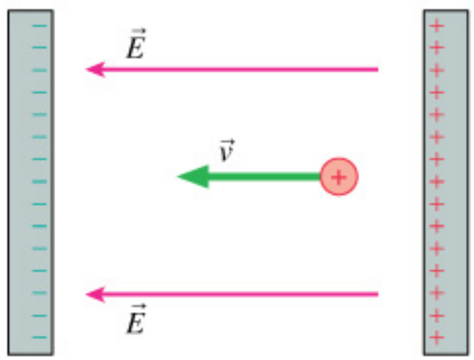
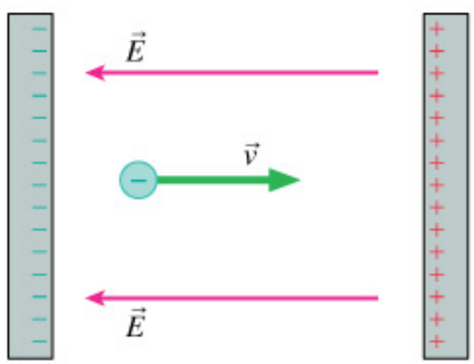
PHY294H

- Professor: Joey Huston
- email:huston@msu.edu
- office: BPS3230
- Homework will be with Mastering Physics (and an average of 1 hand-written problem per week)
  - **Added problem 28.68 for 3rd MP assignment due Wed Feb. 3 as a hand-in problem**
  - **Help-room hours: 12:40-2:40 Tues; 3:00-4:00 PM Friday**
- Quizzes by iclicker (sometimes hand-written)
- Course website: www.pa.msu.edu/~huston/phy294h/index.html
  - lectures will be posted frequently, mostly every day if I can remember to do so

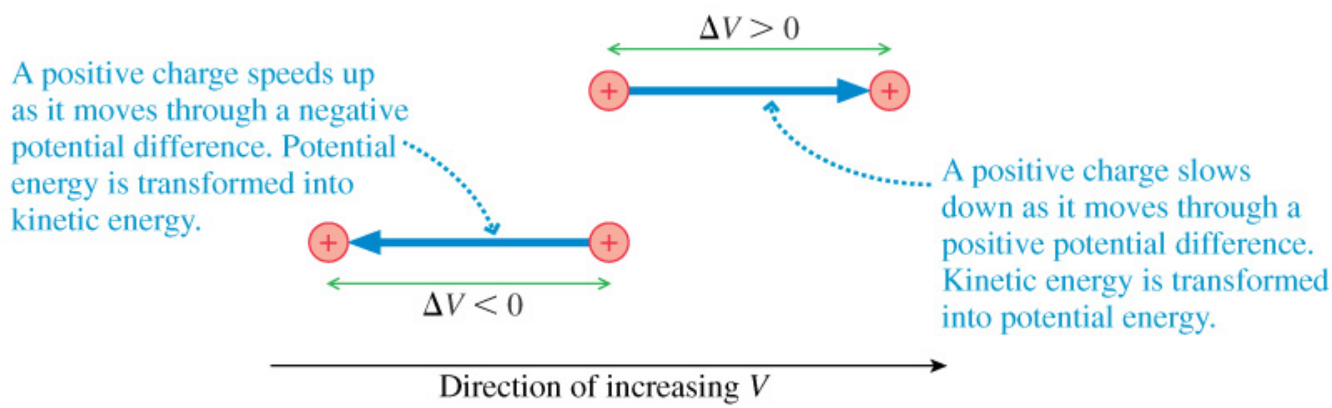
A particle moving in an electric potential



The potential energy of a positive charge decreases in the direction of $\vec{E}$. The charge gains kinetic energy as it moves toward the negative plate.



The potential energy of a negative charge decreases in the direction opposite to $\vec{E}$. The charge gains kinetic energy as it moves away from the negative plate.

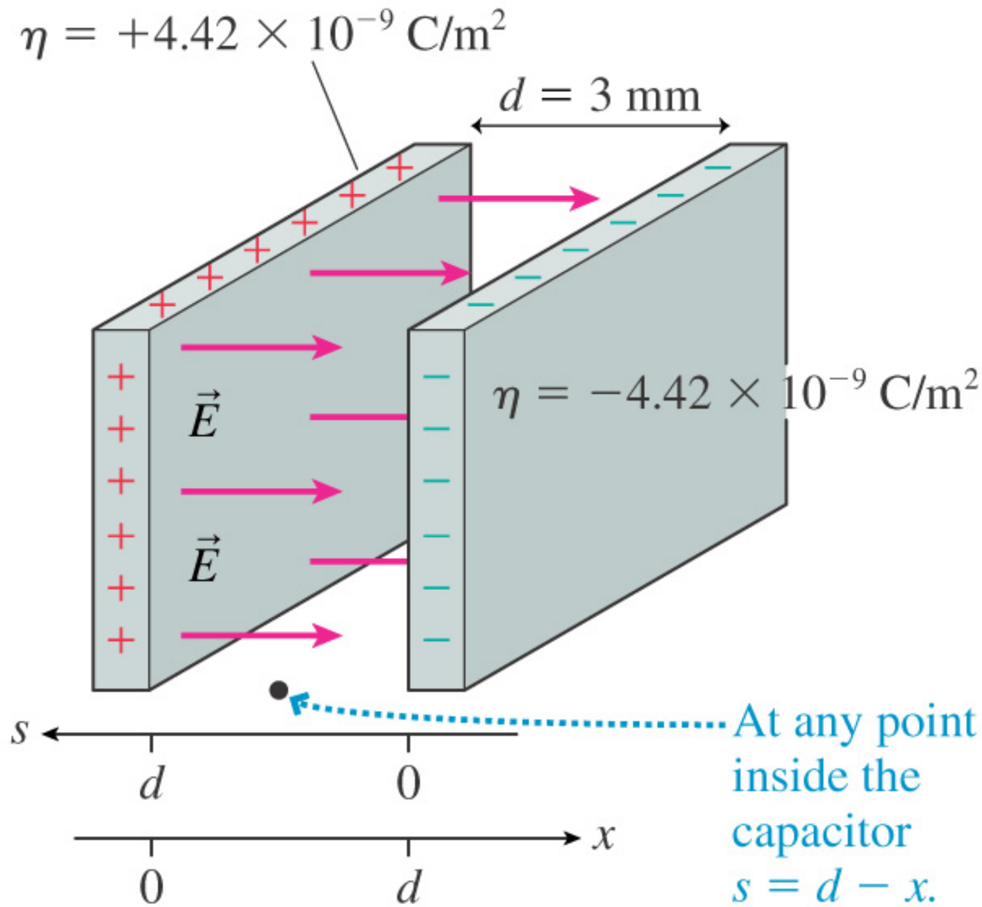


The electric potential increases in the direction opposite the E field.

