PHY132 Introduction to Physics II
Class 12 – **Outline:**

- Electric Potential Difference: a.k.a. “Voltage”
- Electric Potential of:
  – Parallel Plate Capacitor
  – Point Charge
  – Many Charges

- *Next week:* no classes
- *Week of Feb.23:* new teams in Practicals, **Andrew** takes over lectures.

- A battery is designed to supply a steady amount of which of the following quantities?
  A. Energy
  B. Power
  C. Electric potential difference
  D. Electric current

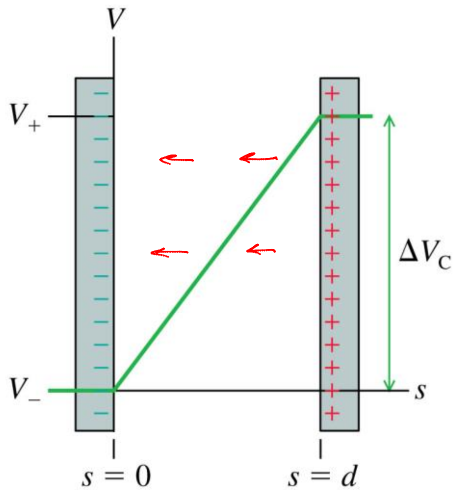
Class 12 Preclass Quiz on MasteringPhysics

- 97% got:The units of potential difference are Volts.
- 78% got: New units for the electric field were introduced in chapter 28. Old units were N/C. The new units are **V/m.**
  - You can show that these units are equivalent to each other:

$$1\ \text{N/C} = 1\ \text{V/m}$$

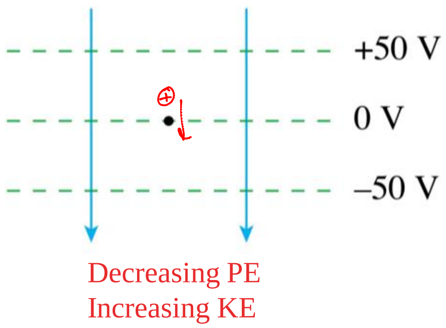
Class 12 Preclass Quiz on MasteringPhysics

- 76% got:The electric potential inside a capacitor increases linearly from the negative to the positive plate.



Class 12 Preclass Quiz on MasteringPhysics

A proton is released from rest at the dot. Afterward, the proton



81% got: Moves downward with an increasing speed.

Class 12 Preclass Quiz – Student Comments…

- *"Can the voltage ever be negative?"*
- **Harlow answer:** Yes! Electric potential is just the electric potential energy divided by charge of the probe charge. The E.P.E. can be negative, so electric potential can be negative too.
- *"Is there a real difference between a "normal" capacitor and a parallel-plate capacitor?"*
- **Harlow answer:** Parallel plate capacitor is more specific. There are many different geometries of capacitors out there, including ones rolled up like a burrito.

Class 12 Preclass Quiz – Student Comments…

- *"I just wish there was a bigger difference in the naming between potential energy and electric potential difference. The day when physics runs out of names for quantities..."*
- **Harlow answer:** agreed. "electric potential" is in Volts, "electric potential energy" is in Joules… They sound the same, but they are not.
- *"when is the next midterm?"*
- **Harlow answer:** Tue. Mar.10 at 6:00pm – about 4 weeks from now.

