Your questions/comments

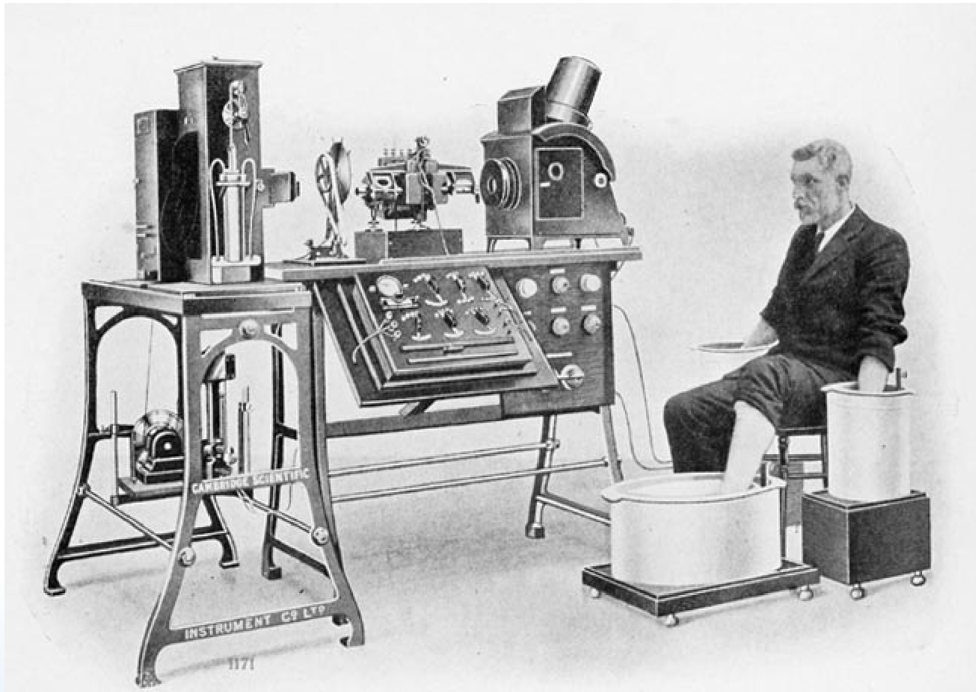
“I am still confused about the difference between electric potential and electric potential difference.”

“I am honestly quite confused on this. I thought I understood it but the checkpoint really proved I had no idea what I was doing.”

“I don't understand how to do questions like checkpoint 1. How are we supposed to know if those points are a test charge or just a point in space?”

“I don't understand how all of the equations we've been in shown in the past 2 or 3 lectures relate to each other mathematically. A review of the equations and what they mean, starting with coulomb's law, would be extremely helpful.”

“I NEEEDDD HHHHEELLLLPPP!!!”



Phys 102 – Lecture 5

Electric potential

Today we will...

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

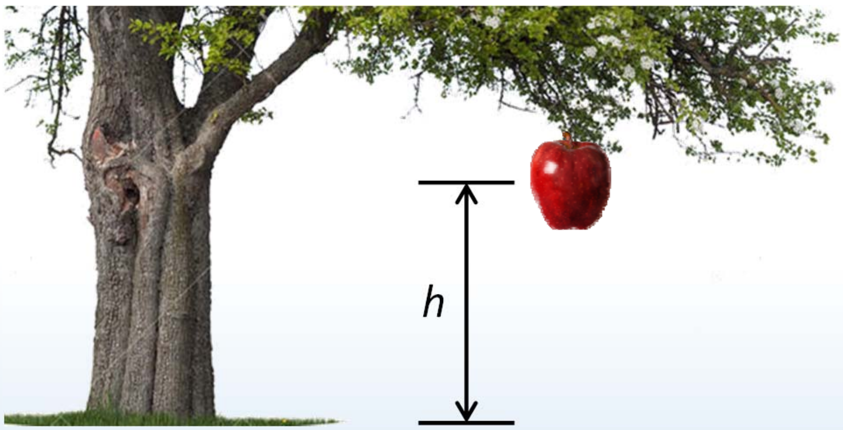
  Ex: point charges
- Represent electric potential with equipotential lines

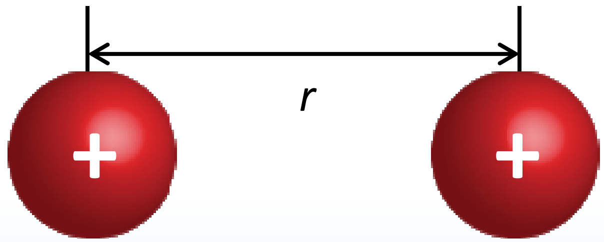
  Relation with electric field
- Apply these concepts

  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

$$V \equiv \frac{U_E}{q}$$

- Electric potential at position *P* → V
- EPE of a charge *q* at position *P* → U_E
- Charge *q* → q

Units: J/C ≡ V ("volts")

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

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

Calculation: potential in H atom

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

r = 0.53 x 10^{-10} m

$$V = \frac{U_E}{q_e} = \frac{kq_p}{r} = \frac{9\times10^9 N\cdot m^2/C^2 \cdot 1.6\times10^{-19} C}{0.53\times10^{-10} m} = 27.2 V$$

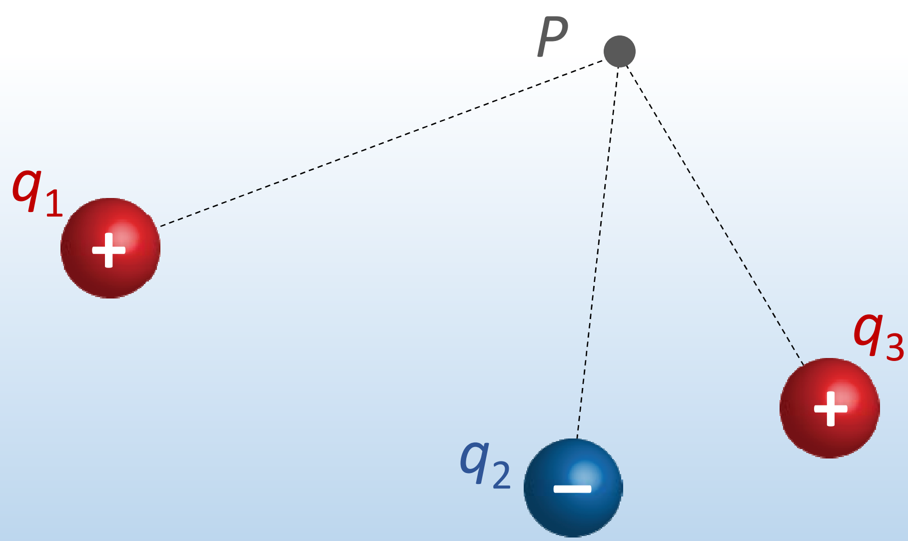
About three 9 V batteries!