Electric potential inside a parallel-plate capacitor

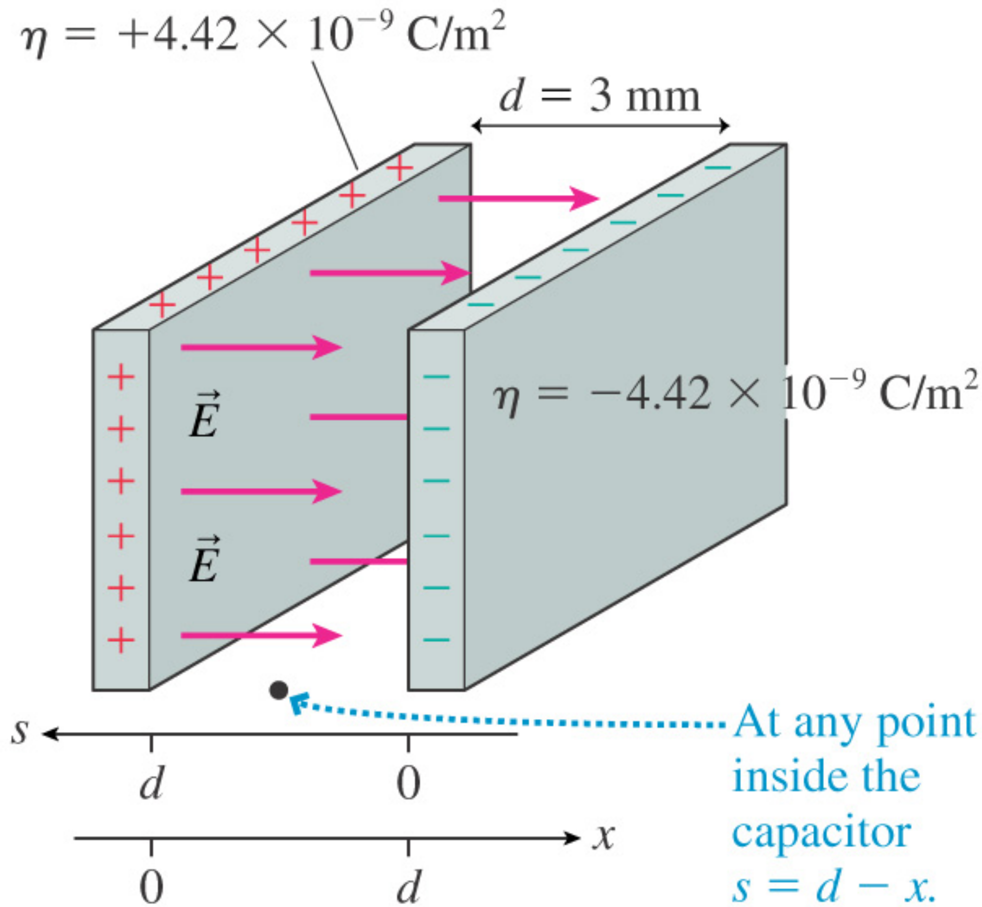
- Go back again to a parallel plate capacitor
  - $E = \eta/\varepsilon_o$
  - for the example given in the book, E = 500 N/C

- Inside the capacitor
  - V=Es, where s is the distance from the negative plate
  - so potential increases linearly with distance from the negative plate
  - $\Delta V_c = Ed$ = (500 N/C)(.003 m) = 1.5 V
  - note: $E=\Delta V_c/d$



Electric potential inside a parallel-plate capacitor

- $E=\Delta V_c/d$
  - I can define the electric field not in terms on the charges creating it (the + and - charges on the parallel plates) but in terms of the voltage between the plates and their separation
- Units for electric field
  - before we used
    - F=qE; E=F/q (N/C)
  - now: $E=\Delta V_c/d$ (V/m)
    - 1 N/C = 1 V/m
    - can use either set of units depending on which is more convenient for the problem at hand