Class 12 Preclass Quiz – Student Comments…

- *Q: What did one quantum physicist say when he wanted to fight another quantum physicist?*
- *A: Let me atom!*
- *Did you hear oxygen and magnesium got together?*
- *OMg!*
- *What type of rodent causes another creature to accelerate when near it?*
- *A field mouse!*

The Electric Potential

- We define the electric potential V (or, for brevity, just the potential) as

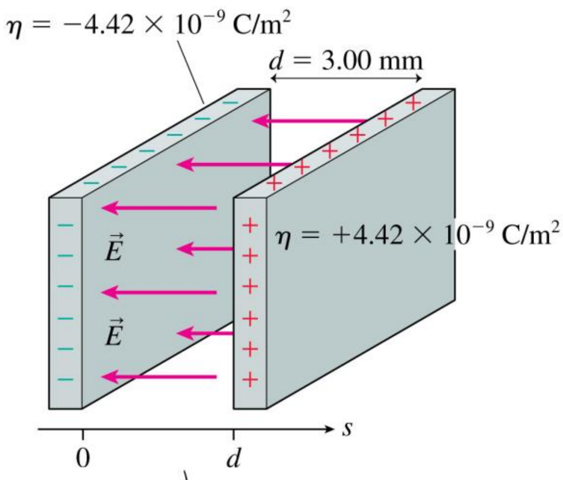
$$V \equiv \frac{U_{q+\text{sources}}}{q}$$

- This is NOT the same as electric potential energy. (different units, for one thing).
- The unit of electric potential is the joule per coulomb, which is called the volt V:

$$1 \text{ volt} = 1 \text{ V} \equiv 1 \text{ J/C}$$

The Electric Field Inside a Parallel-Plate Capacitor

This is a review of Chapter 26.



$$\vec{E} = \left(\frac{\eta}{\epsilon_0}, \text{from positive toward negative}\right)$$

$$= (500 \text{ N/C, from right to left})$$

The Electric Potential Inside a Parallel-Plate Capacitor

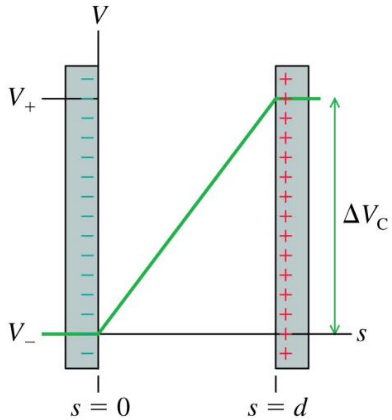
- The electric potential inside a parallel-plate capacitor is

$$V = Es \qquad \text{(electric potential inside a parallel-plate capacitor)}$$

where s **is the distance from the *negative* electrode.**

- The *potential difference* ΔV_C, or "voltage" between the two capacitor plates is

$$\Delta V_C = V_+ - V_- = Ed$$



Units of Electric Field

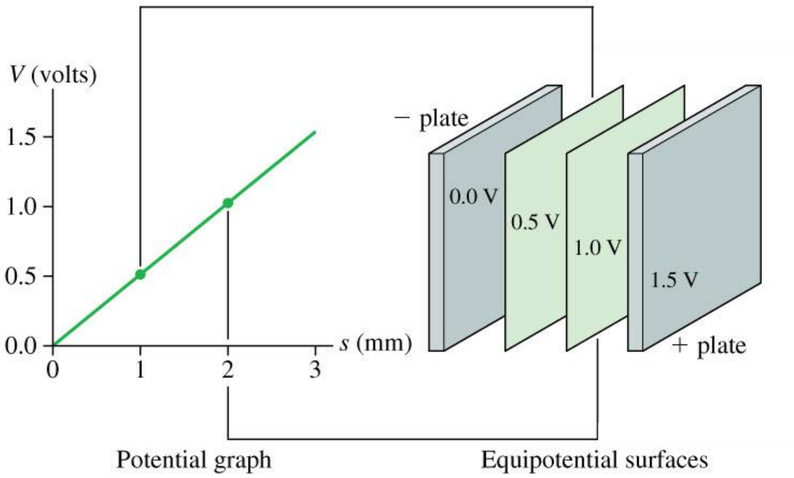
- If we know a capacitor's voltage ΔV and the distance between the plates d, then the electric field strength within the capacitor is:

