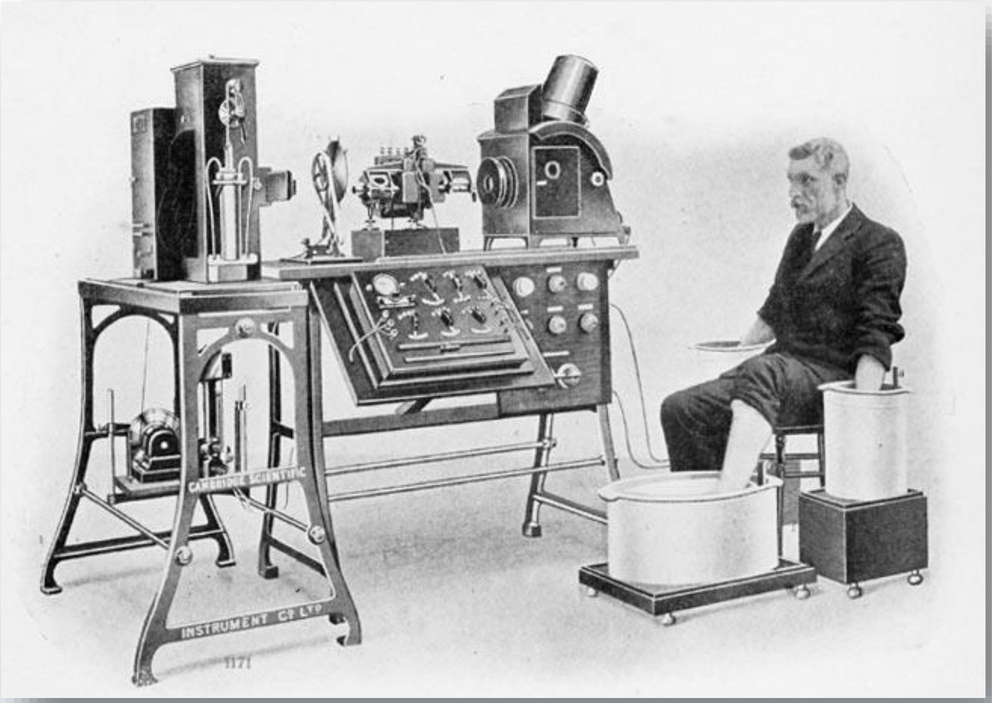


Phys 102 – Lecture 5

Electric potential

Today we will...

- Learn about the *electric potential*
- Use the principle of superposition

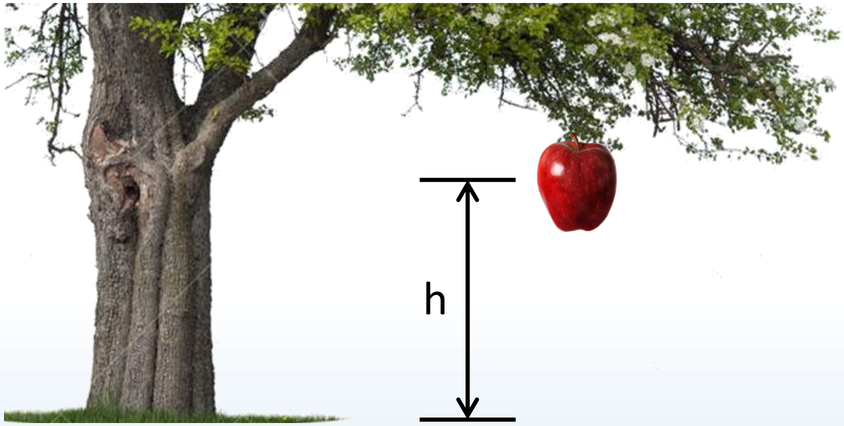
  Ex: point charges
- Represent electric potential with equipotential lines

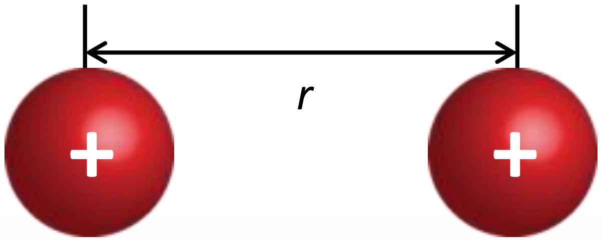
  Relation with electric field
- Apply these concepts

  Ex: Electrocardiogram (ECG)

Recall last time

Gravitational potential energy ⟷ Electric potential energy





Height or altitude ⟷ Electric potential

The electric potential

The electric potential is defined at a *location* in space around a charge or set of charges

Electric potential at position *P* → $$V \equiv \frac{U_E}{q}$$ ← EPE of a charge *q* at position *P*; ← Charge *q*

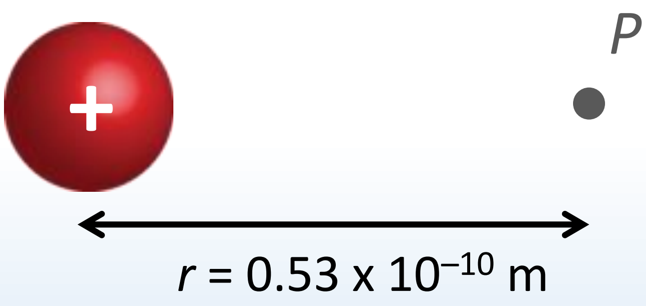
Units: J/C ≡ V ("volts")

Electric potential is 9 V higher at + end than – end

Electric potential is a ***scalar*** (a number) NOT a vector. Signs matter!