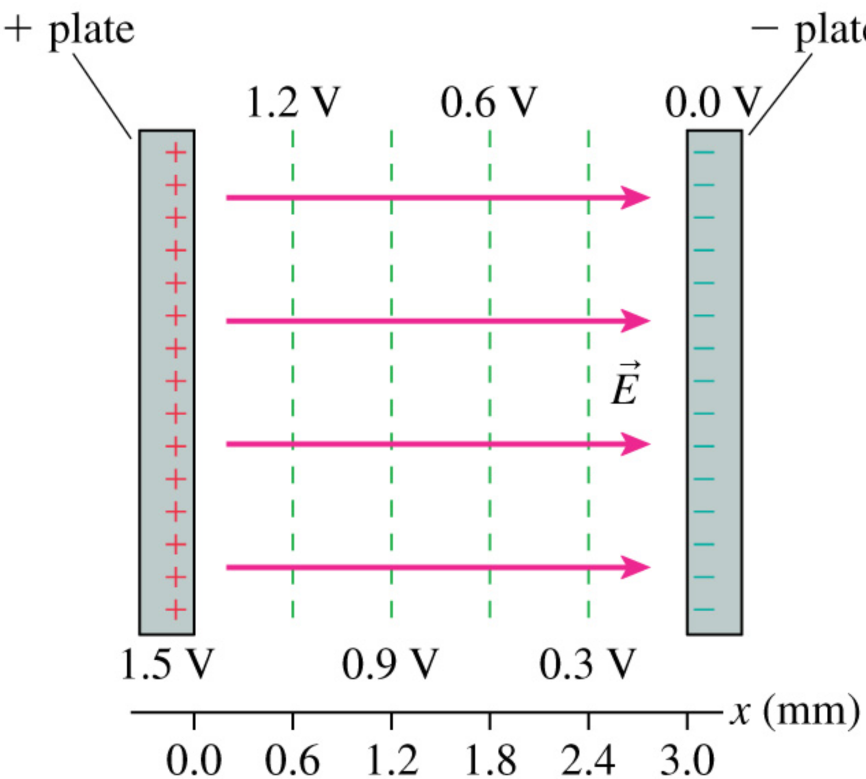


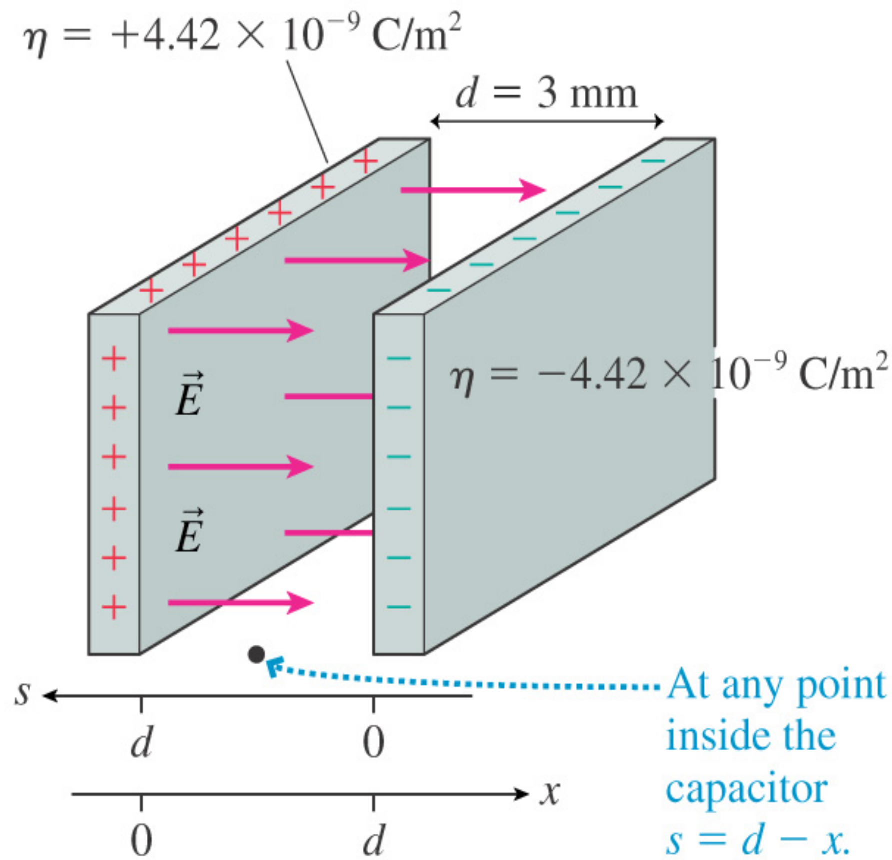
Electric potential inside a parallel-plate capacitor