$$E = \frac{\Delta V_C}{d}$$

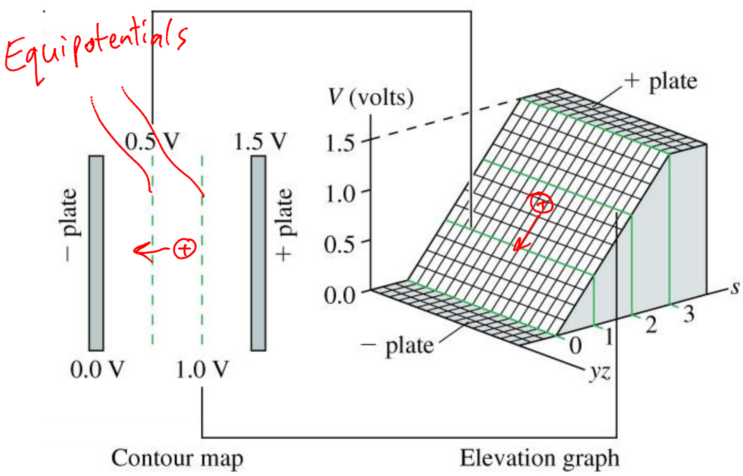
- This implies that the units of electric field are volts per meter, or V/m.
- Previously, we have been using electric field units of newtons per coulomb.
- In fact, as you can show as a homework problem, these units are equivalent to each other:

$$1\ \text{N/C} = 1\ \text{V/m}$$

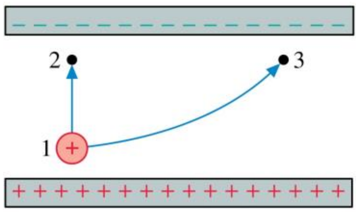
The Electric Potential Inside a Parallel-Plate Capacitor



The Electric Potential Inside a Parallel-Plate Capacitor



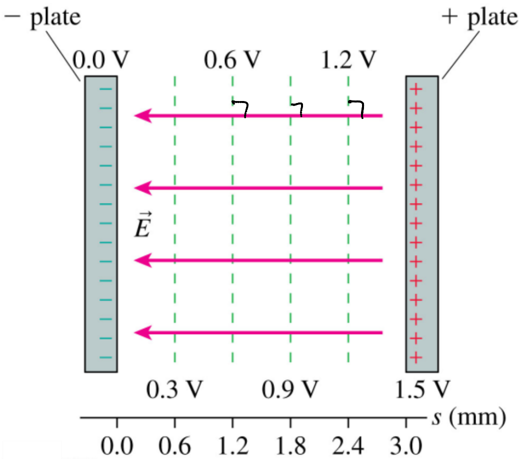
Two protons, one after the other, are launched from point 1 with the same speed. They follow the two trajectories shown. The protons' speeds at points 2 and 3 are related by



