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

- Electric Potential of:
  - Parallel Plate Capacitor
  - Point Charge
  - Many Charges

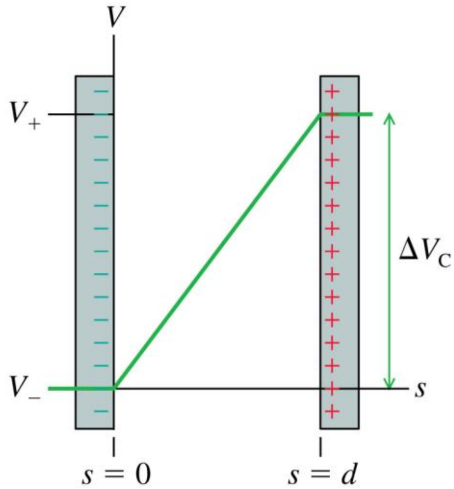
Class 12 Preclass Quiz on MasteringPhysics

- 98% got:The units of potential difference are **Volts**.
- 82% got: New units for the electric field were introduced in this chapter. Old units were N/C. The new units are **V/m**.
  - You can show that these units are equivalent to each other:

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

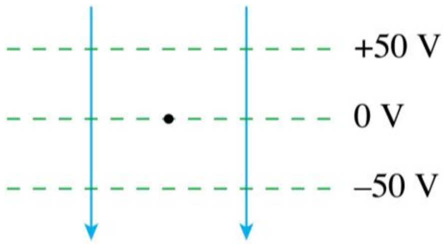
Class 12 Preclass Quiz on MasteringPhysics

- 86% 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



85% got: Moves downward with an increasing speed.

Class 12 Preclass Quiz – Student Comments…

- *“Could we go over what is meant by arbitrarily choosing the zero point of voltage? I'm not too sure on how to apply this concept.”*
- **Harlow answer:** In order to determine motion of charge, and actual measureable things, only the ***change*** in electric potential matters. So it really doesn’t matter where you define zero electric potential to be; we just choose a convenient location.
- *“what exactly is a capacitor, laymans terms”*
- **Harlow answer:** Two pieces of metal, separated by an insulator. There might be opposite electric charges on the capacitor.
- “Do I want to put a fork in the outlet?”
- **Harlow answer:** No! Trust me, don’t do this!

Class 12 Preclass Quiz – Student Comments…

- Jokes:
- *“Two protons part ways after a date. As they are walking away from each other, one proton calls to the other "we had to such potential"”*
- *“What did the proton say to the electron? - I'm attracted to you! Happy Valentine's Day.”*

Last time I asked you to consider…

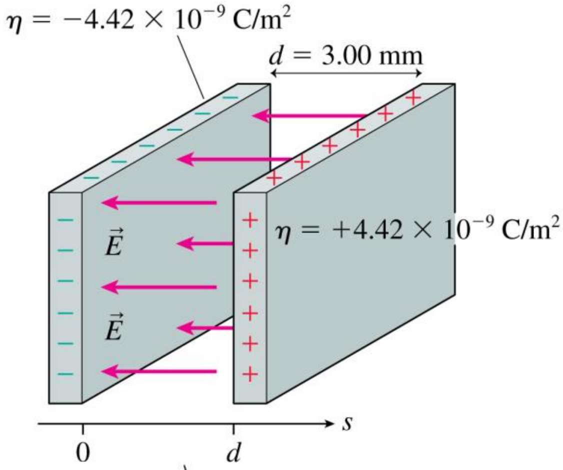
- A battery is designed to supply a steady amount of which of the following quantities?
  - Energy
  - Power
  - Electric potential difference
  - Electric current

The Electric Field Inside a Parallel-Plate Capacitor

This is a review of Chapter 26.