- Note that I can write the potential as

$$V = Es = \Delta V_c \frac{(d-x)}{d}$$

$$V = Es = \left(1 - \frac{x}{d}\right)\Delta V_c$$

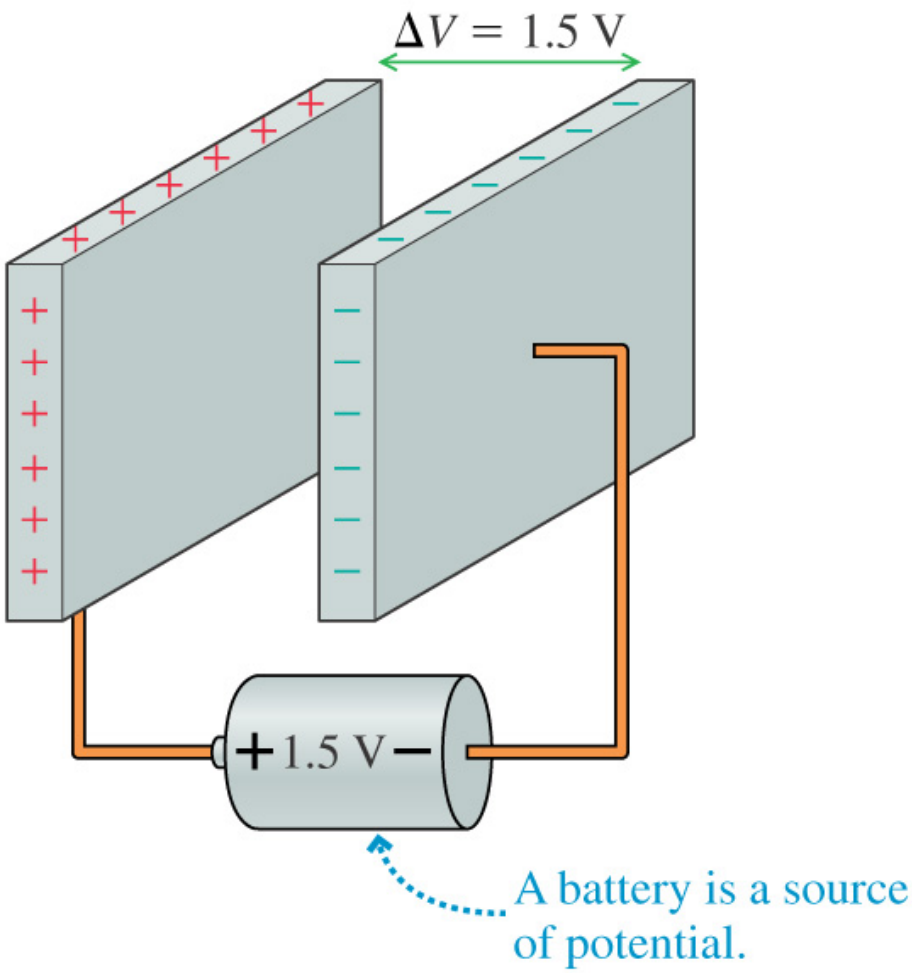




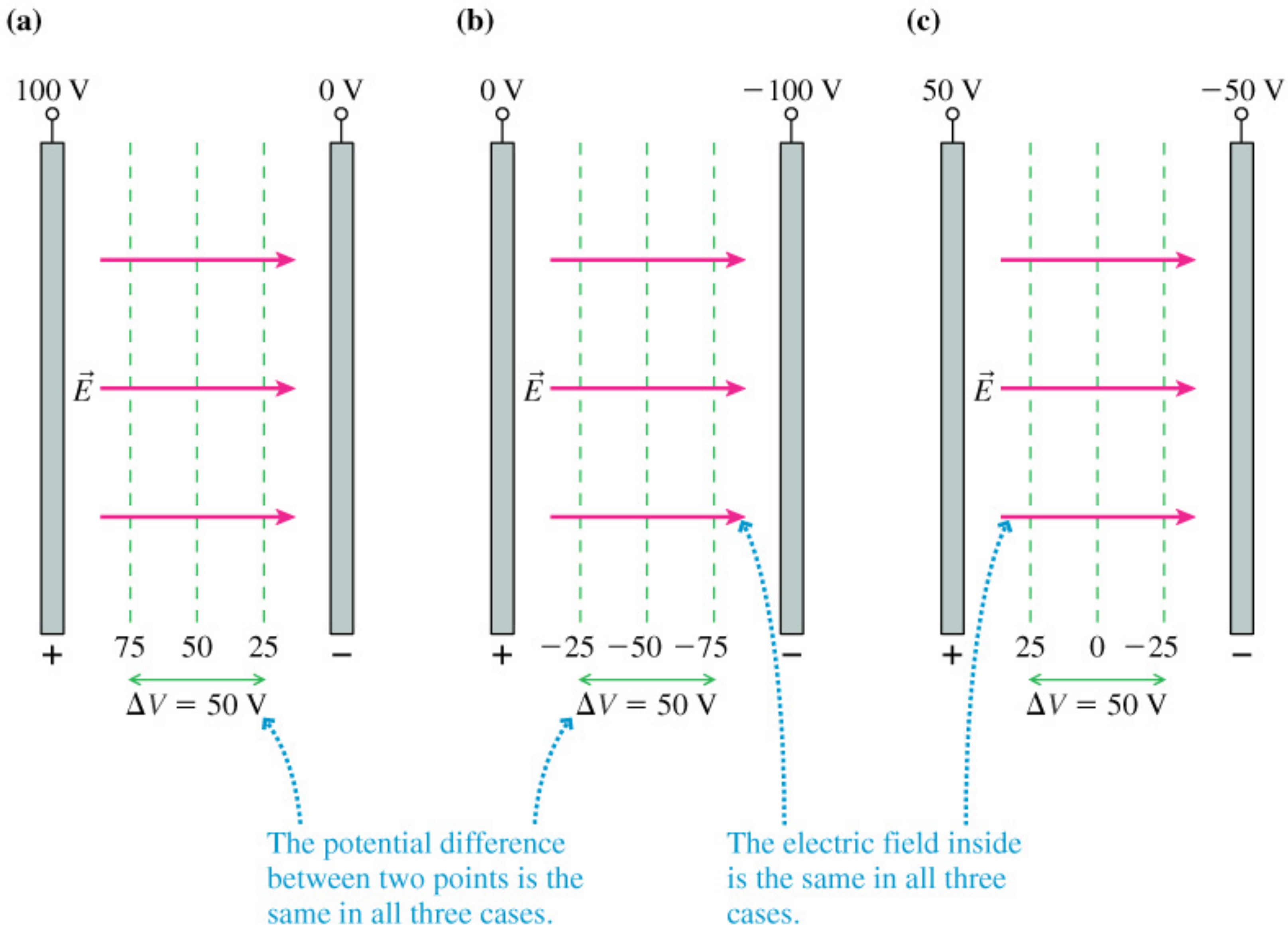
can draw equipotential lines inside capacitor

Potential

- We have a potential difference between the two plates equal to 1.5 V if we put a charge density of 4.42×10^{-9} C/m^2 on each of the plates
- An easy way of doing that is to connect a 1.5 V battery across the two plates of the capacitor

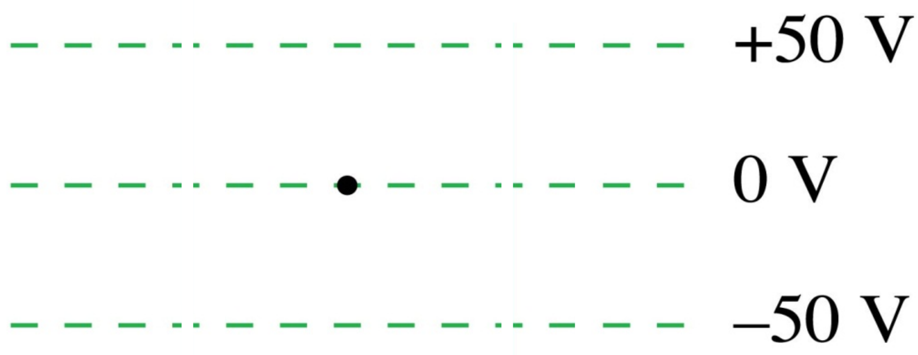


Arbitrariness of reference potential



iclicker question

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



A. Remains at the dot.

B. Moves upward with steady speed.

C. Moves upward with an increasing speed.

D. Moves downward with a steady speed.

E. Moves downward with an increasing speed.

iclicker question

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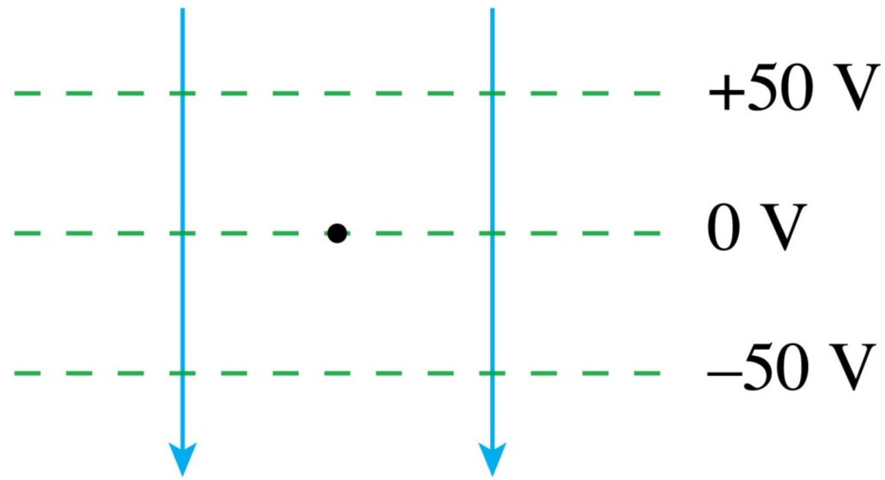