A. $v_2 > v_3$.
B. $v_2 = v_3$.
C. $v_2 < v_3$.
D. Not enough information to compare their speeds.

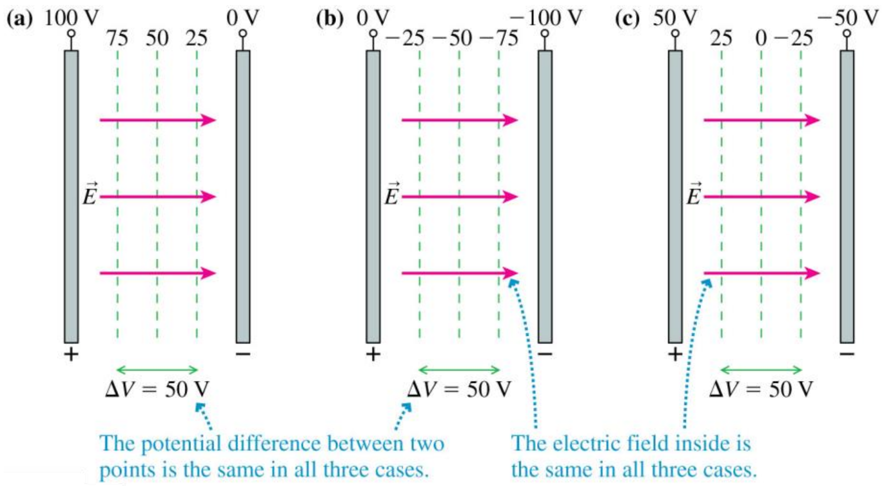
The Parallel-Plate Capacitor

- The figure shows the contour lines of the electric potential and the electric field vectors inside a parallel-plate capacitor.
- The electric field vectors are *perpendicular* to the equipotential surfaces.
- The electric field points in the direction of *decreasing* potential.



The Zero Point of Electric Potential

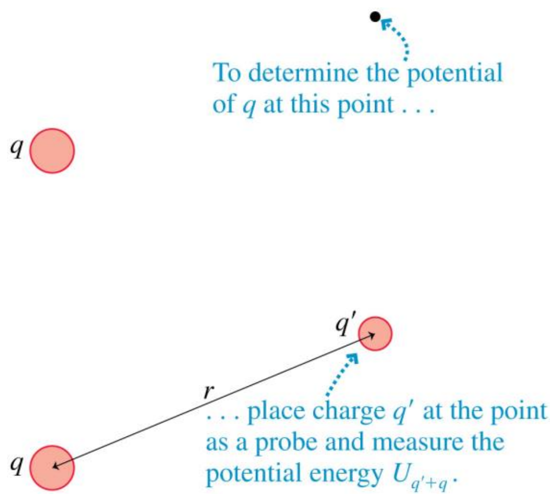
Where you choose $V = 0$ is arbitrary. The three contour maps below represent the *same physical situation*.



The Electric Potential of a Point Charge

- Let q in the figure be the source charge, and let a second charge q', a distance r away, probe the electric potential of q.
- The potential energy of the two point charges is

$$U_{q'+q} = \frac{1}{4\pi\epsilon_0}\frac{qq'}{r}$$



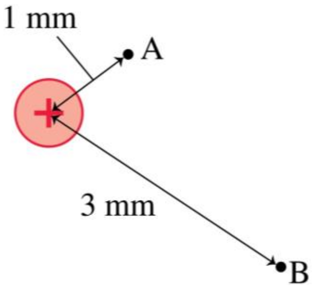
The Electric Potential of a Point Charge

- The electric potential due to a point charge q is

$$V = \frac{U_{q'+q}}{q'} = \frac{1}{4\pi\epsilon_0}\frac{q}{r} \qquad \text{(electric potential of a point charge)}$$

- The potential extends through all of space, showing the influence of charge q, but it weakens with distance as $1/r$.
- This expression for V assumes that we have chosen $V = 0$ to be at $r = \infty$.

What is the ratio V_B/V_A of the electric potentials at the two points?



A. 9.
B. 3.
C. 1/3.
D. 1/9.
E. Undefined without knowing the charge.

Quick Equations Quiz.. [1/4] Which is which?

The magnitude of the **force**, in Newtons, on a point charge that is near another point charge is:

A. $K\frac{q}{r}$

C. $K\frac{q_1 q_2}{r}$

B. $K\frac{q}{r^2}$

D. $K\frac{q_1 q_2}{r^2}$

$$K = \frac{1}{4\pi\varepsilon_0}$$

Quick Equations Quiz.. [2/4] Which is which?

The magnitude of the **Electric Field**, in Newtons per Coulomb, near a point charge is:

A. $K\frac{q}{r}$

C. $K\frac{q_1 q_2}{r}$

B. $K\frac{q}{r^2}$

D. $K\frac{q_1 q_2}{r^2}$

$$K = \frac{1}{4\pi\varepsilon_0}$$

Quick Equations Quiz.. [3/4] Which is which?