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?

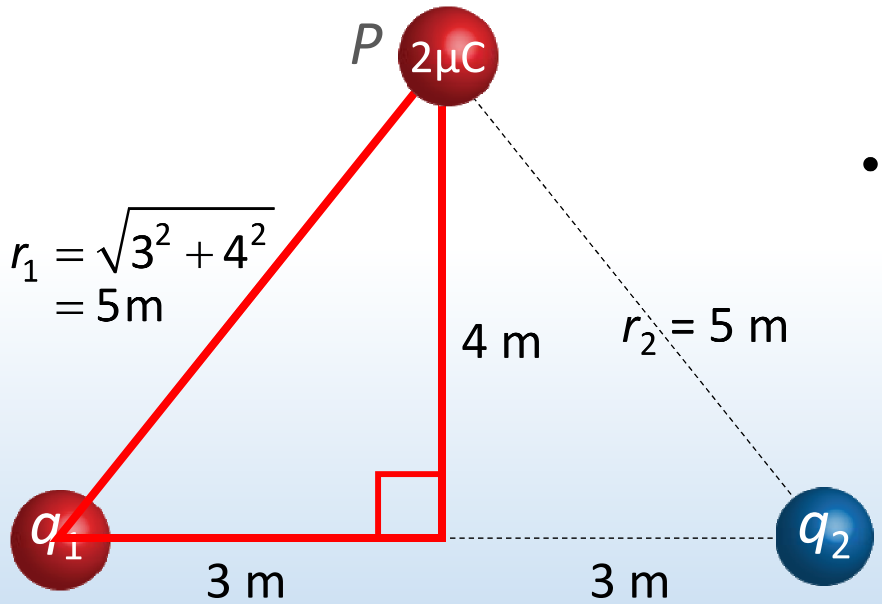


Simple addition, no vectors!
Watch for signs, though!

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

Calculation: two charges

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



- Fundamental concept: Superposition

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

- Calculate each potential

$$V_1 = k\frac{q_1}{r_1} = 9\times10^9\frac{(+7\times10^{-6})}{5} = 12.6\times10^3\,V$$

$$V_2 = k\frac{q_2}{r_2} = 9\times10^9\frac{(-3.5\times10^{-6})}{5} = -6.3\times10^3\,V$$

Watch signs!

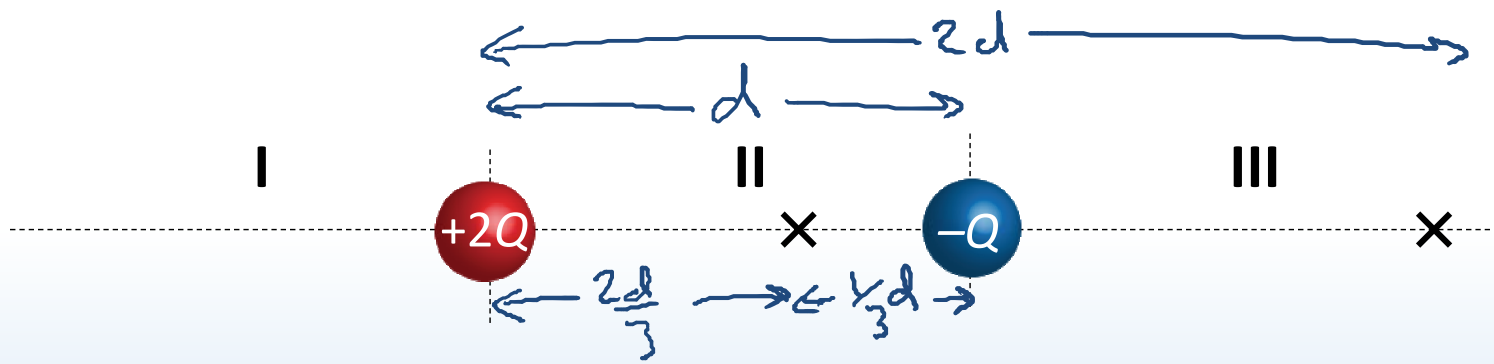
$$V_{tot} = +6.3\times10^3\,V \checkmark$$

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

$$W_{you} = +\Delta U = q\Delta V$$
$$= (+2\times10^{-6})(+6.3\times10^3 - 0) = 12.6\,mJ \checkmark$$