Calculation: potential in H atom

What is the magnitude of the electric potential due to the proton at the *position* of the electron?

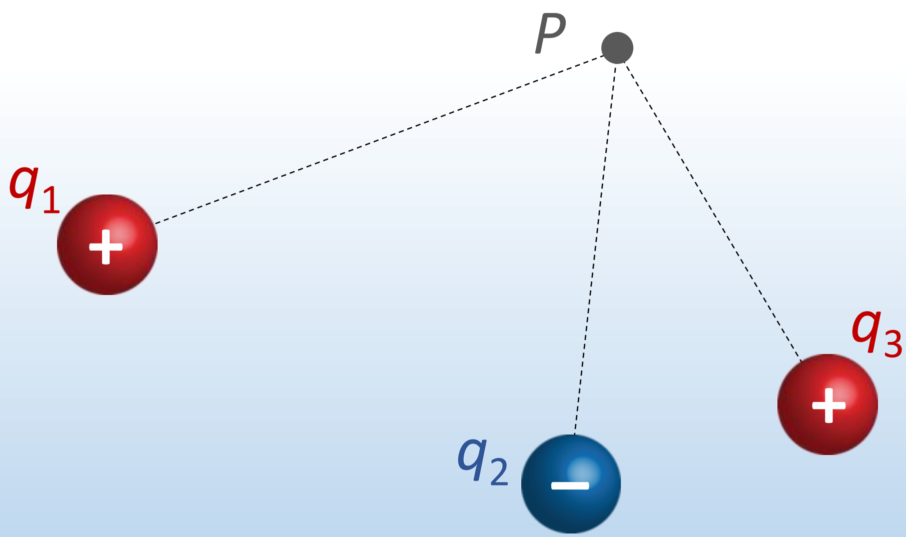


Superposition principle

Total potential due to several charges = sum of individual potentials

$$V_{tot} = \sum V$$

Ex: what is the electric potential at point *P* due to q_1, q_2, and q_3?

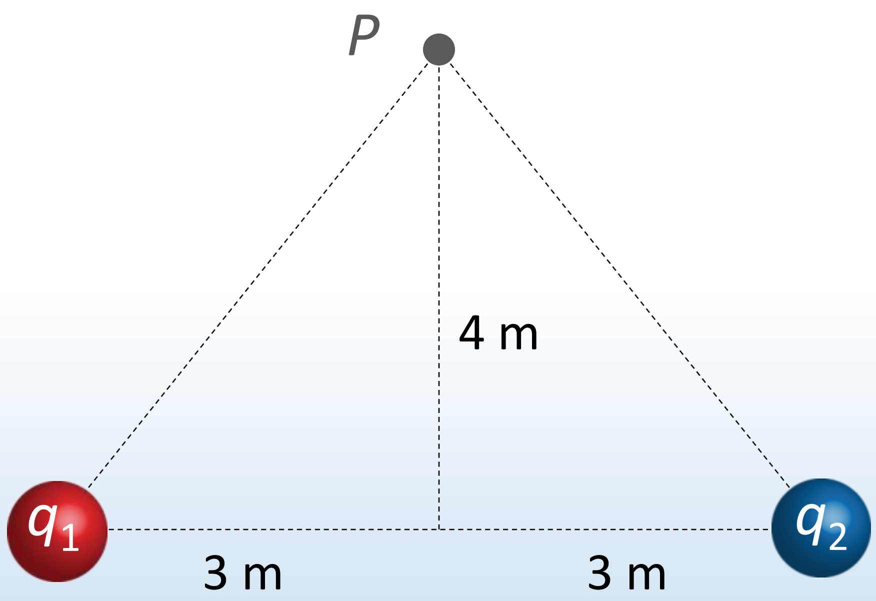


Simple addition, no vectors!
Watch for signs, though!

$$V_{tot} = V_1 + V_2 + V_3$$

Calculation: two charges

Calculate the electric potential at point *P* due to charges q_1 = +7 μC and q_2 = –3.5 μC



How much work <u>do you do</u> bringing a +2 μC charge from far away to point *P*?

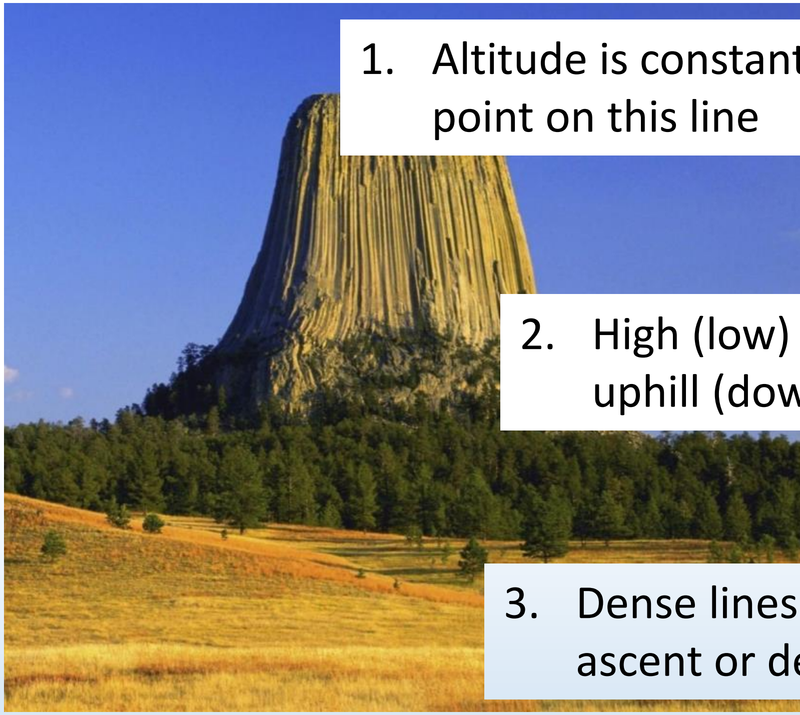
ACT: Electric potential

Two charges +2*Q* and –*Q* are placed on the *x*-axis. In which of the three regions **I**, **II**, or **III** on the *x*-axis can the electric potential be zero?