The **electric potential energy**, in Joules, of two point charges is:

A. $K\frac{q}{r}$

C. $K\frac{q_1 q_2}{r}$

B. $K\frac{q}{r^2}$

D. $K\frac{q_1 q_2}{r^2}$

$$K = \frac{1}{4\pi\varepsilon_0}$$

Quick Equations Quiz.. [4/4] Which is which?

The **electric potential**, in Volts, near a point charge is:

A. $K\frac{q}{r}$

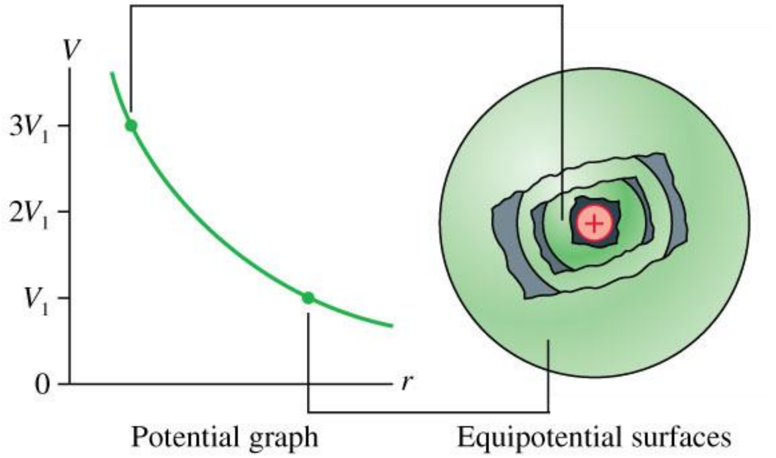
C. $K\frac{q_1 q_2}{r}$

B. $K\frac{q}{r^2}$

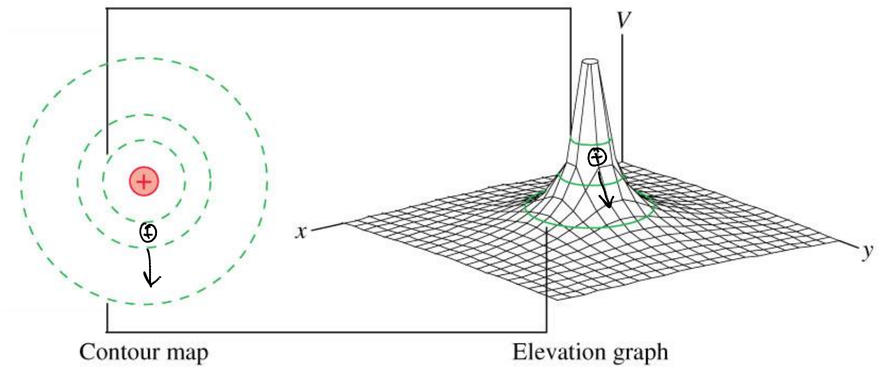
D. $K\frac{q_1 q_2}{r^2}$

$$K = \frac{1}{4\pi\varepsilon_0}$$

The Electric Potential of a Point Charge

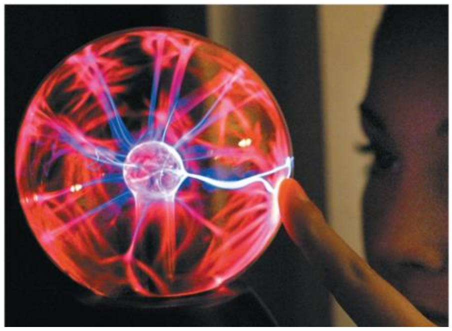


The Electric Potential of a Point Charge



The Electric Potential of a Charged Sphere

Outside a uniformly charged sphere of radius R, the electric potential is identical to that of a point charge Q at the center.