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

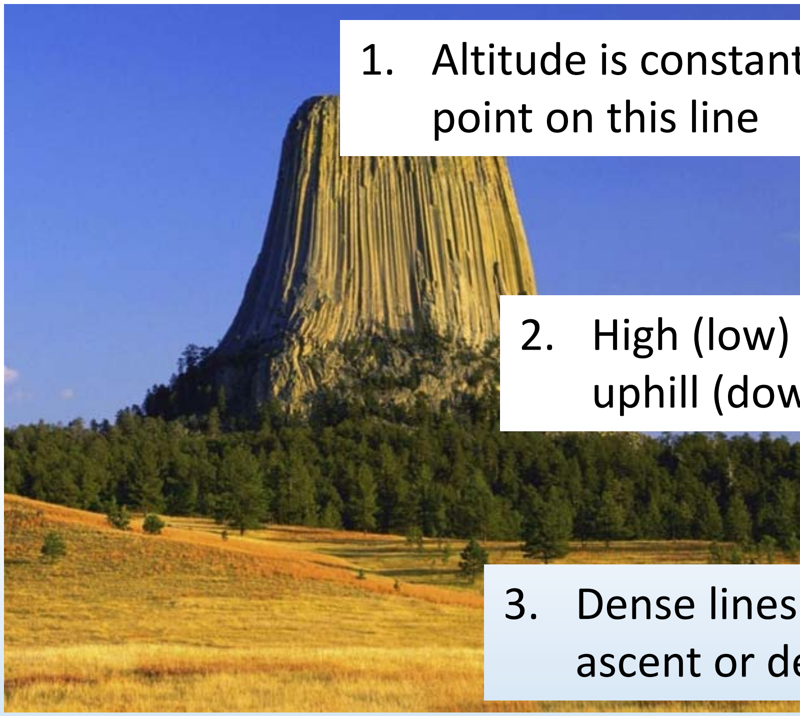
D. II and III

E. I, II, and III

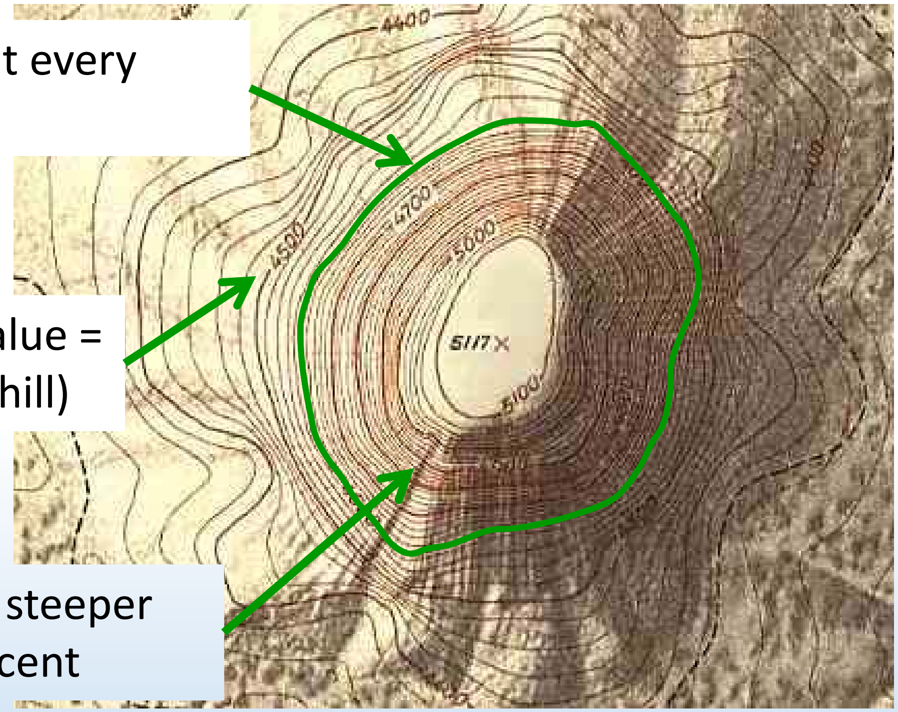
$V \propto \frac{q}{r}$ Potentials can only cancel at a point 2X as far from +2*Q* as from –*Q*

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

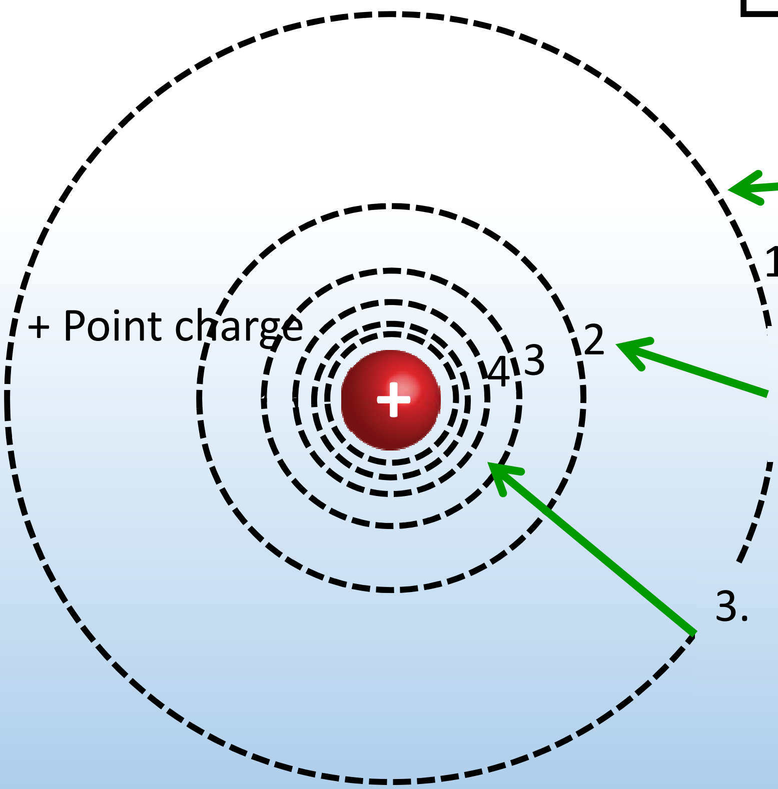
Gravitational potential energy ⟷ Electric potential energy