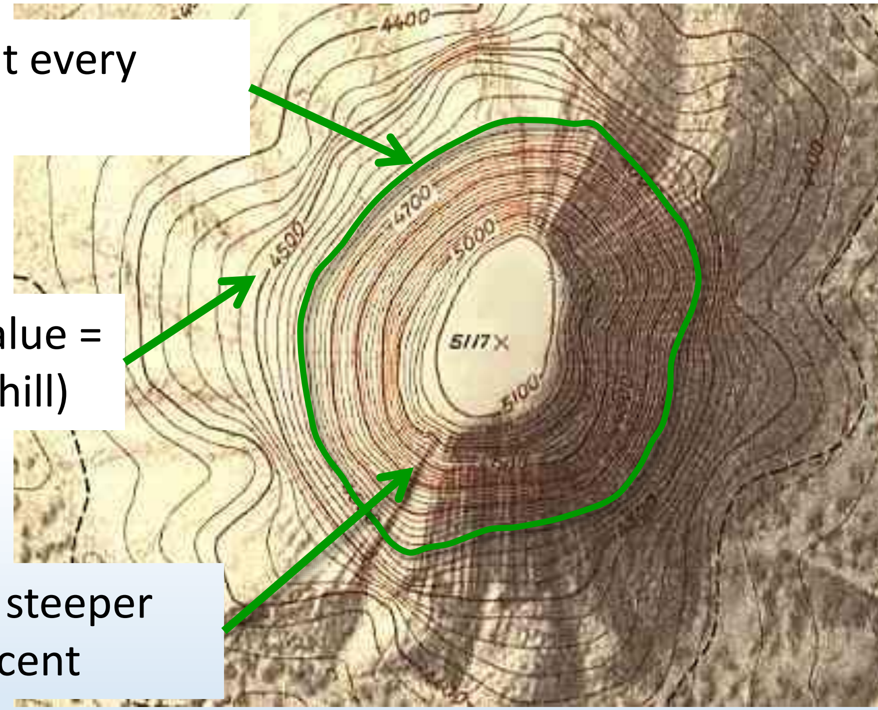
A. I
B. II
C. III
D. II and III
E. I, II, and III

Equipotential lines

Devils tower, WY



Topographical map



1. Altitude is constant at every point on this line
2. High (low) value = uphill (downhill)
3. Dense lines = steeper ascent or descent

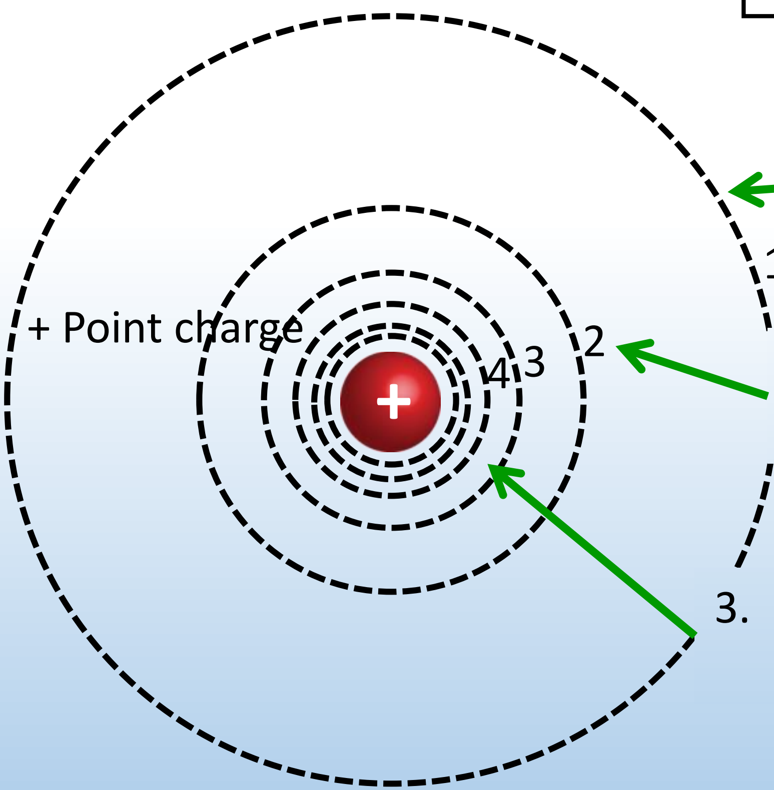
Gravitational potential energy ⟷ Electric potential energy