$\epsilon_0 = \frac{1}{4\pi K}$

$K = \frac{1}{4\pi\epsilon_0}$



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

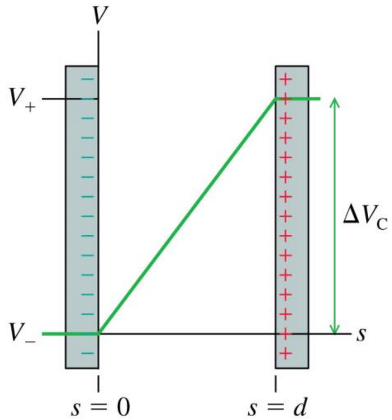
$$= (500\ \text{N/C, from right to left})$$

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, these units are equivalent to each other:

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

Electric Potential = Electric Potential Energy per charge

$$V = \frac{U_e}{q}$$

units check:

$$V = \frac{J}{C}$$

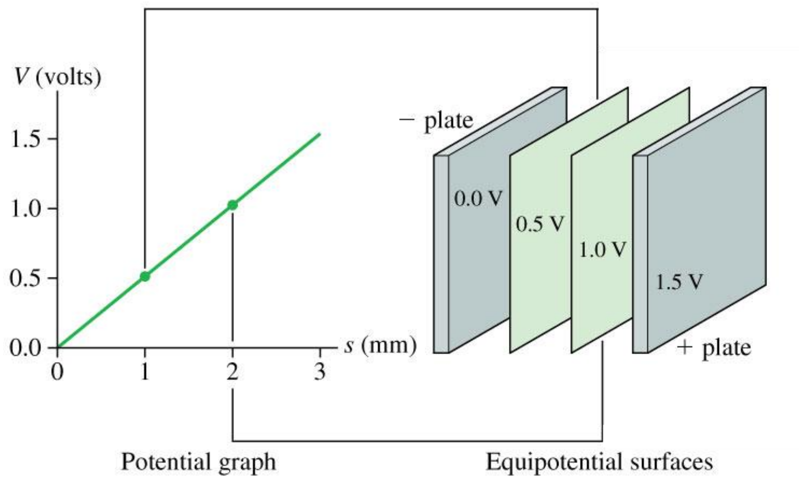
Work = Force × distance

$J = N \cdot m$

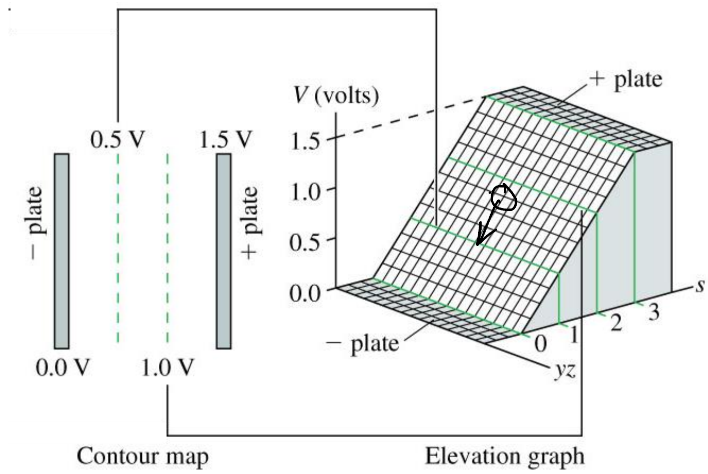
$$V = \frac{N \cdot m}{C}$$

$$\left[\frac{V}{m}\right] = \left[\frac{N}{C}\right] \quad \checkmark$$

The Electric Potential Inside a Parallel-Plate Capacitor

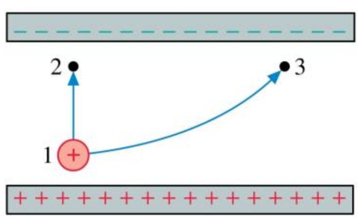


The Electric Potential Inside a Parallel-Plate Capacitor



$U = qV$

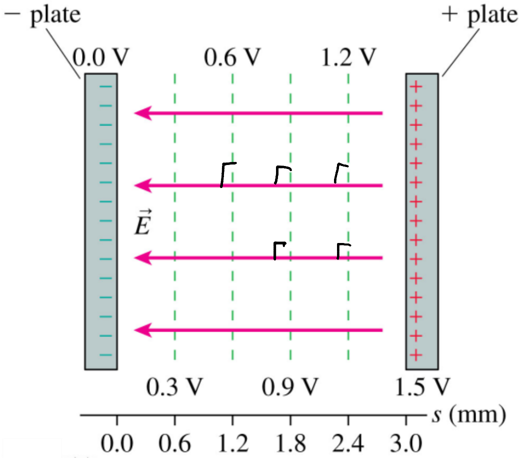
Two protons, one after the other, are launched from point 1 with the same speed. They follow the two trajectories shown. The protons' speeds at points 2 and 3 are related by