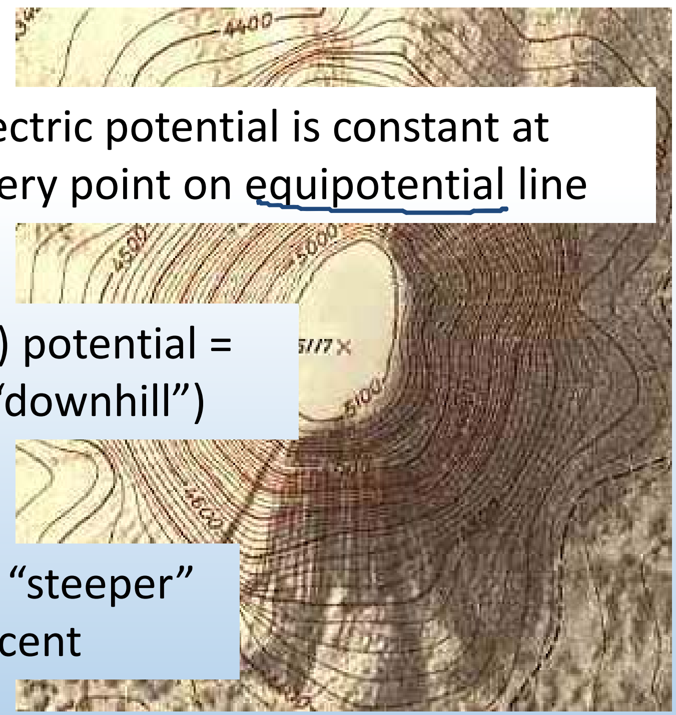
Height or altitude ⟷ Electric potential

Electric potential for a charge

Equipotential lines represent electric potential in space graphically

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



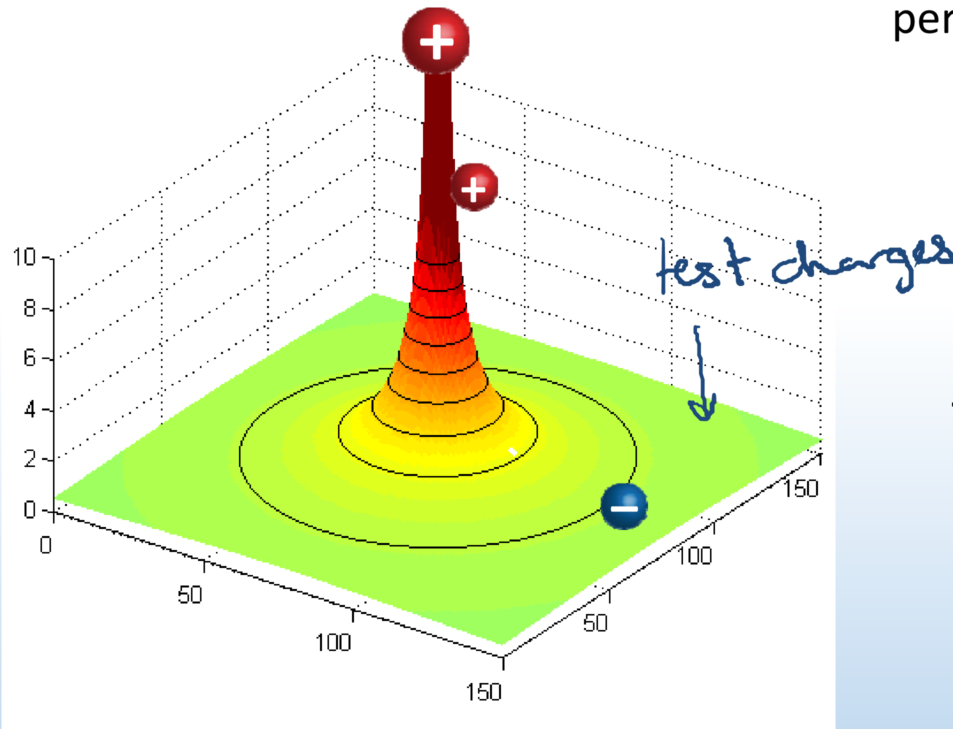


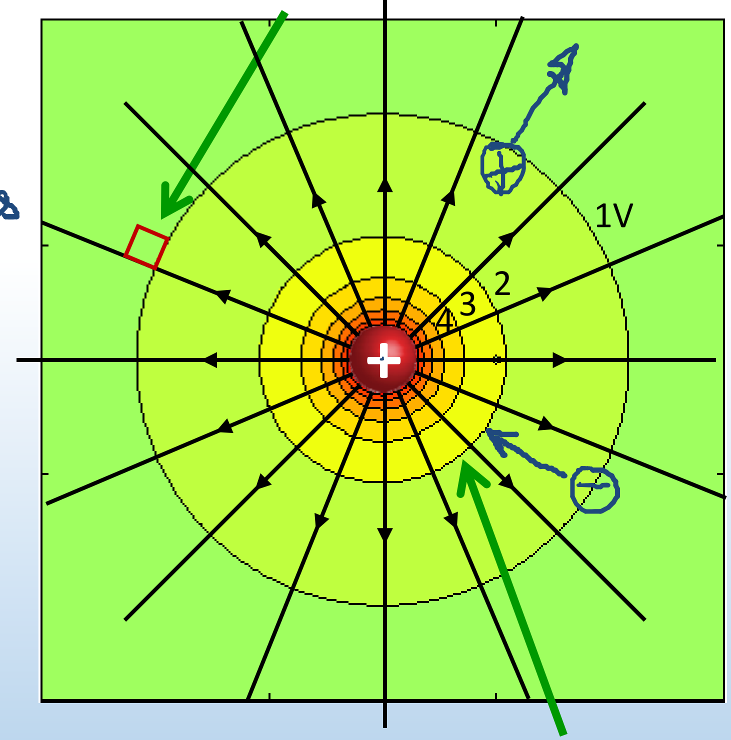
1. Electric potential is constant at every point on equipotential line
2. High (low) potential = "uphill" ("downhill")
3. Dense lines = "steeper" ascent or descent