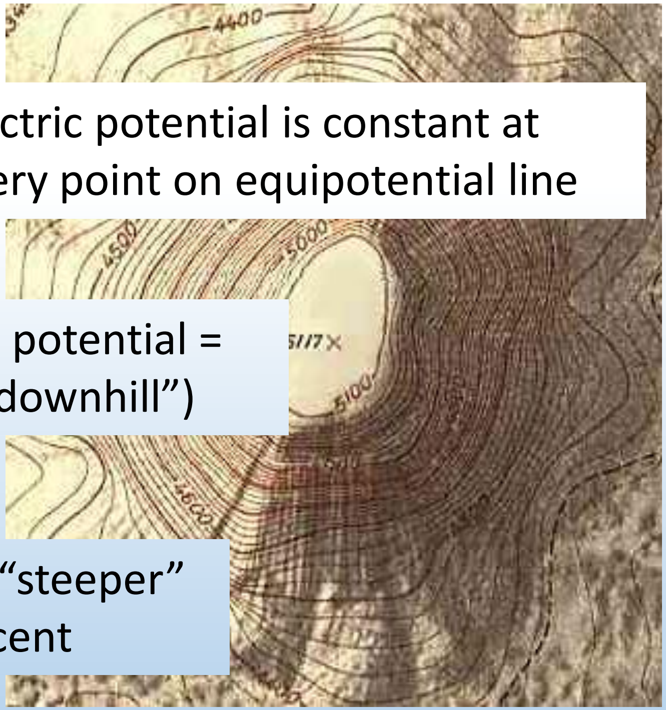
Height or altitude ⟷ Electric potential

Electric potential for a charge

Equipotential lines represent electric potential in space graphically

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

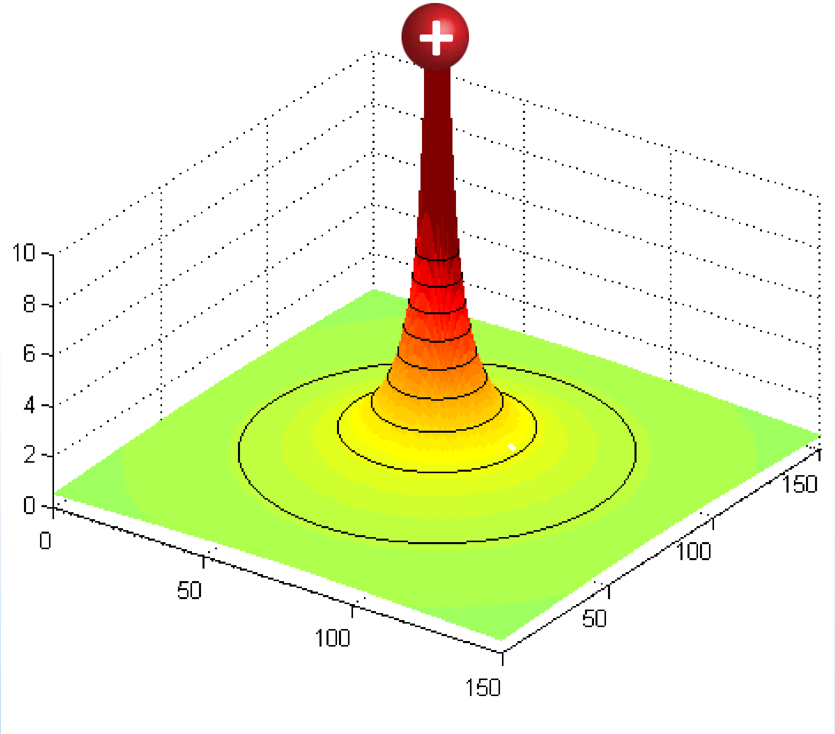




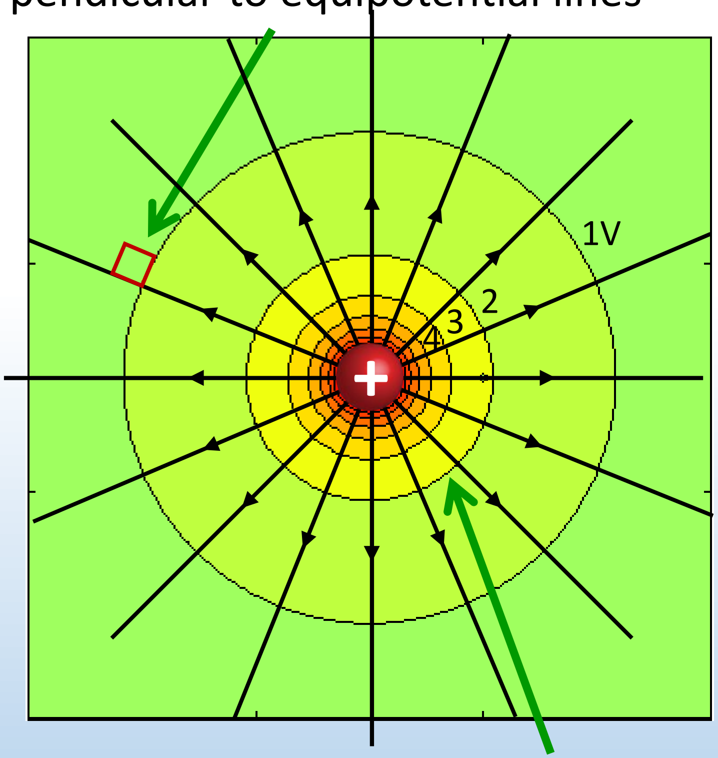
1. Electric potential is constant at every point on equipotential line
2. High (low) potential = “uphill” (“downhill”)
3. Dense lines = “steeper” ascent or descent