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

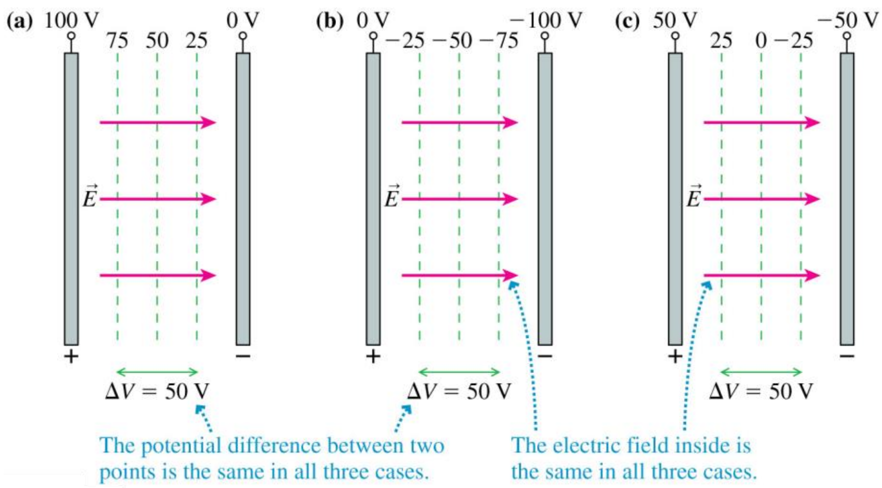
- The figure shows the contour lines of the electric potential and the electric field vectors inside a parallel-plate capacitor.



- The electric field vectors are *perpendicular* to the equipotential surfaces.
- The electric field points in the direction of *decreasing* potential.

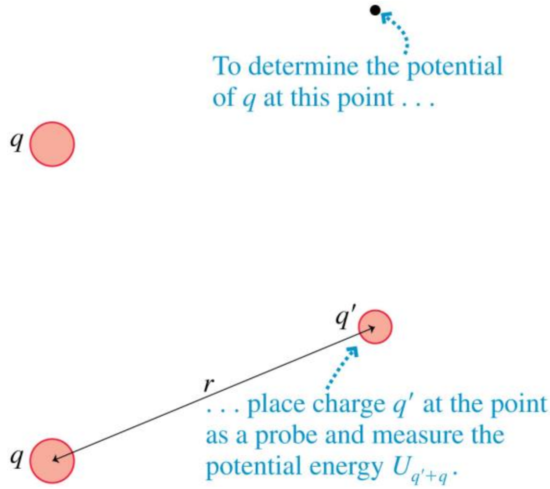
The Zero Point of Electric Potential

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



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

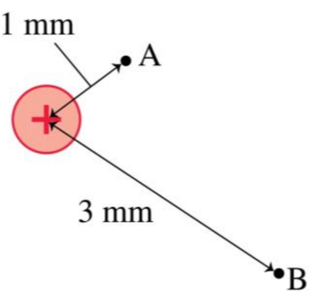
The Electric Potential of a Point Charge

- The electric potential due to a point charge q is

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

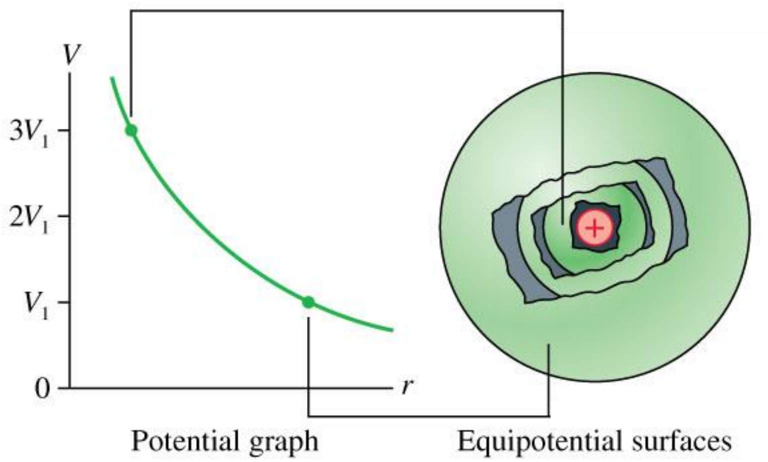
- The potential extends through all of space, showing the influence of charge q, but it weakens with distance as $1/r$.
- This expression for V assumes that we have chosen $V = 0$ to be at $r = \infty$.

