Lecture 17
(Electric Potential and Calculations)

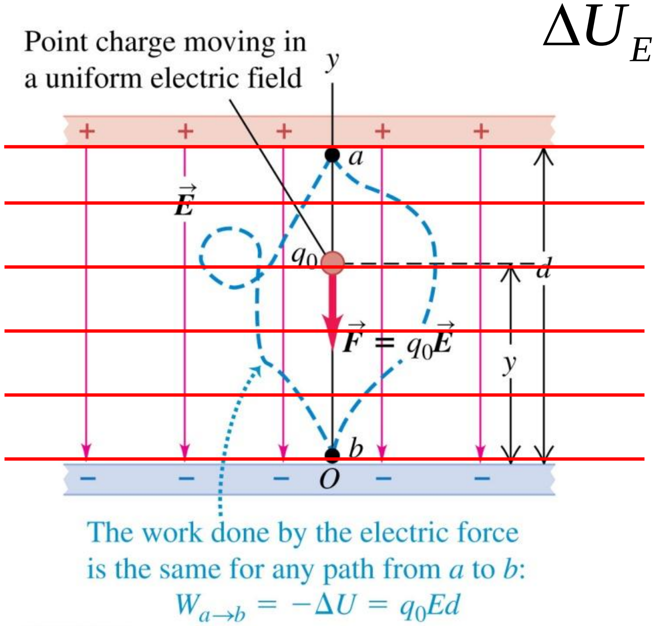
Physics 161-01 Spring 2012

Douglas Fields

Electric Potential Energy and the Electric Field

- From the last slide of the last lecture, we see that there are lines of constant potential energy given a certain field ***AND*** a certain charge.
- We can remove the dependence on the charge…

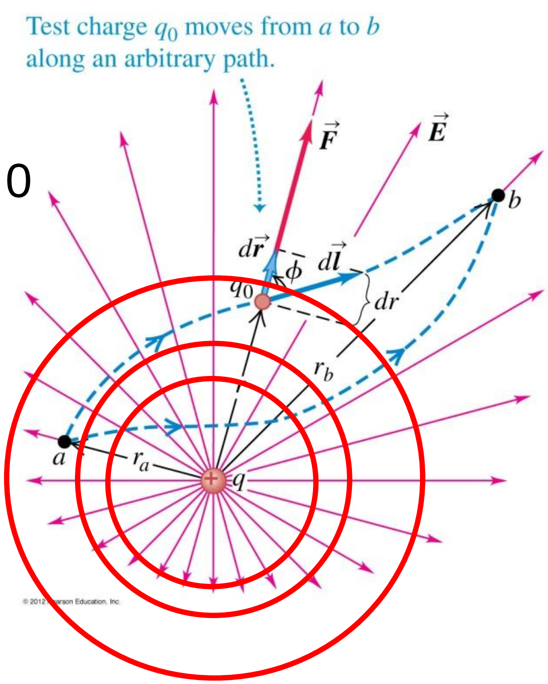
$$\Delta U_E = -W_E = -\int_{r_1}^{r_2} q\vec{E}\cdot d\vec{r}$$