Equipotential & electric field lines

Equipotentials & electric field lines are geometrically related

1. Electric field points "downhill", perpendicular to equipotential lines

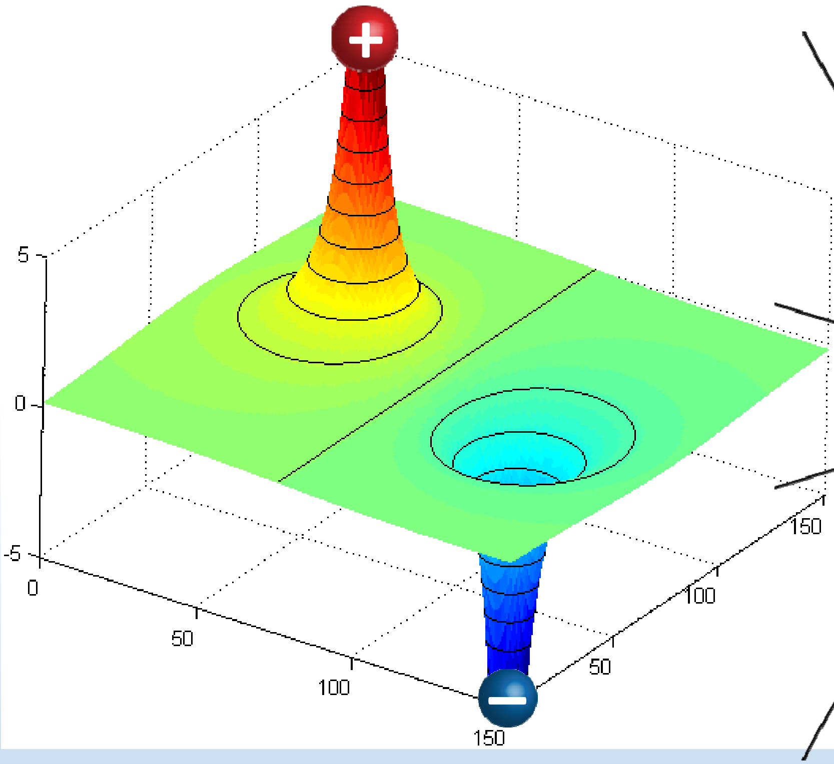


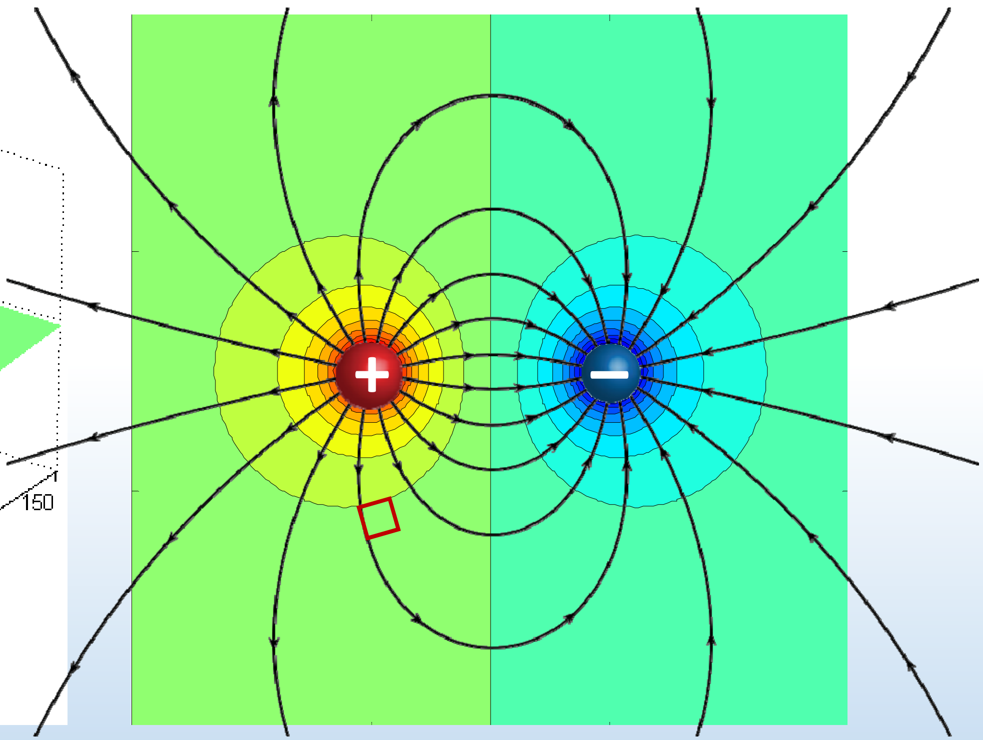


2. Dense equipotential lines = large E field

3. Positive charge moves "downhill" Negative charge moves "uphill"

Electric potential for a dipole





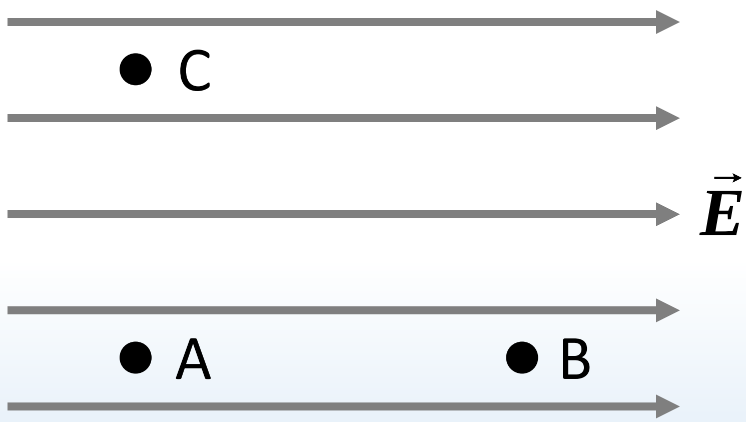
DEMO

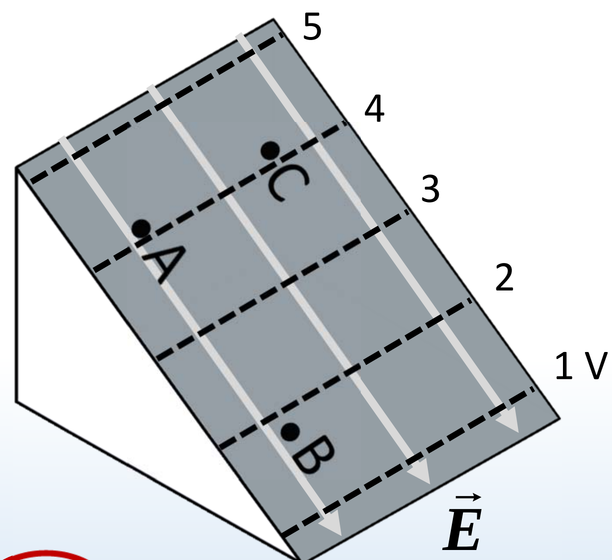
ACT: Uniform electric field

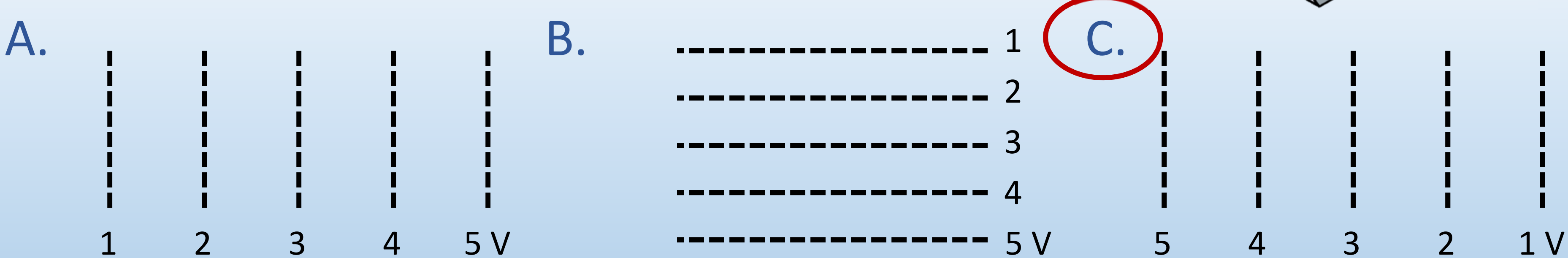
Which diagram best represents the equipotential lines corresponding to a <u>uniform</u> *E* field pointing to the right?