Equipotential & electric field lines

Equipotentials & electric field lines are geometrically related



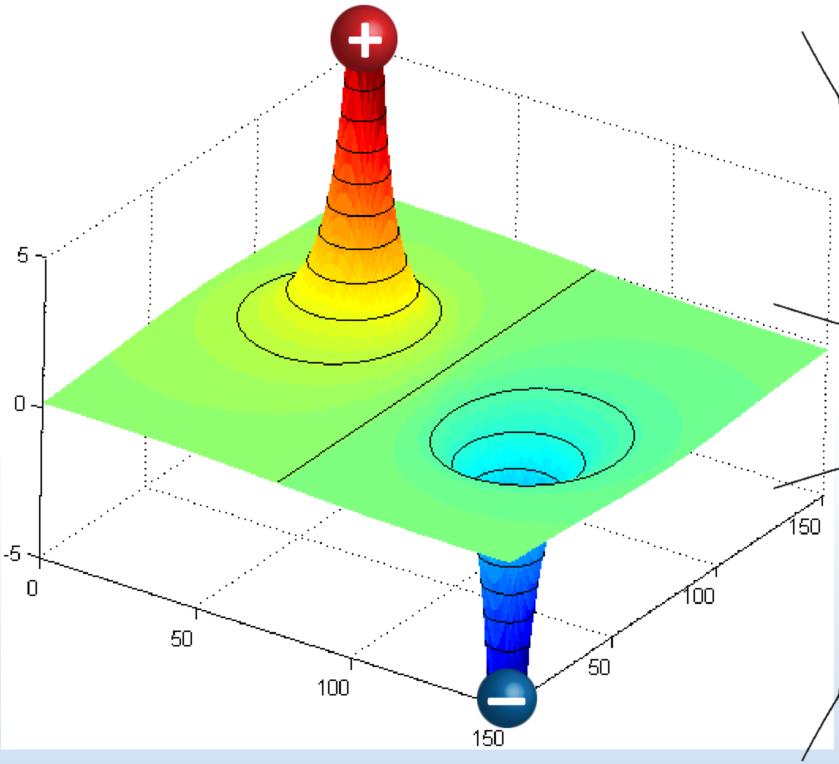
1. Electric field points “downhill”, perpendicular to equipotential lines