U_E = qEd

U_E = 0

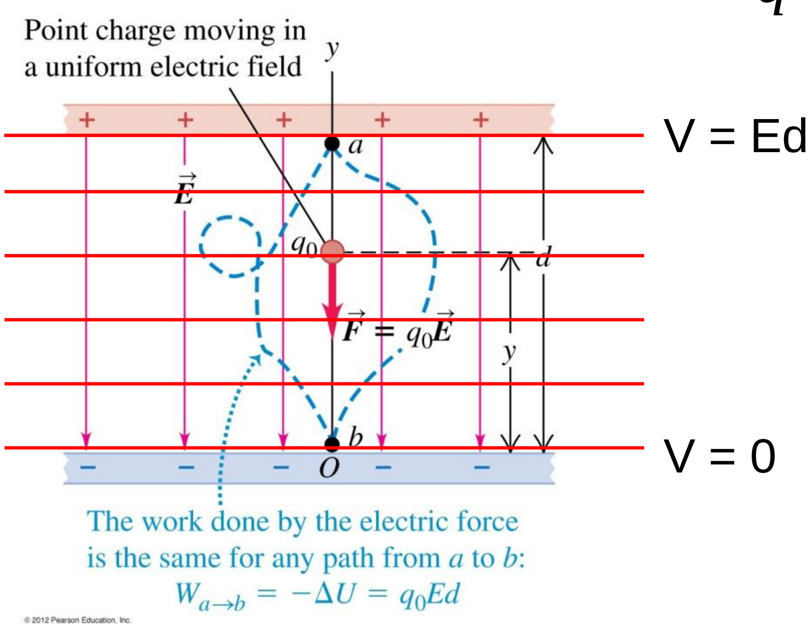
U_E = 0

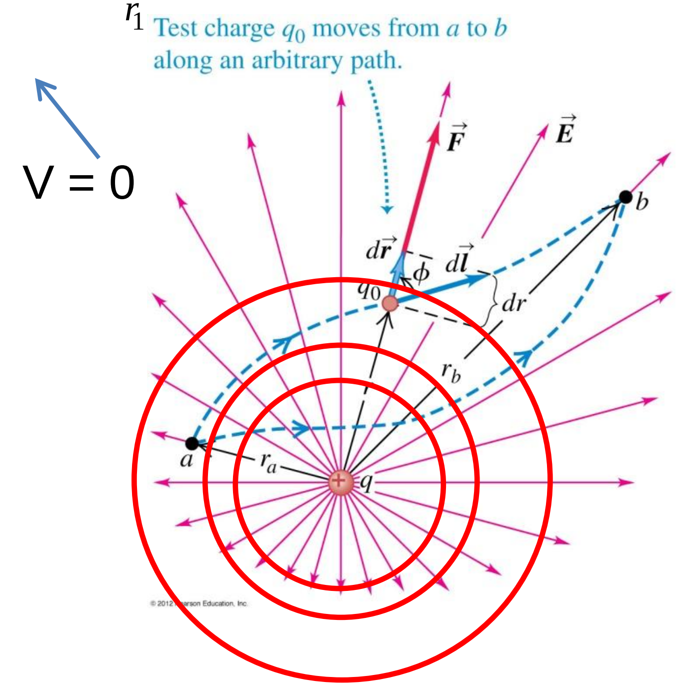


Electric Potential and the Electric Field

- By dividing out the charge, what we will call ***the potential*** is only dependent on the configuration of the charges that cause the electric field.

$$\Delta V = \frac{\Delta U_E}{q} = -\frac{W_E}{q} = -\int_{r_1}^{r_2} \vec{E} \cdot d\vec{r}$$