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

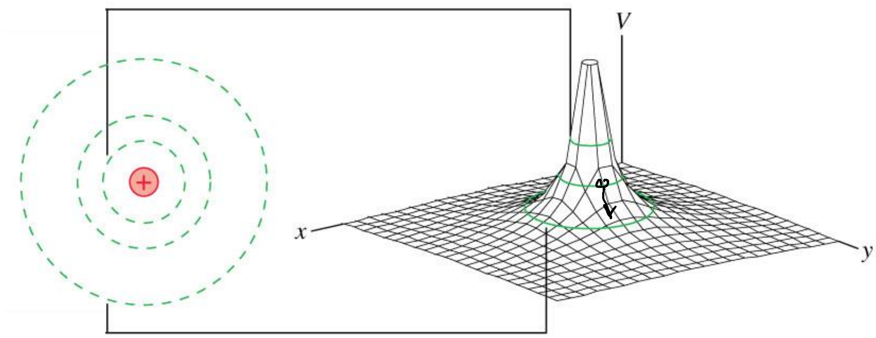


A. 9.
B. 3.
C. 1/3.
D. 1/9.
E. Undefined without knowing the charge.

The Electric Potential of a Point Charge



The Electric Potential of a Point 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. $K\dfrac{q}{r}$

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

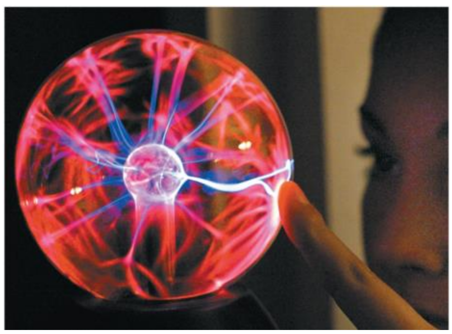
C. $K\dfrac{q_1 q_2}{r}$

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

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

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.

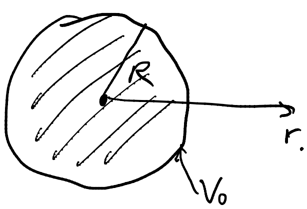


$$V = \frac{1}{4\pi\epsilon_0}\frac{Q}{r}$$

where $r > R$.

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

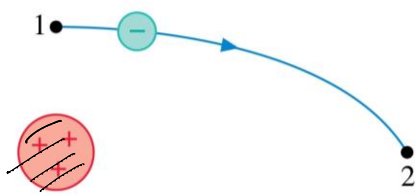
$$V = \frac{R}{r}V_0$$



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.**

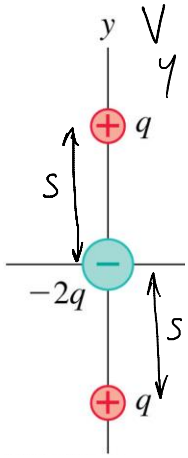
Problem 28.66

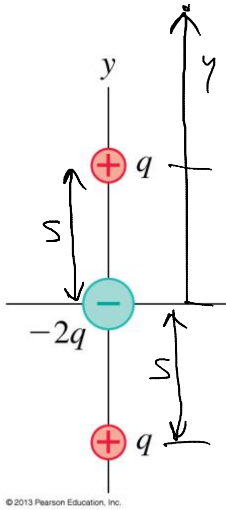
The arrangement of charges shown is called a linear electric quadrupole. The positive charges are located at $y = \pm s$.