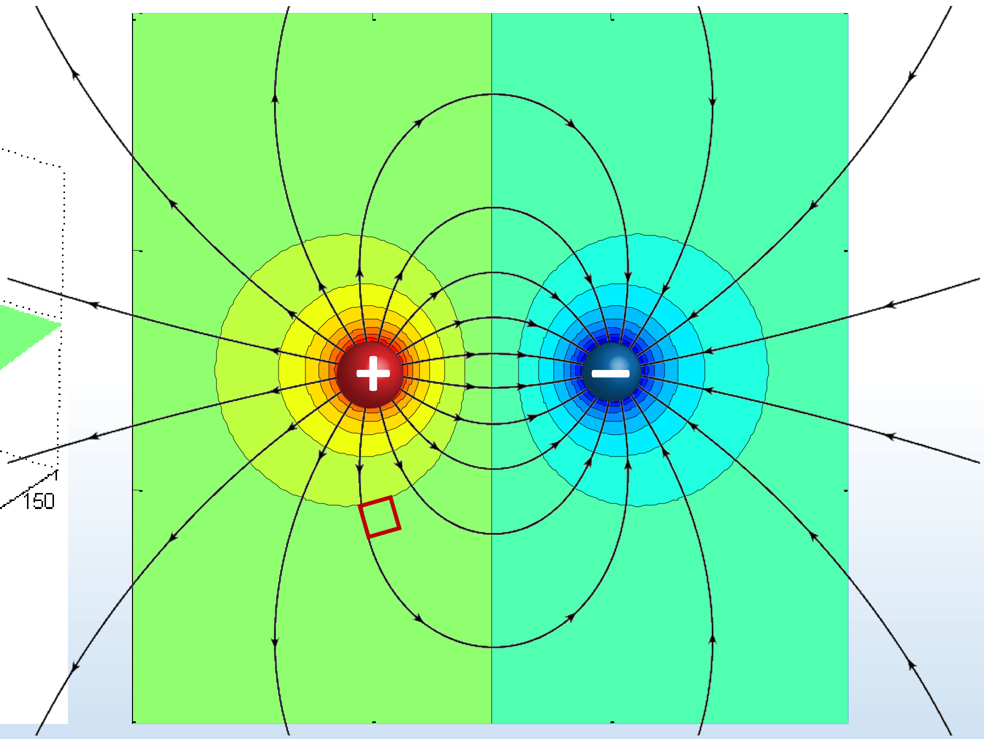


2. Dense equipotential lines = large E field

3. Positive charge moves “downhill”
Negative charge moves “uphill”

Electric potential for a dipole

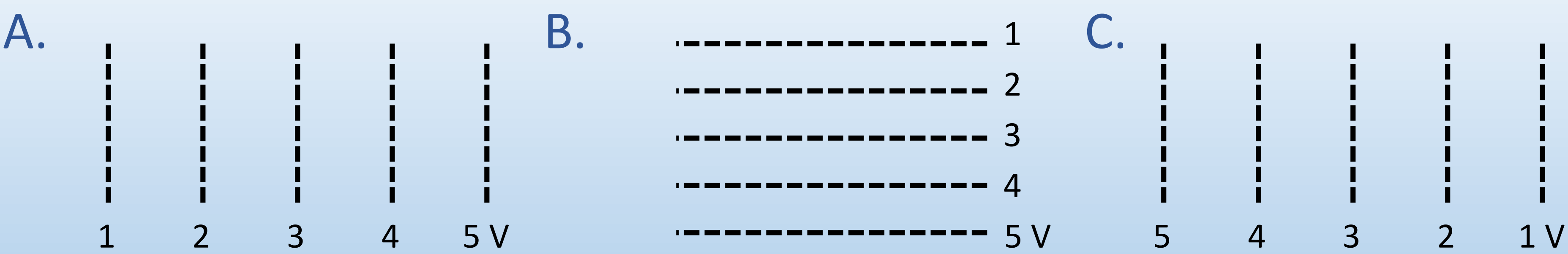




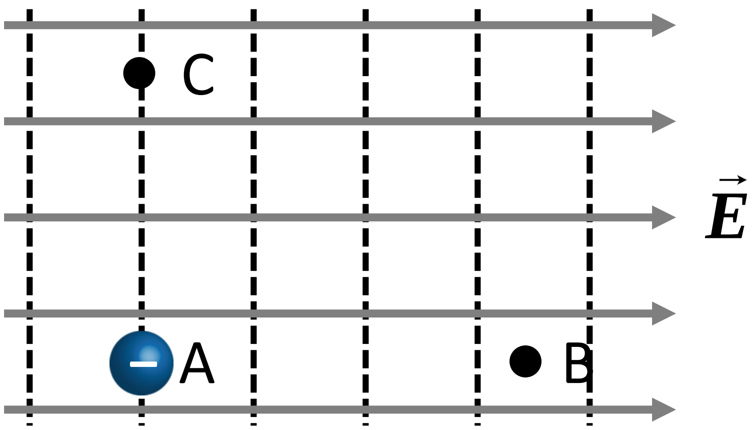
DEMO

ACT: Uniform electric field

Which diagram best represents the equipotential lines corresponding to a <u>uniform</u> *E* field pointing to the right?



Lect. 4 Checkpoint 1.2 (Revisited)



When a negative charge is moved from A to C, it moves along an equipotential line

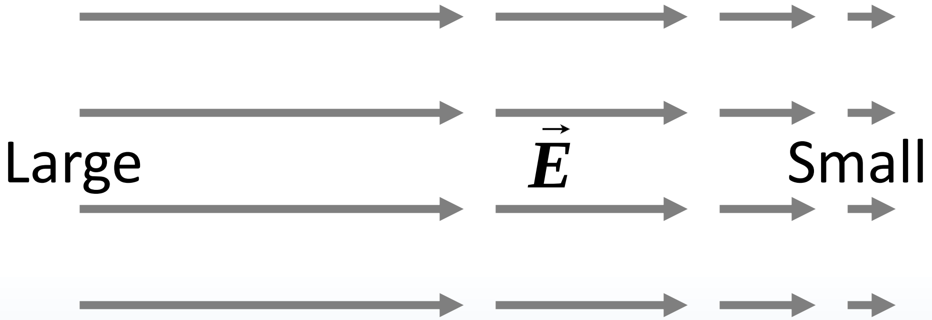
A. positive work

B. zero work

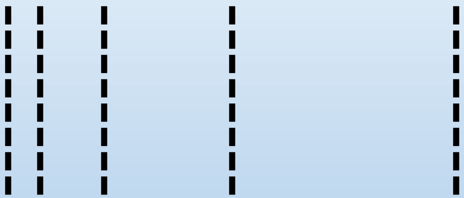
C. negative work

ACT: Electric field gradient

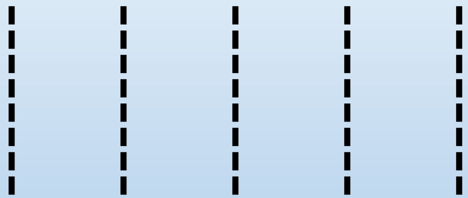
Now consider an *E* field that <u>decreases</u> going to the right. Which diagram best represents the equipotential lines?



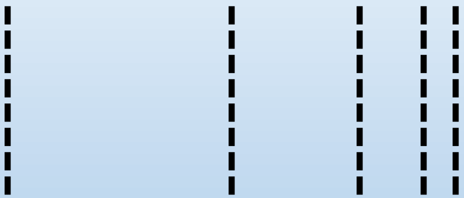
A.



B.

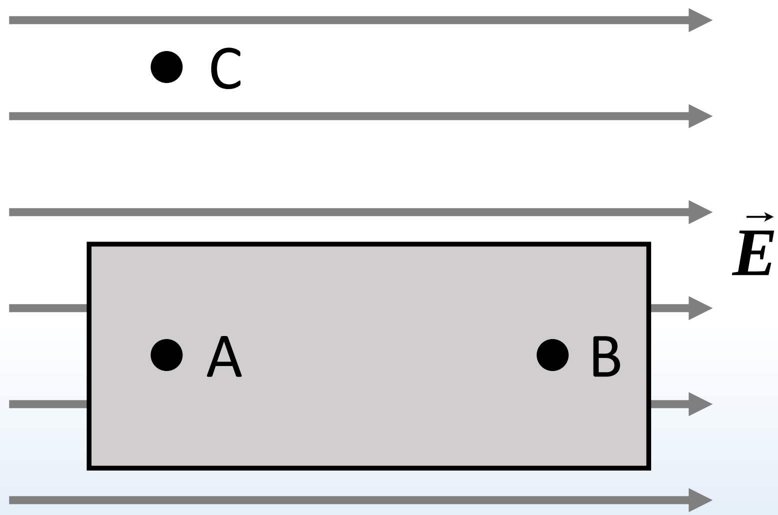


C.