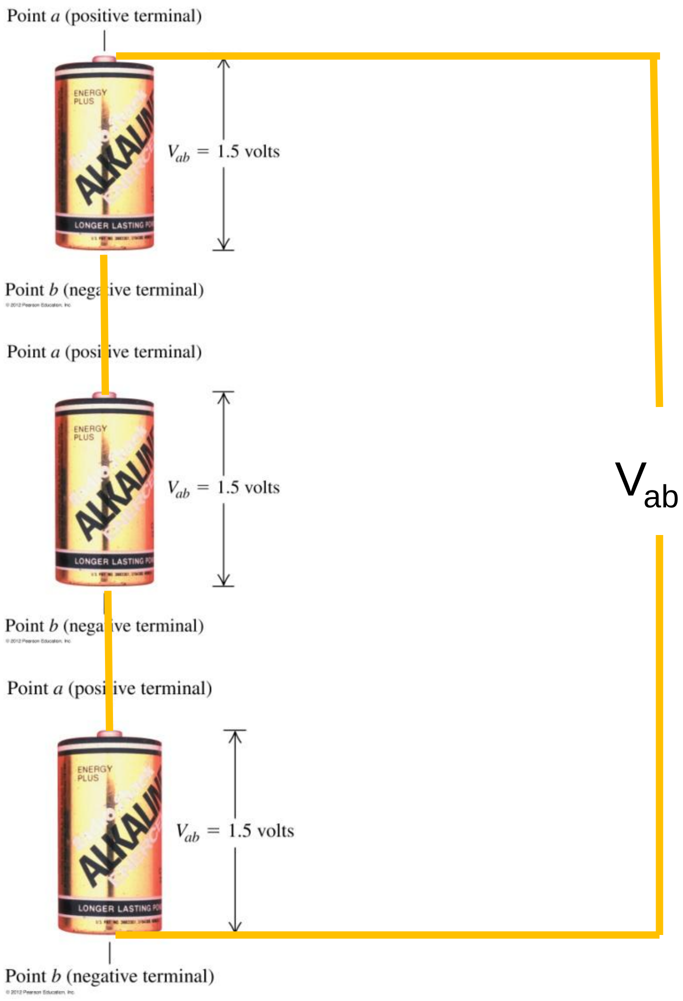
Electric Potential

- Because, like for potential energy, potentials only are useful when you are talking about the potential difference between two points, we are free to define the potential of one point any way we choose.
- Once we have done that, the potential of all other points are defined by:

$$\Delta V = V\left(r_2\right) - V\left(r_1\right) = -\int_{r_1}^{r_2} \vec{E} \cdot d\vec{r}$$

- Now, where we define the potential will depend on the charge distribution that we are examining.
- Let’s do a few.

Potentials and Batteries



- Remember, that there is no such thing as an absolute potential, only potential differences.

Electric Potential of a Point Charge

- For a point charge (and for many other distributions of charge), we will choose our point of reference to be at infinity, such that V = 0 at infinity.

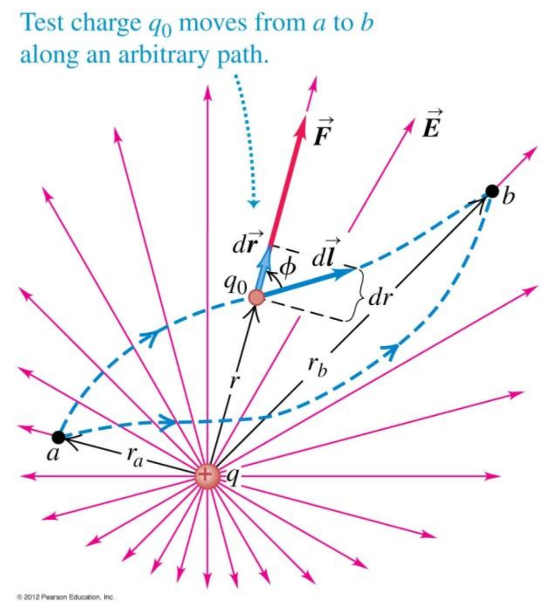
$$\Delta V = V(r) - \cancel{V(\infty)}^{\,0} = -\int_{\infty}^{r} \vec{E} \cdot d\vec{r} = \int_{r}^{\infty} \vec{E} \cdot d\vec{r}$$

$$= \frac{q}{4\pi\varepsilon_0} \int_{r}^{\infty} \frac{\hat{r}}{r^2} \cdot d\vec{r}$$

$$= \frac{q}{4\pi\varepsilon_0} \left[-\frac{1}{r} \right]_{r}^{\infty}$$

$$= \frac{q}{4\pi\varepsilon_0} \left[-\frac{1}{\infty} + \frac{1}{r} \right]$$

$$= \frac{q}{4\pi\varepsilon_0 r}$$



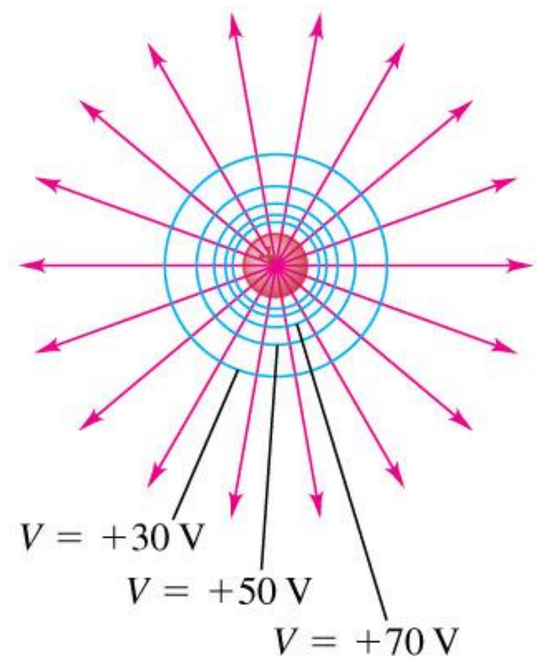
Electric Potential of a Point Charge

- Now, there is something that I want all of you to pay close attention to.
- What is the direction of V?

$$V(r) = \frac{q}{4\pi\varepsilon_0 r}$$

- That's right, it's a scalar. It has no direction.
- And yet, it encodes all the information of the charge distribution, and hence, as we shall see, all the information about the electric field.