CheckPoint 1.1

53%

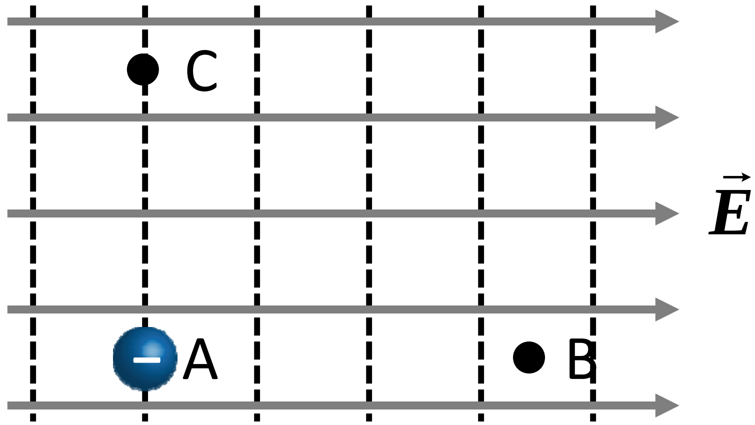






Electric field points "downhill", from high to low potential

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

V is constant

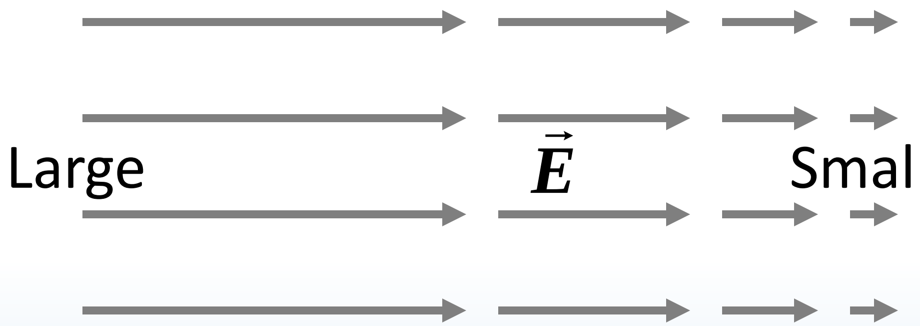
$U = qV$ is constant

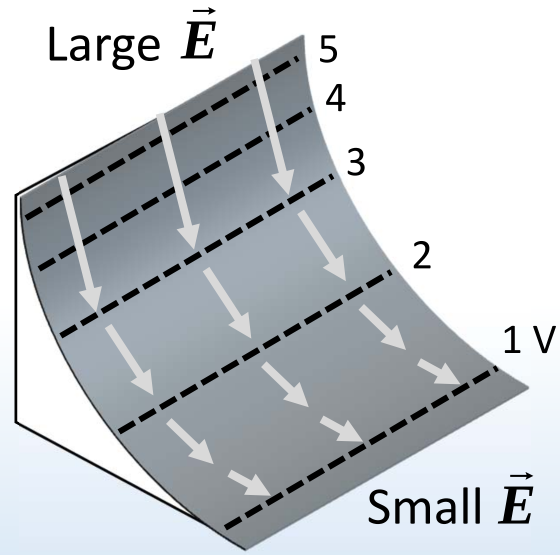
$\Delta U = 0$

$W = 0$

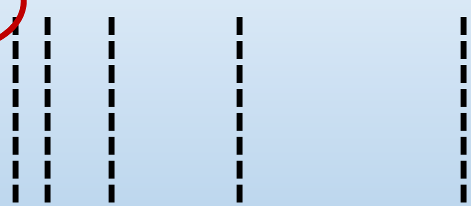
ACT: Electric field gradient

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

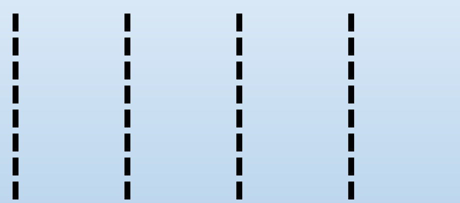




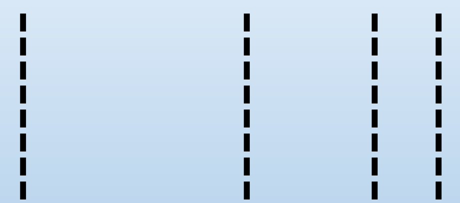
A.



B.



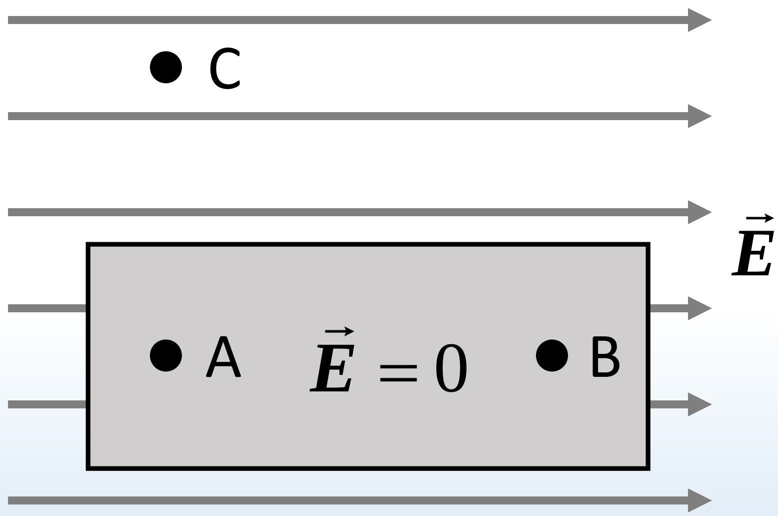
C.

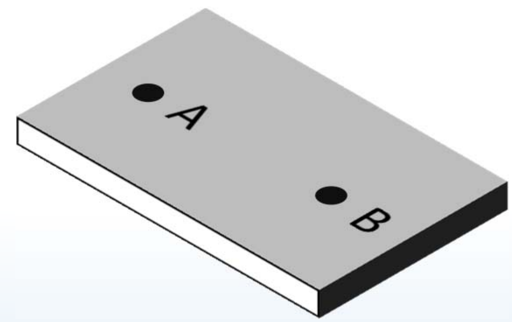


Large electric field = “steep” descent = dense equipotential lines

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

5% A. Greater than

90% B. Equal to

5% C. Less than

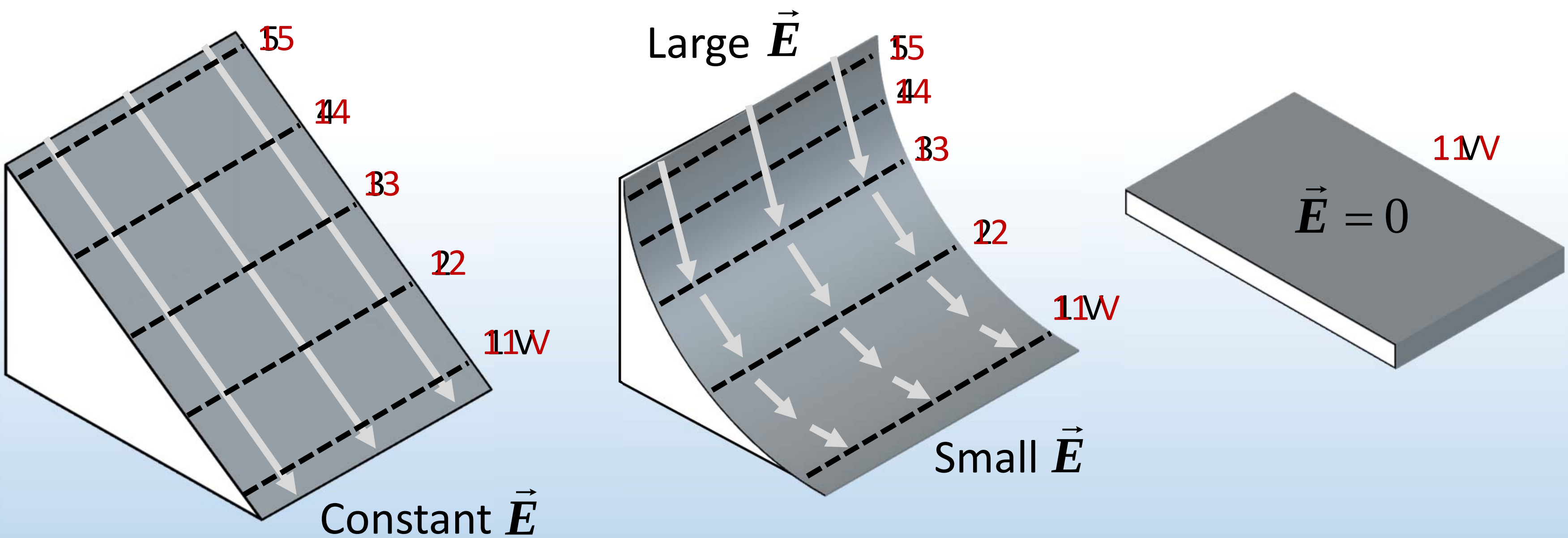
$\vec{E} = 0$ means not "uphill" nor "downhill", but "flat"

V is constant everywhere inside conductor

Note: *V* is not necessarily 0, just constant!