ACT: CheckPoint 2.1

Points A and B lie in an ideal conductor inside a uniform *E* field

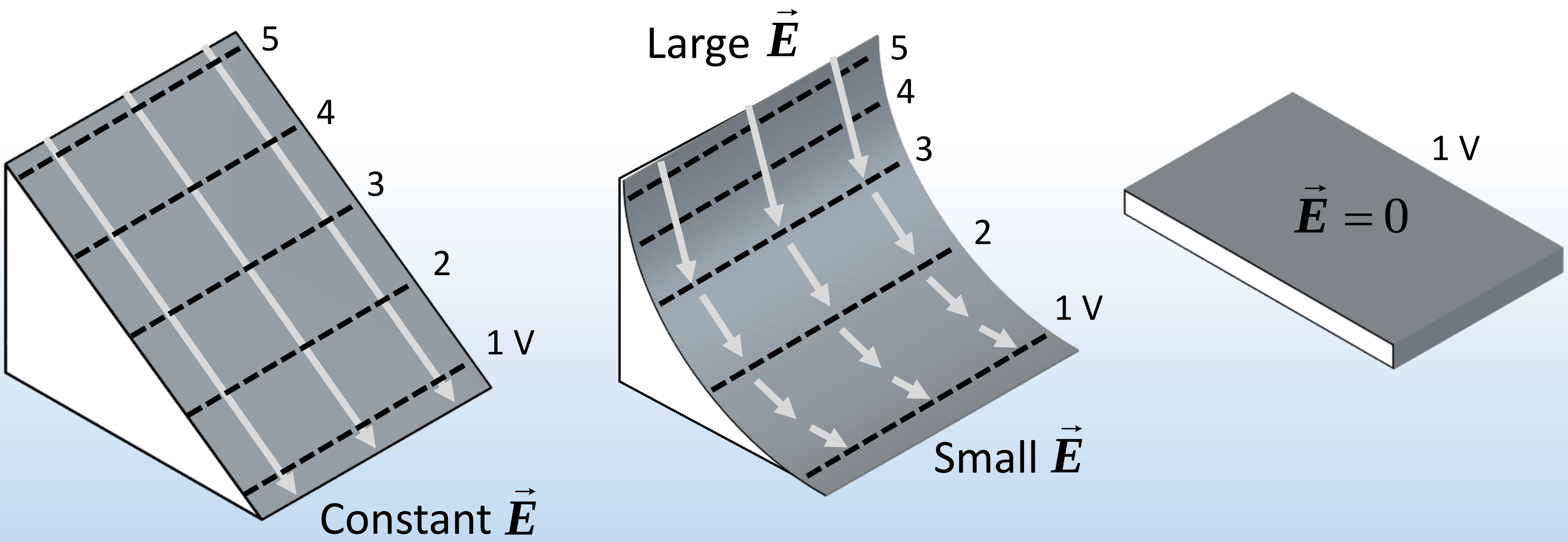


The electric potential at point A is ______ at point B

A. Greater than
B. Equal to
C. Less than

Electric potential difference

Note that the electric field and force depend on electric potential <u>*difference*</u> Δ*V*, NOT on electric potential *V* itself



This will be important starting next lecture with circuits

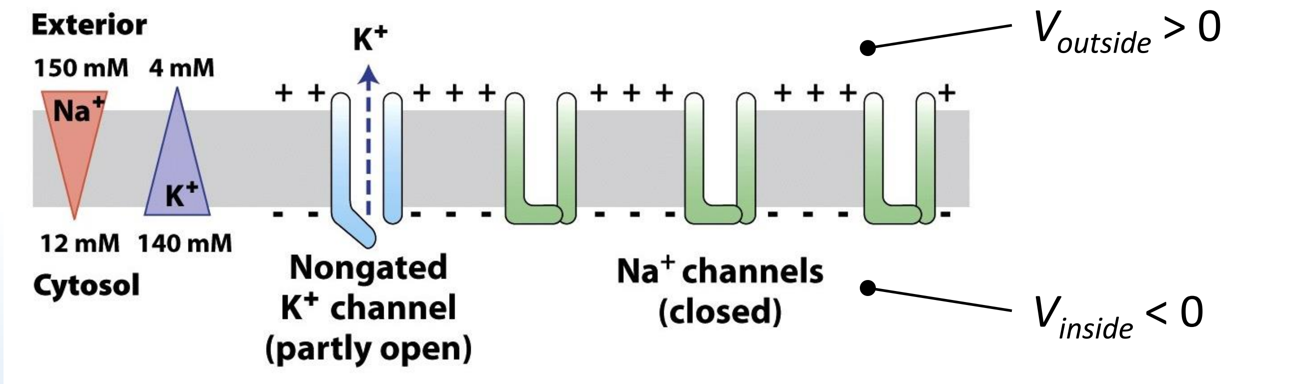
Relationship between F, E, U_E, V

	Vector		Number ("scalar")
Property of interacting charges	F [N] Ex: $F = k\dfrac{q_1 q_2}{r^2}$	$W_E = F\Delta r\cos\theta = -\Delta U_E$	U_E [J] Ex: $U = k\dfrac{q_1 q_2}{r}$
	$\vec{E} \equiv \vec{F}/q$		$V \equiv U_E/q$
Property of point in space	E [N/C]=[V/m] Ex: $E = k\dfrac{q}{r^2}$	*E* points from high to low *V*	V [J/C]=[V] Ex: $V = k\dfrac{q}{r}$