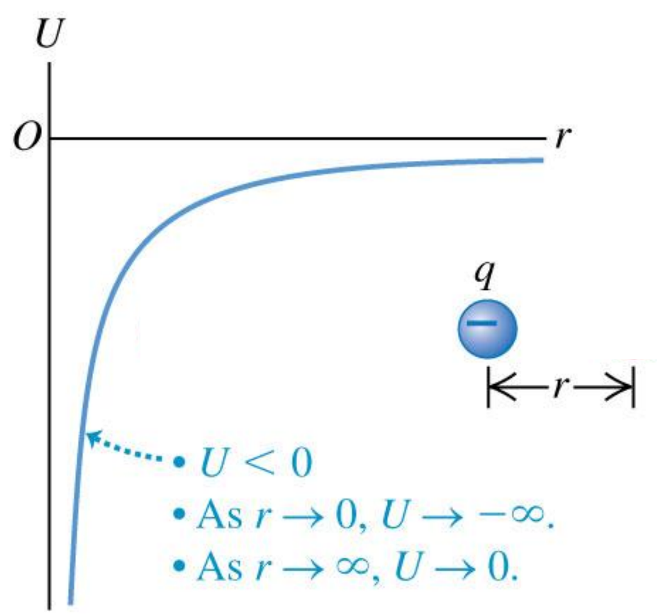
(a) A single positive charge

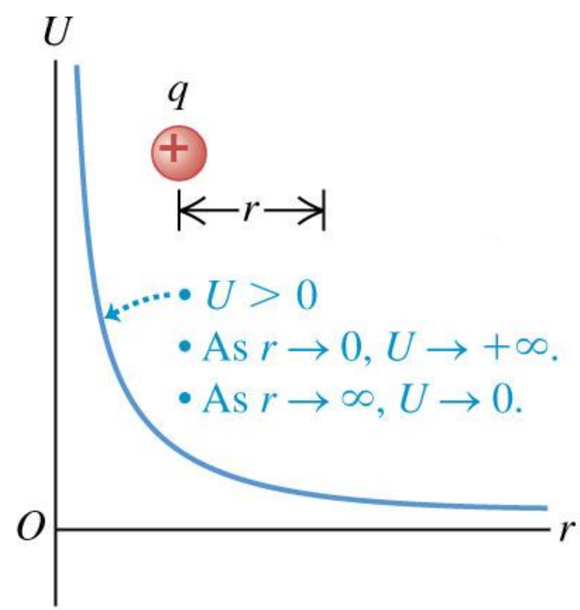


Electric Potential Energy

- The potential is ONLY dependent on the distribution of charges considered.

$$V(r) = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}; \quad V(\infty) = 0$$





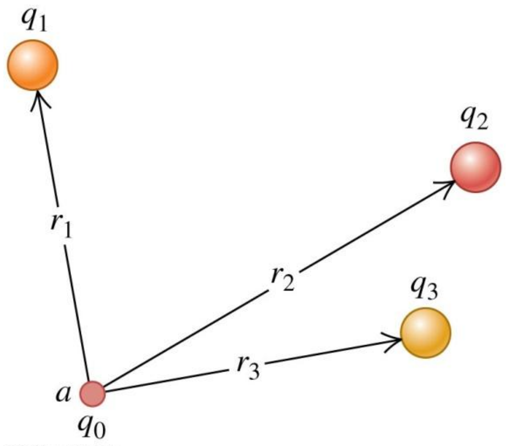
Electric Potential

- And, again, if we have more than one charge involved, then the electric potential due to charges q_1, q_2, etc. is just the sum of the potential due to each charge:

$$V = \frac{kq_1}{r_1} + \frac{kq_2}{r_2} + \frac{kq_3}{r_3} \ldots$$

$$= \frac{1}{4\pi\varepsilon_0} \sum_i \frac{q_i}{r_i}$$

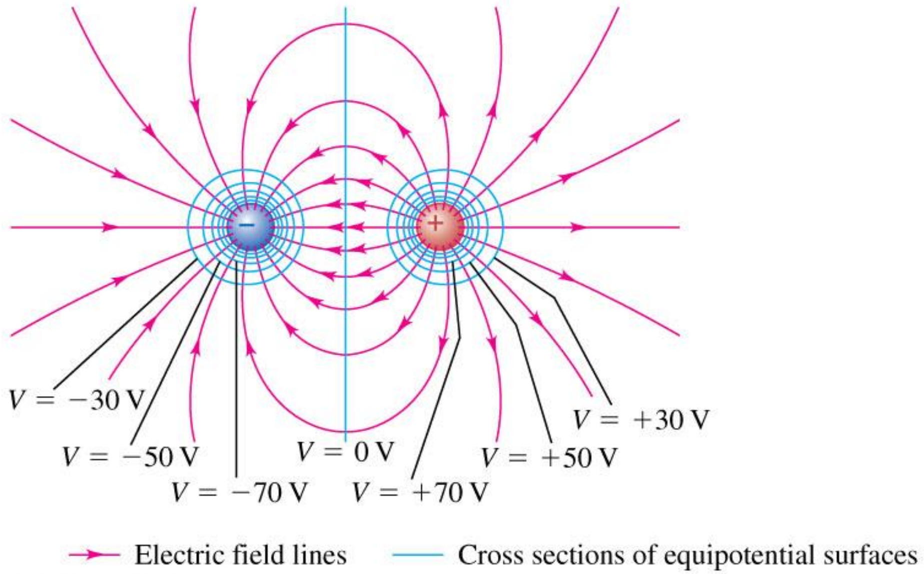
$$= \frac{1}{4\pi\varepsilon_0} \int \frac{dq}{r} \quad \text{(continuous charge distribution)}$$



Electric Potential of a Dipole

- And, again, if we have more than one charge involved, then the electric potential due to charges q_1, q_2, etc. is just the sum of the potential due to each charge:

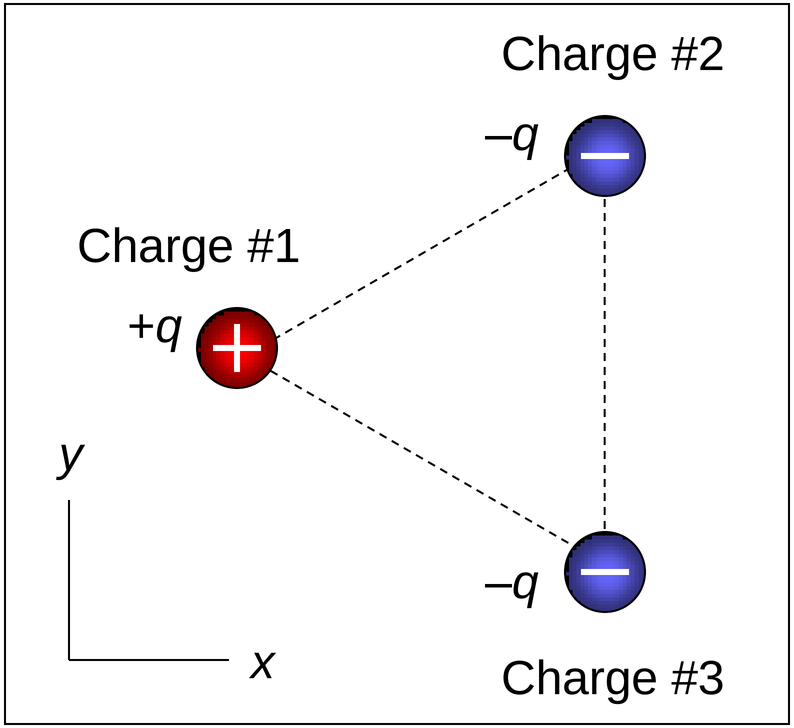
(b) An electric dipole



CPS 17-1

The electric potential due to a point charge approaches zero as you move farther away from the charge.