A. Remains at the dot.

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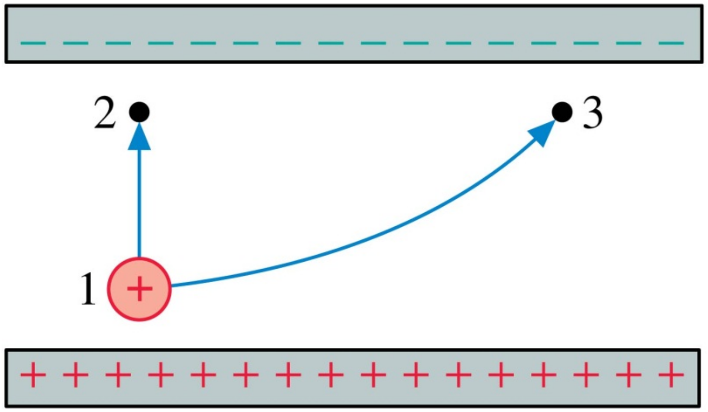
iclicker question

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.

iclicker question

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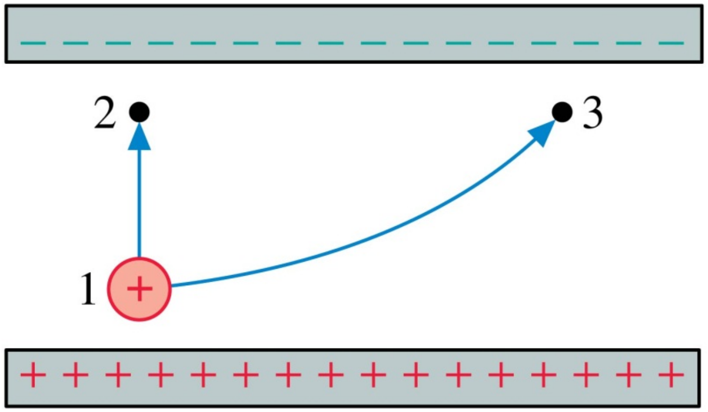


A. $v_2 > v_3$.

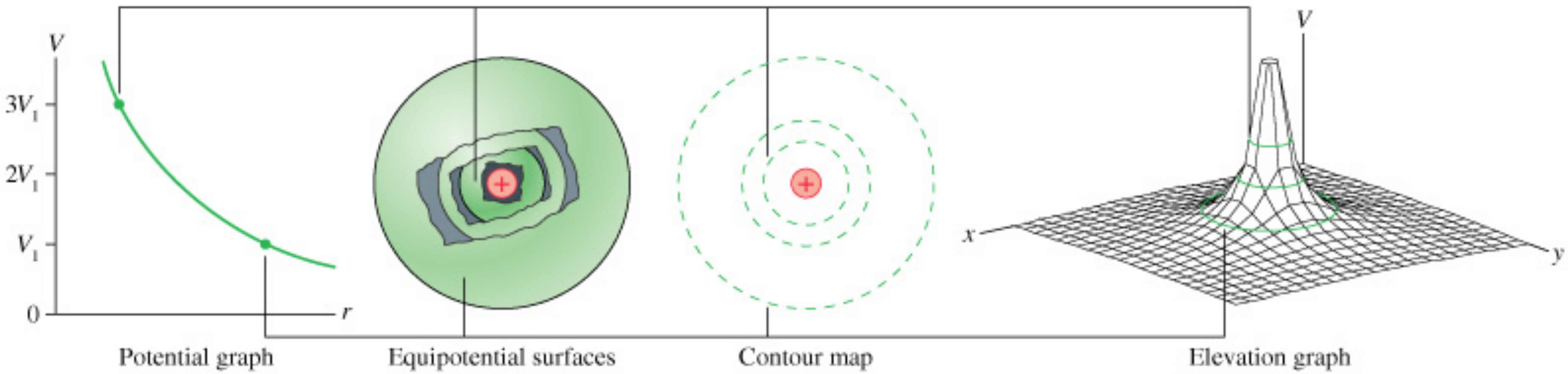
B. $\boldsymbol{v_2 = v_3}$. Energy conservation

C. $v_2 < v_3$.

D. Not enough information to compare their speeds.

Potential from a point charge

$$V = \frac{q}{4\pi\varepsilon_o r}$$



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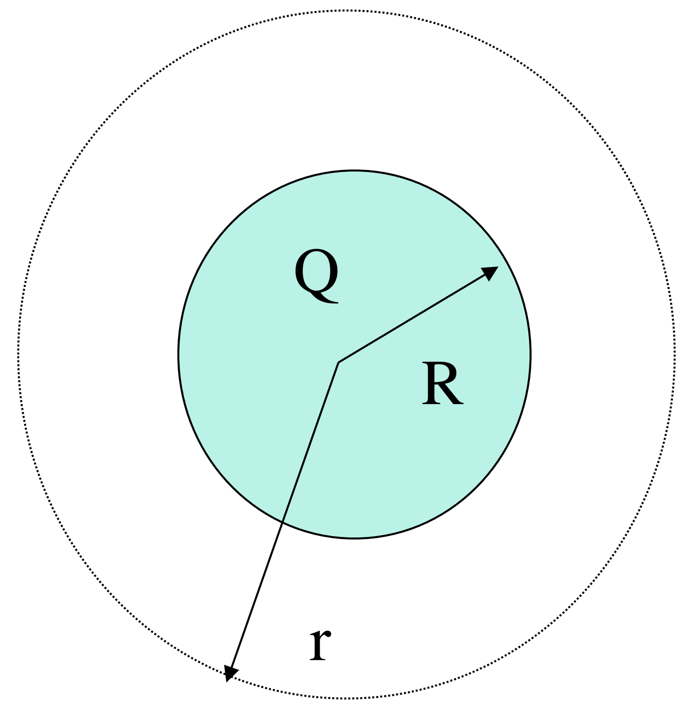
Potential from a charged sphere

- What if I have a charged sphere of radius R?
- What does the potential look like outside the sphere (r>R)?