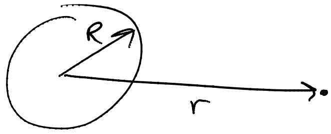
$$V = \frac{1}{4\pi\epsilon_0}\frac{Q}{r}$$

where $r > R$.
If the potential at the surface V_0 is known, then the potential at $r > R$ is:

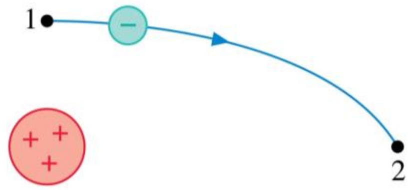
$$V = \frac{R}{r}V_0$$

Class 12 Preclass Quiz – Student Comments…

- *"What is the difference between R and r in the equation for the electric potential of a charged sphere?"*
- **Harlow answer:** R is a constant: the radius of the sphere. r is the distance from the centre of the sphere (independent variable)



An electron follows the trajectory shown from point 1 to point 2. At point 2,



A. $v_2 > v_1$.

B. $v_2 = v_1$.

C. $v_2 < v_1$.

D. Not enough information to compare the speeds at these points.

The Electric Potential of Many Charges

- The electric potential V at a point in space is the sum of the potentials due to each charge:

$$V = \sum_i \frac{1}{4\pi\epsilon_0} \frac{q_i}{r_i}$$

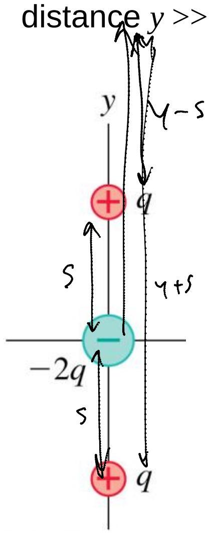
  where r_i is the distance from charge q_i to the point in space where the potential is being calculated.

- **The electric potential, like the electric field, obeys the principle of superposition.**

Problem 28.66

The arrangement of charges shown is called a linear electric quadrupole. The positive charges are located at $y = \pm s$.

Find an expression for the electric potential on the y-axis at a distance $y >> s$.



top, middle, bottom

$$V = +\frac{Kq}{y-s} - \frac{K(2q)}{y} + \frac{Kq}{y+s}$$

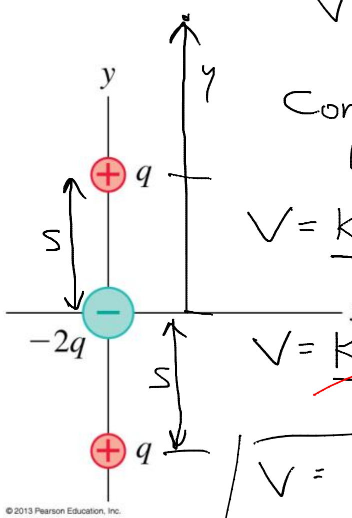
simplify....

Common denominator:

$$(y-s)y(y+s) = y(y^2-s^2)$$

$$V = \frac{kqy(y+s) - 2kq(y^2-s^2) + Ky(y-s)}{y(y^2-s^2)}$$

$$= \frac{kqy^2 + kqys - 2kqy^2 + 2kqs^2 + kqy^2 - kqys}{y(y^2-s^2)}$$



$$V = \frac{Kq}{y-s} - \frac{K(2q)}{y} + \frac{Kq}{y+s}$$

Common denominator:

$$(y-s)y(y+s) = y(y^2-s^2)$$

$$V = \frac{Kqy(y+s) - 2Kq(y^2-s^2) + Kqy(y-s)}{y(y^2-s^2)}$$

$$V = \frac{Kqy^2 + Kqys - 2Kqy^2 + 2Kqs^2 + Kqy^2 - Kqys}{y(y^2-s^2)}$$

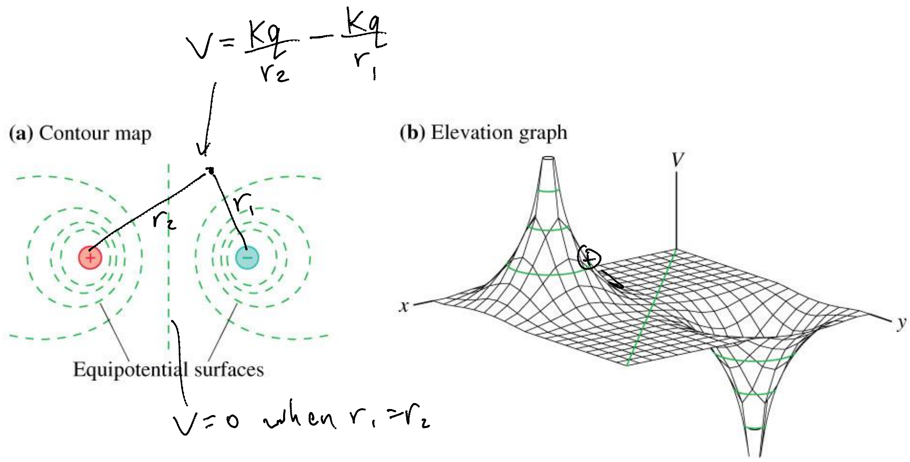
$$V = \frac{2Kqs^2}{y(y^2-s^2)}$$

If $y >> s$

$$(y^2 - s^2) \rightarrow y^2$$

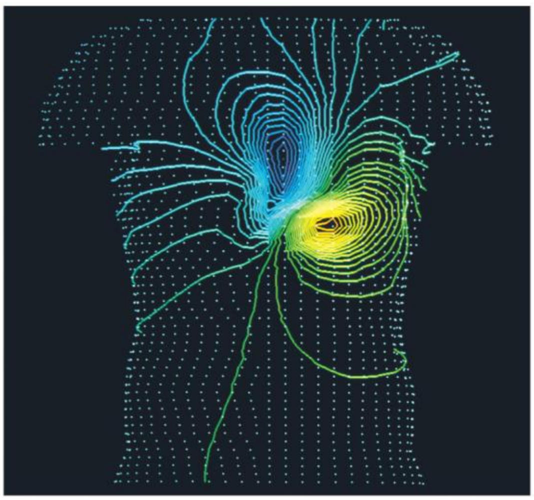
$$V \simeq \frac{2Kqs^2}{y^3}$$

The Electric Potential of an Electric Dipole



The Electric Potential of a Human Heart

- Electrical activity within the body can be monitored by measuring equipotential lines on the skin.
- The equipotentials near the heart are a slightly distorted but recognizable *electric dipole.*



At the midpoint between these two equal but opposite charges,

A. $\vec{E} = \vec{0};\ V = 0.$

B. $\vec{E} = \vec{0};\ V > 0.$

C. $\vec{E} = \vec{0};\ V < 0.$

D. $\vec{E}$ points right; $V = 0.$

E. $\vec{E}$ points left; $V = 0.$

The next test…

- Term Test 2 is in 4 weeks:
- Tuesday, Mar. 10 6:10pm in room TBA
- This will cover Chapters 25, 26, 28, 29 and conceptual questions (clicker-style questions) from Chapter 30
- Remember the second half of chapter 23 on lenses will ***not*** be tested on the midterm or final exam.

Have a great Reading Week!!

- I hope you enjoy the rest of your semester, and please keep coming to see me in **office hours**: Tuesdays 12-1 and Fridays 10-11am, plus any time you see my door is open on your way to Practicals!! Feel free to stop by and even just say hi!
- Exception: Next week, Reading Week, I do not have office hours.
- When you get back on Feb. 23, Professor Meyertholen will start where I am leaving off: Chapter 29, connecting Electric Potential with Electric Field.
- And even after you are no longer my students, please stay in touch and drop by whenever you like!