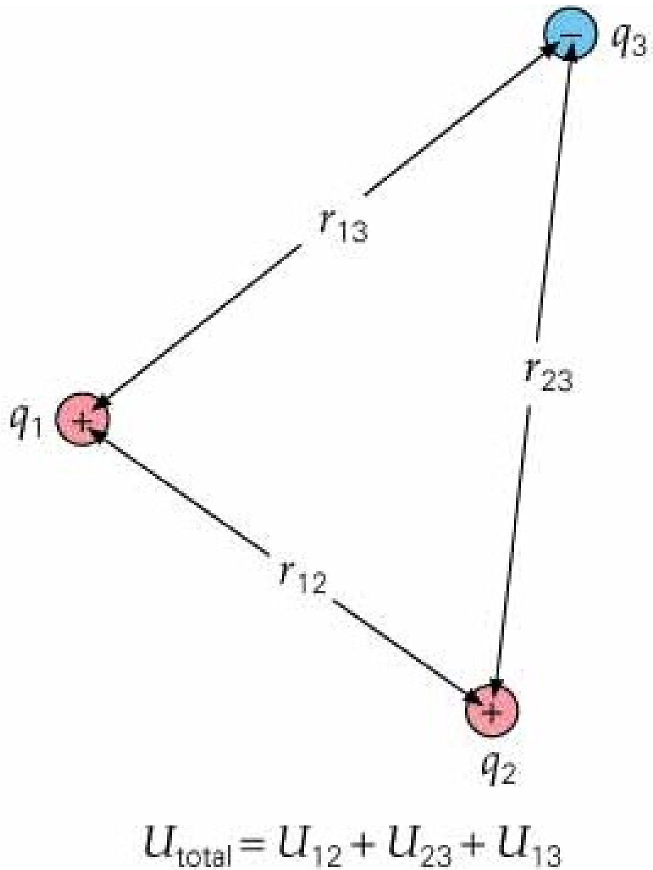
$$\Delta U_{12} = q_2 \Delta V_1$$



$$\Delta V_1 = V_{at\ q_2} - V_\infty = \frac{kq_1}{r_{12}} - \frac{kq_1}{\infty}$$

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)