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

- At the surface,

$$V = \frac{1}{4\pi\varepsilon_o}\frac{Q}{R}$$



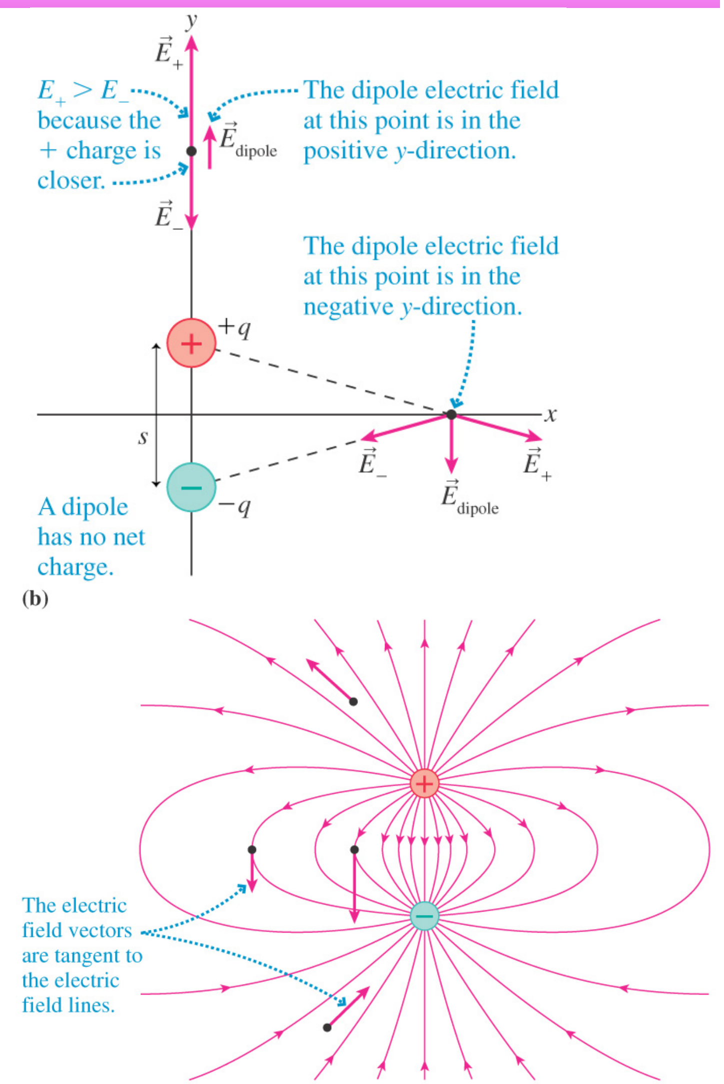
What about inside the sphere? That depends on how the charge is distributed.

Potential of many charges

- If I have multiple charges, then I have to calculate the potential at any point from each charge

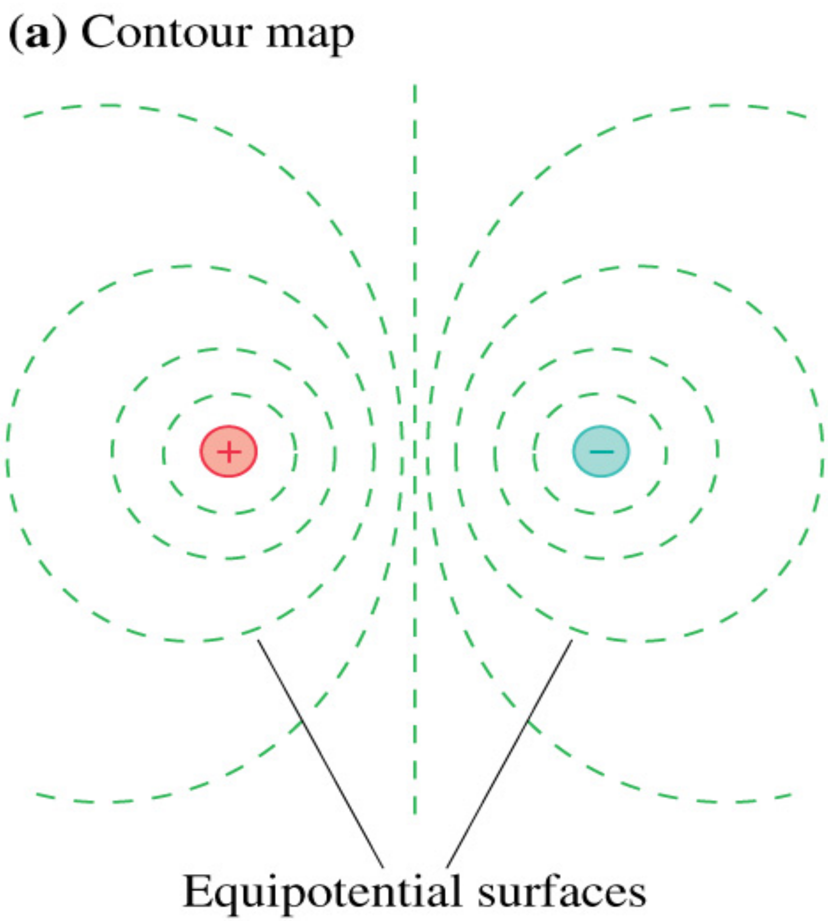
$$V = \sum_i \frac{1}{4\pi\varepsilon_o} \frac{q_i}{r_i}$$