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

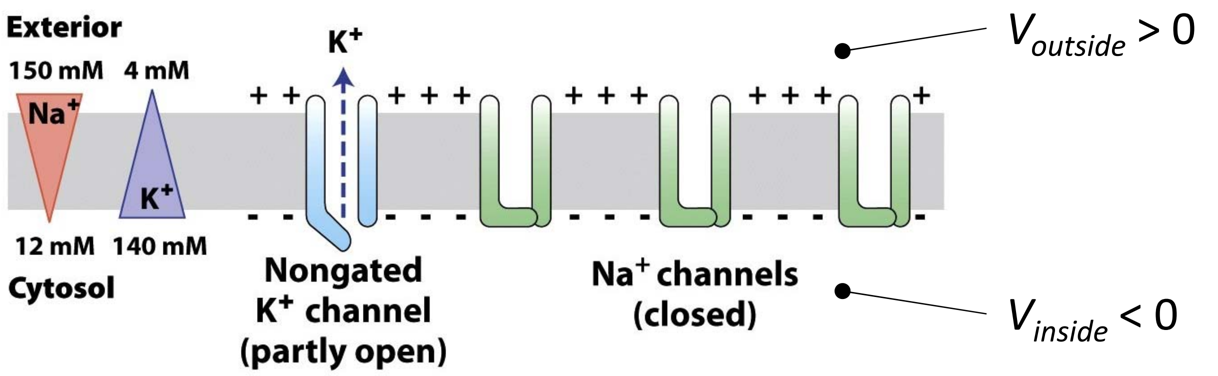


This will be important starting next lecture with circuits

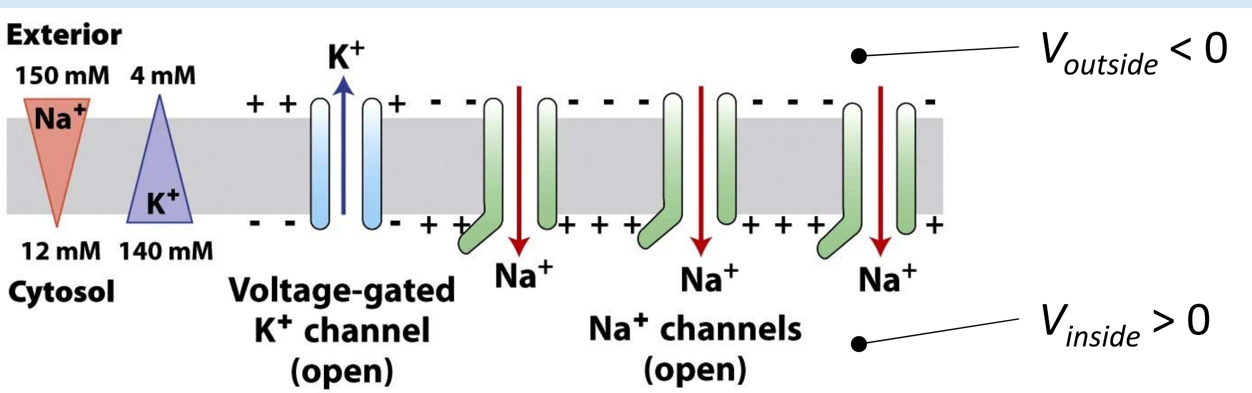
Electric potential in biology

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

Cells at rest are *polarized*

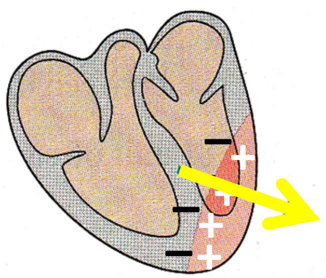


Some cell types (ex: neurons and muscle cells) *depolarize* when they fire

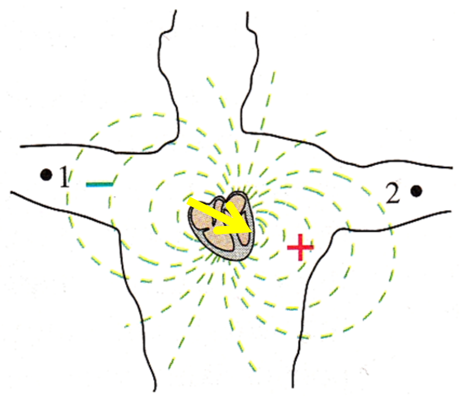


Electrocardiogram (ECG)

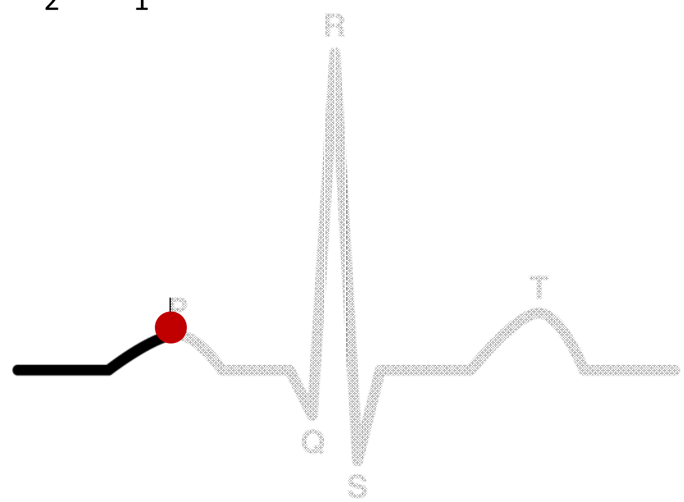
ECG detects electric potential difference from depolarization and polarization of cardiac tissue



Ventricular depol.