If the three point charges shown here lie at the vertices of an equilateral triangle, the electric potential at the center of the triangle is



A. positive.

B. negative.

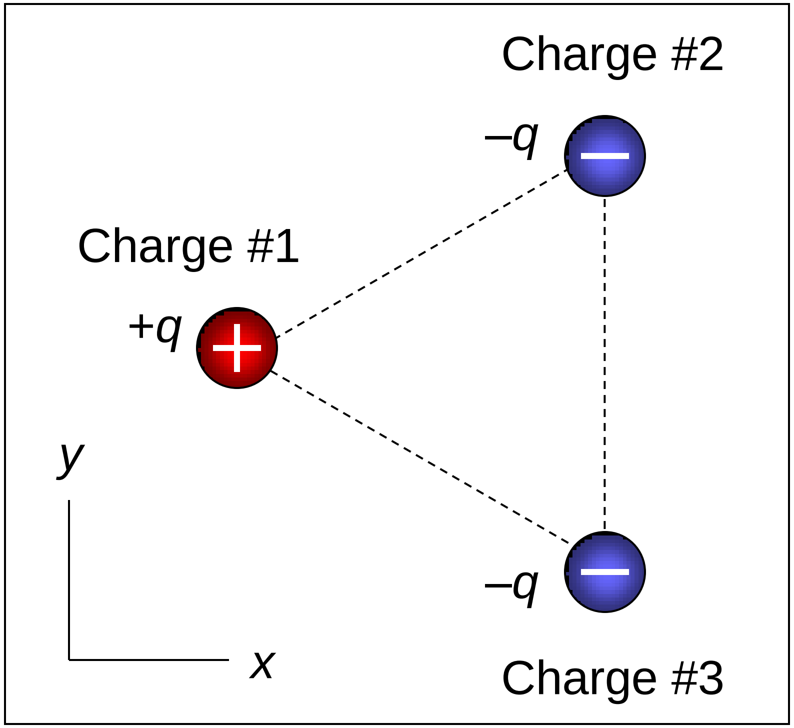
C. zero.

D. not enough information given to decide

CPS 17-1

The electric potential due to a point charge approaches zero as you move farther away from the charge.

If the three point charges shown here lie at the vertices of an equilateral triangle, the electric potential at the center of the triangle is



A. positive.

B. negative.

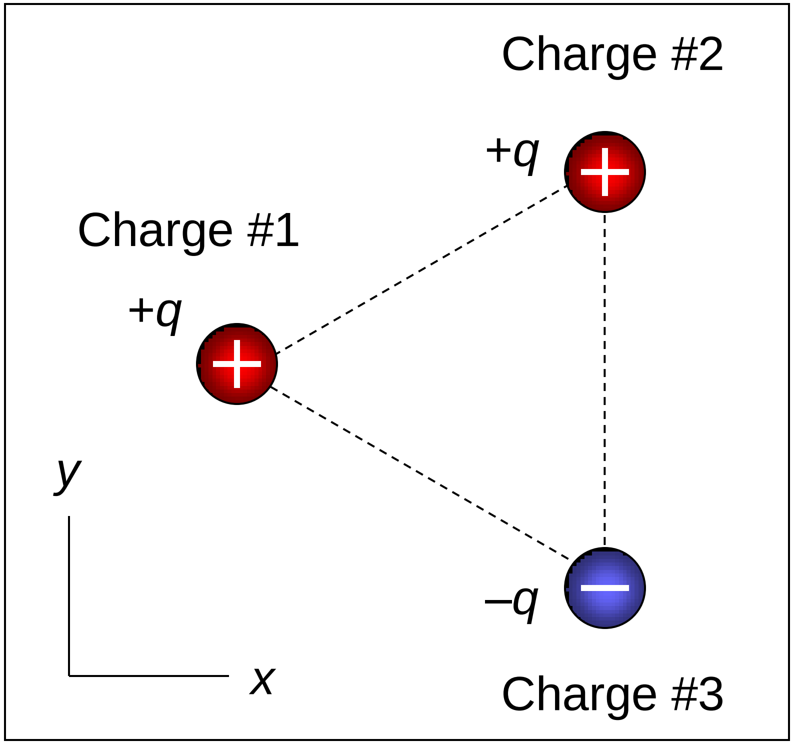
C. zero.