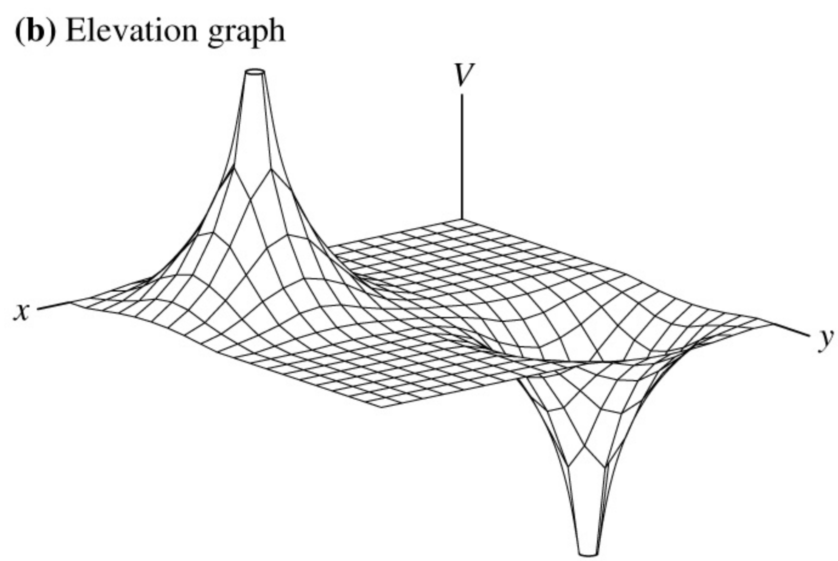
- The electric potential, like the electric field, obeys the principle of superposition
- Let's consider an electric dipole; we already know what the electric field looks like



Potential of electric dipole

$$V = \frac{1}{4\pi\varepsilon_o}\left[\frac{q_1}{r_1} + \frac{q_2}{r_2}\right]$$





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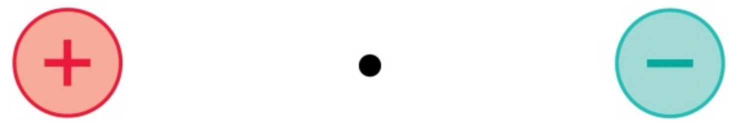
At the midpoint between these two equal but opposite charges,



A. $E = 0$; $V = 0$.

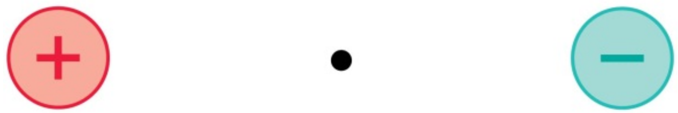
B. $E = 0$; $V > 0$.

C. $E = 0$; $V < 0$.

D. E points right; $V = 0$.

E. E points left; $V = 0$.

At the midpoint between these two equal but opposite charges,



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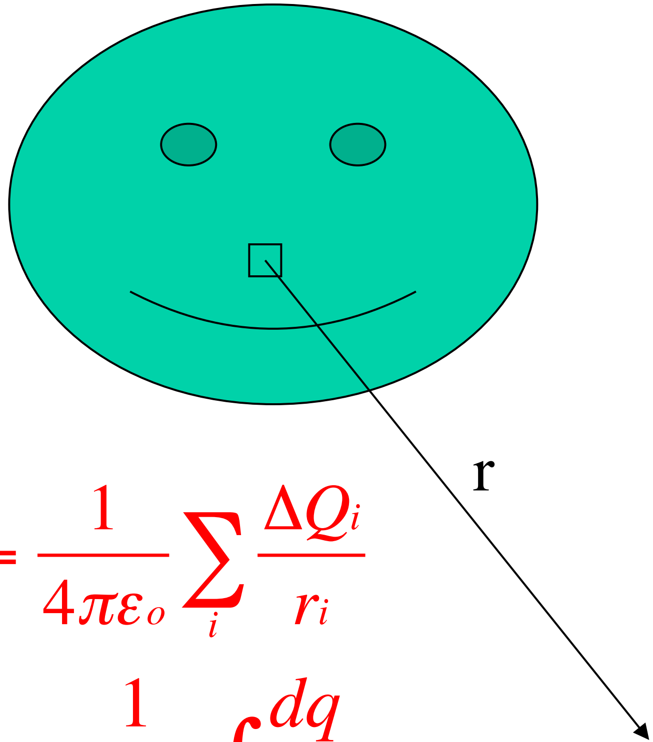
Potential from continuous charge distributions

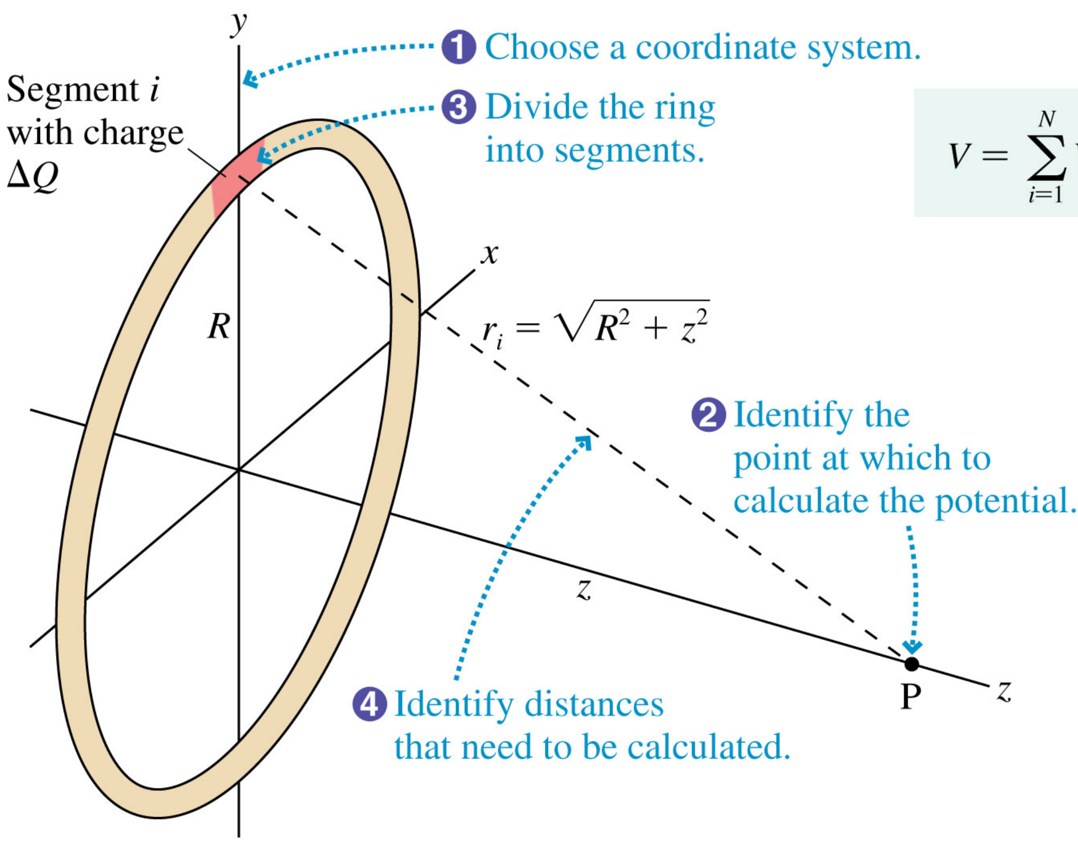
- What if I have a continuous charge distribution?
- Like the electric field for a continuous charge distribution, I
  - divide the total charge Q into many small point-like charges ΔQ
  - use the knowledge of potential of a point charge to calculate the potential from each ΔQ
  - calculate the total potential by summing (integrating) the potentials of all ΔQ (dQ)