$V_2 - V_1$

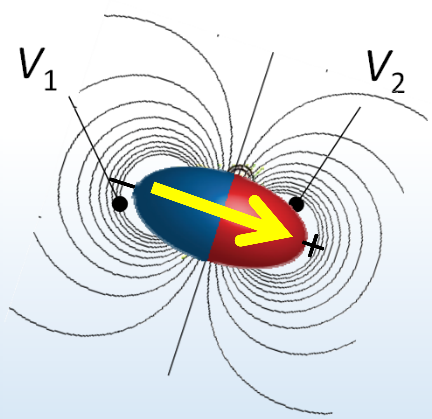


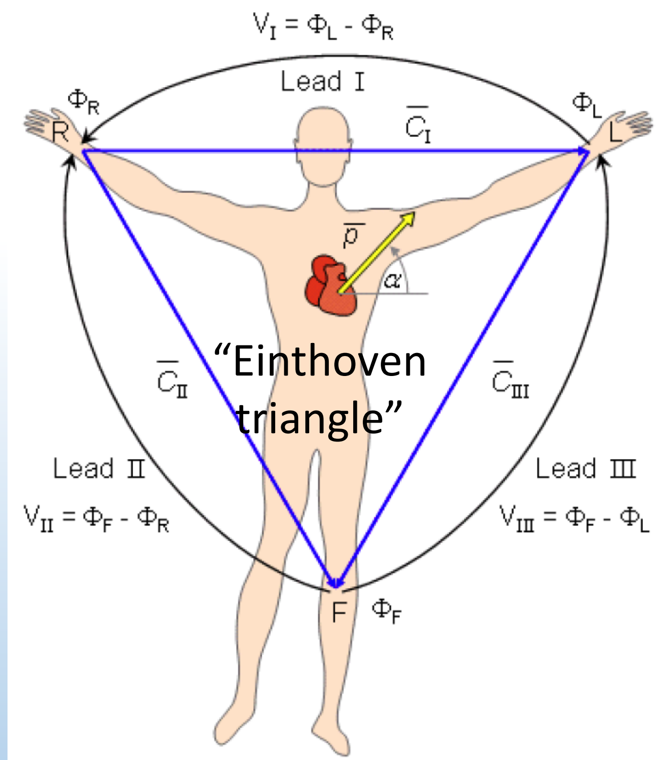
The heart behaves as time-varying electric dipole

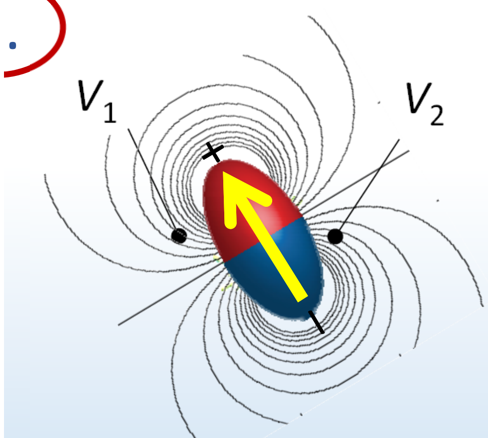
ACT: Electrocardiogram

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.

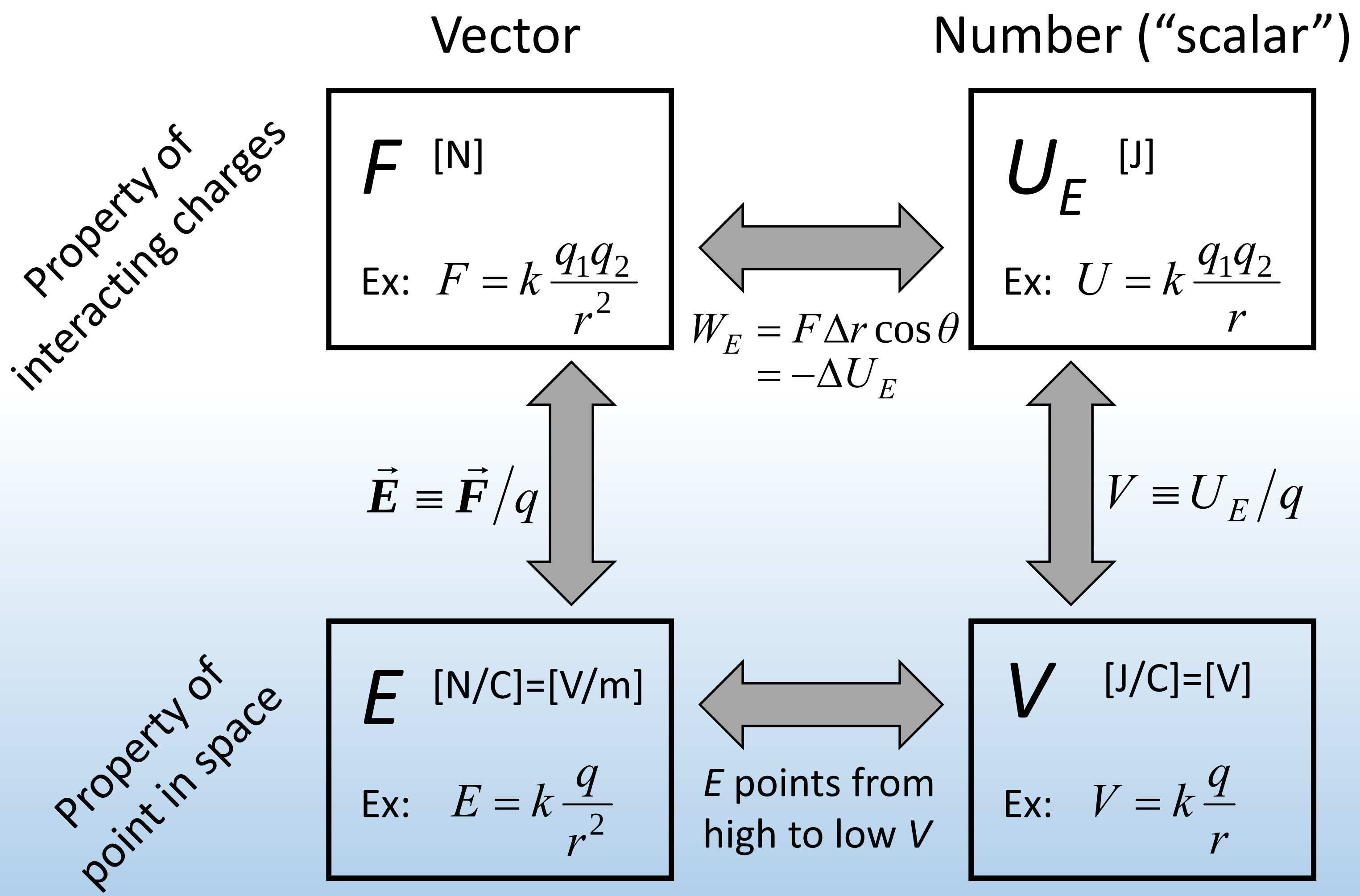






Usually ECG is done with 3, 6, or 12 leads
Need minimum of 3 to get dipole direction

Relationship between F, E, U_E, V



Exam 1 two weeks from Thursday!

- How do you best study for a Phys 102 exam?

  Start reviewing now! (cramming DOES NOT work)

  Emphasize understanding concepts & problem solving, NOT memorization

  Review lecture notes (ACTs), discussion summary

  Understand formulas (i.e. when to use and when NOT to use an equation) & know what each symbol means

  Do practice exam problems (time yourself!)

  Go to office hours & review session & ASK QUESTIONS

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