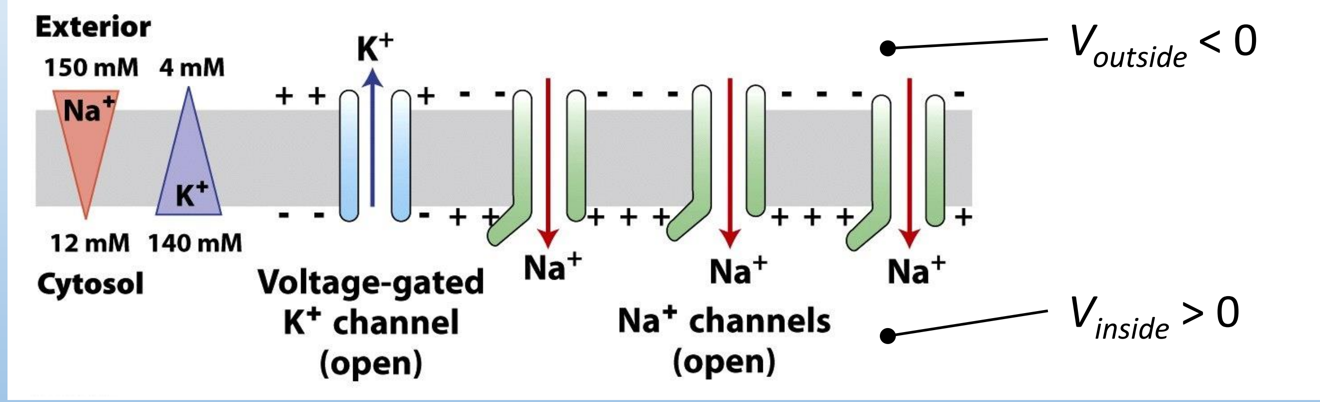
Electric potential in biology

Ion channels in cell membrane create a charge imbalance
Cells have an electric potential difference across membrane

Cells at rest are *polarized*

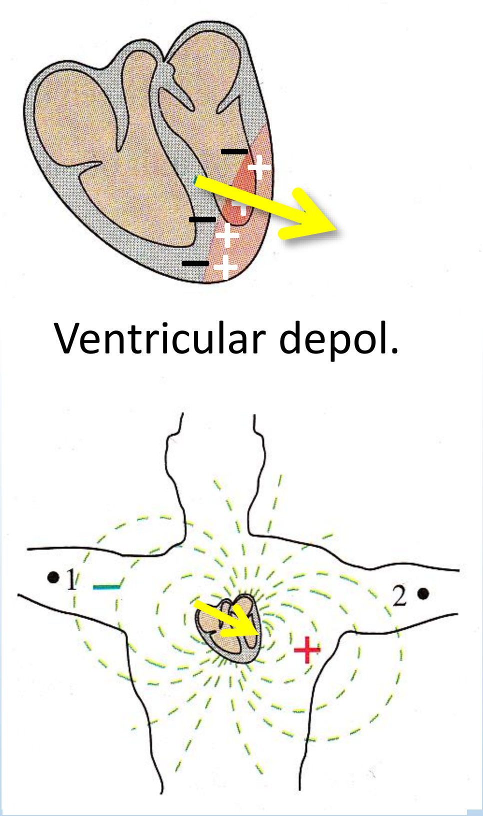


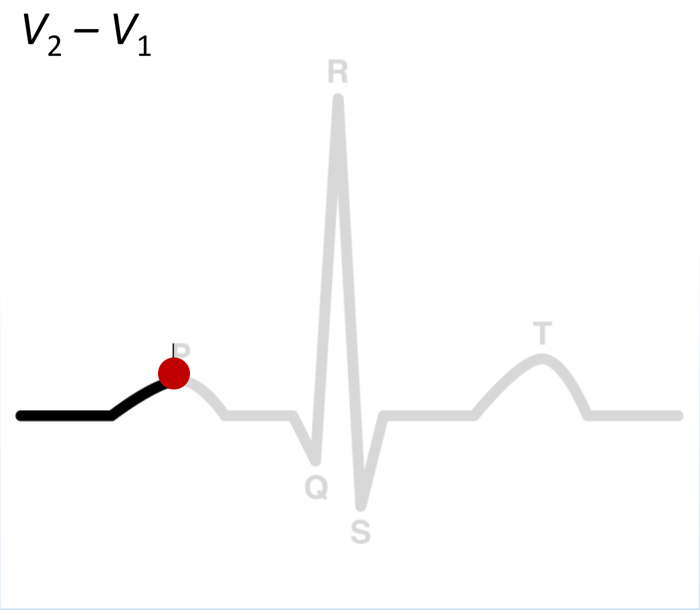
Some cell types (ex: neurons and muscle cells) *depolarize* when they fire



Electrocardiogram (ECG)

ECG detects electric potential difference from depolarization and polarization of cardiac tissue



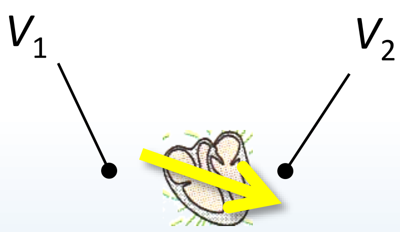


The heart behaves as time-varying electric dipole

ACT: Electrocardiogram

At a certain time during an ECG you measure a ***negative*** electric potential difference $V_2 - V_1$. Which diagram of the cardiac dipole could be correct?

A.



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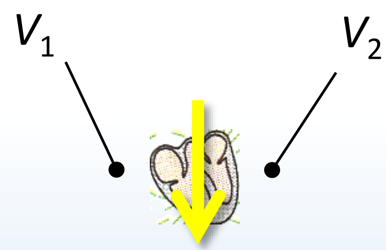

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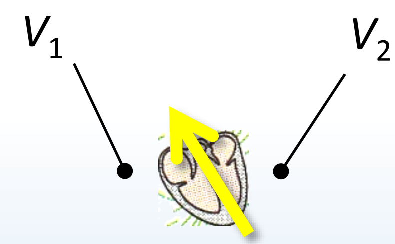

Summary of today's lecture

- Electric potential
  - Superposition & point charges $V_{tot} = \sum \frac{kq}{r}$
- Equipotential lines
  - Relationship with electric field
  - Ex: Uniform field, non-uniform field, conductor, ECG