$$V = \frac{1}{4\pi\varepsilon_o}\sum_i \frac{\Delta Q_i}{r_i}$$

$$V = \frac{1}{4\pi\varepsilon_o}\int \frac{dq}{r}$$

Potential from charged ring

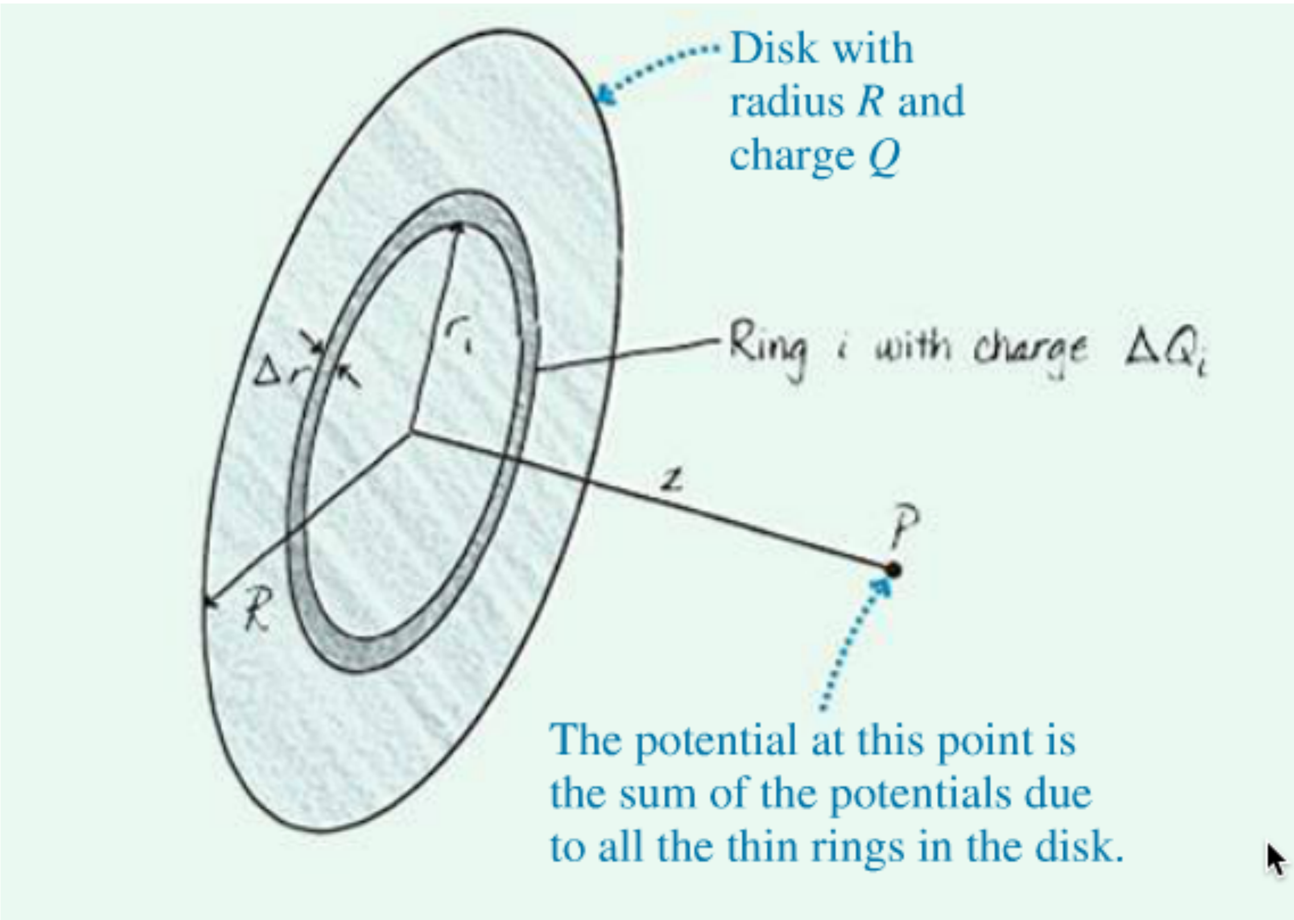


$$V = \sum_{i=1}^{N} V_i = \sum_{i=1}^{N} \frac{1}{4\pi\epsilon_0} \frac{\Delta Q}{r_i} = \frac{1}{4\pi\epsilon_0} \frac{1}{\sqrt{R^2 + z^2}} \sum_{i=1}^{N} \Delta Q$$

…no integral to do

$$V_{\text{ring on axis}} = \frac{1}{4\pi\epsilon_0} \frac{Q}{\sqrt{R^2 + z^2}}$$

Potential from disk of charge



Another example before we leave this chapter

- What is:
  - the potential at points a and b
  - the potential difference between a and b
  - the potential energy of a proton at a and b
  - the speed at point b of a proton that was moving to the right at point a with a speed of 4×10^5 m/s
  - the speed at point a of a proton that was moving to the left at point b with a speed of 5.3×10^5 m/s