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

Find V at y

$$V = \frac{kq}{y-s} + \frac{k(-2q)}{y} + \frac{kq}{y+s}$$





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

Common denominator:

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

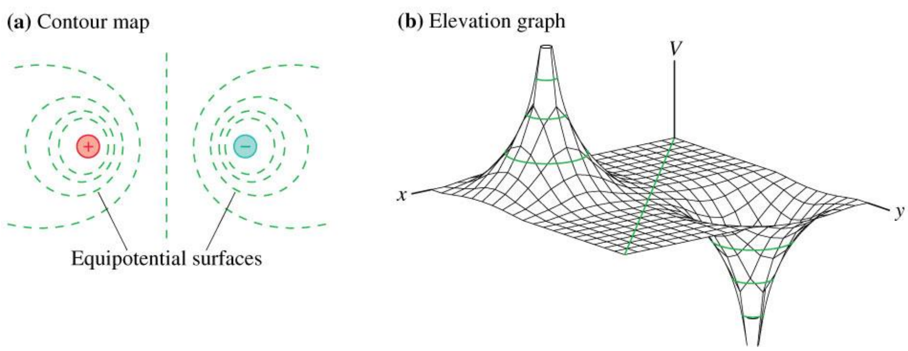
$$V = \frac{Kqy(y+s) - 2Kq(y^2-s^2) + Kqy(y-s)}{y(y^2-s^2)}$$

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

$$V = \frac{2kqs^2}{y(y^2-s^2)}$$ ← exact, if $y \gg s$, $(y^2-s^2) \approx y^2$

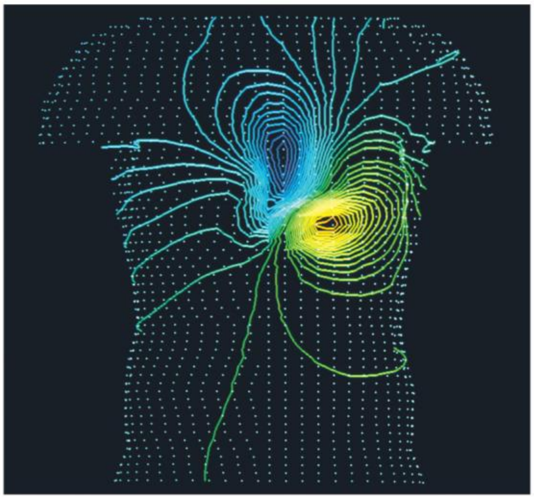
$$\boxed{V \approx \frac{2kqs^2}{y^3}}$$

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.*



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

At the midpoint between these two equal but opposite charges,

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

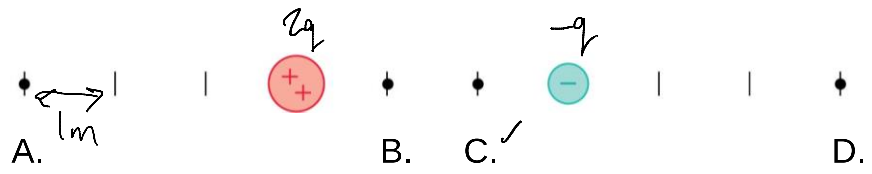
B. $\vec{E} = \vec{0}$; $V > 0$.

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

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

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

At which point or points is the electric potential zero?



E. More than one of these.

$$A: V = \frac{K(2q)}{3} - \frac{Kq}{6} = kq\left(\frac{2}{3} - \frac{1}{6}\right) \neq 0$$

$$B: V = \frac{K(2q)}{1} - \frac{Kq}{2} = kq\left(2 - \frac{1}{2}\right) \neq 0$$

$$C: V = \frac{K(2q)}{2} - \frac{Kq}{1} = 0 \qquad D: V = \frac{K(2q)}{6} - \frac{Kq}{3} = 0$$

Have a great Reading Week!!

- When you get back on Feb. 24, Professor Meyertholen will start where I am leaving off: Chapter 29, connecting Electric Potential with Electric Field.
- You will learn all about electric circuits, magnetism, and Einstein’s theory of relativity.
- I hope you enjoy it, and please keep coming to see me in office hours; you are my students until the final exam is done!
- And even after you are no longer my students, please stay in touch and drop by whenever you like!
- Best wishes and see you around!