D. not enough information given to decide

CPS 17-2

The electric potential due to a point charge approaches zero as you move farther away from the charge.

If the three point charges shown here lie at the vertices of an equilateral triangle, the electric potential at the center of the triangle is



A. positive.

B. negative.

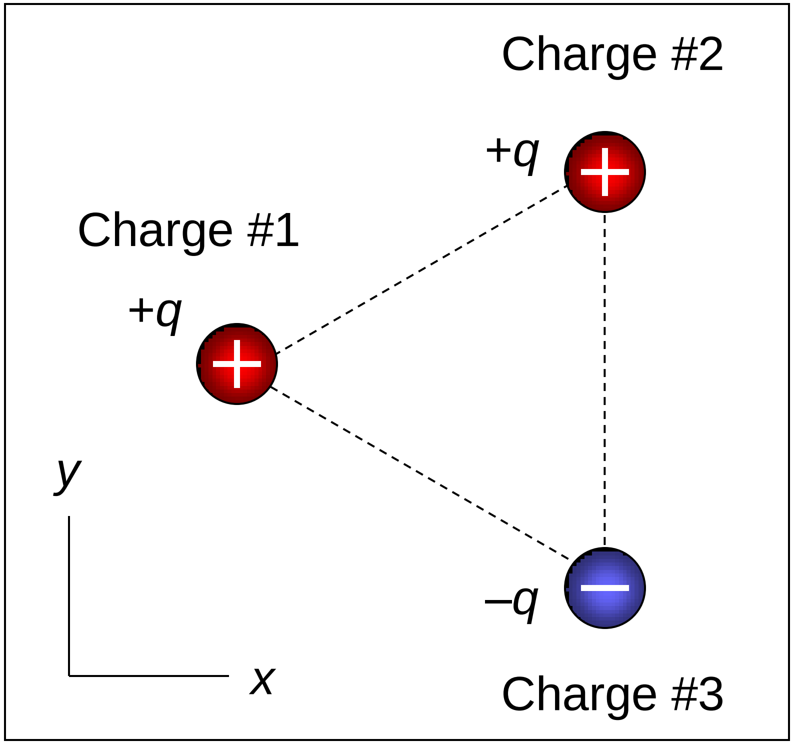
C. zero.

D. not enough information given to decide

CPS 17-2

The electric potential due to a point charge approaches zero as you move farther away from the charge.

If the three point charges shown here lie at the vertices of an equilateral triangle, the electric potential at the center of the triangle is



A. positive.

B. negative.

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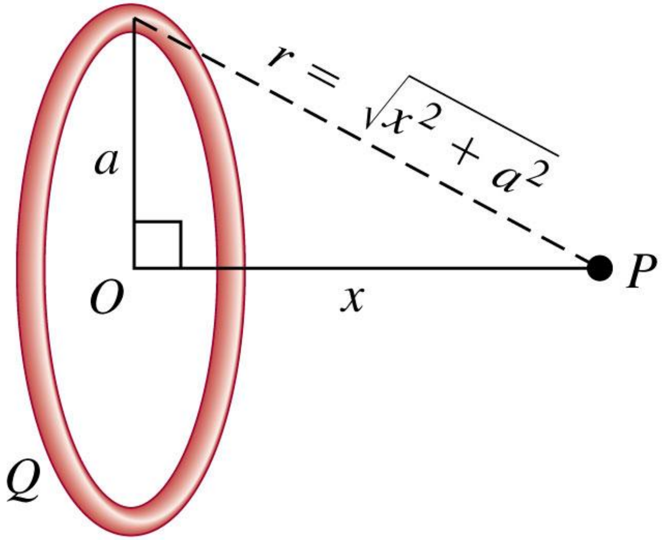
Potential Calculations Using Charge Distributions

- Let's do one calculation for an extended object using this method.

$$V = \frac{1}{4\pi\varepsilon_0}\int \frac{dq}{r} \quad \text{(continuous charge distribution)}$$



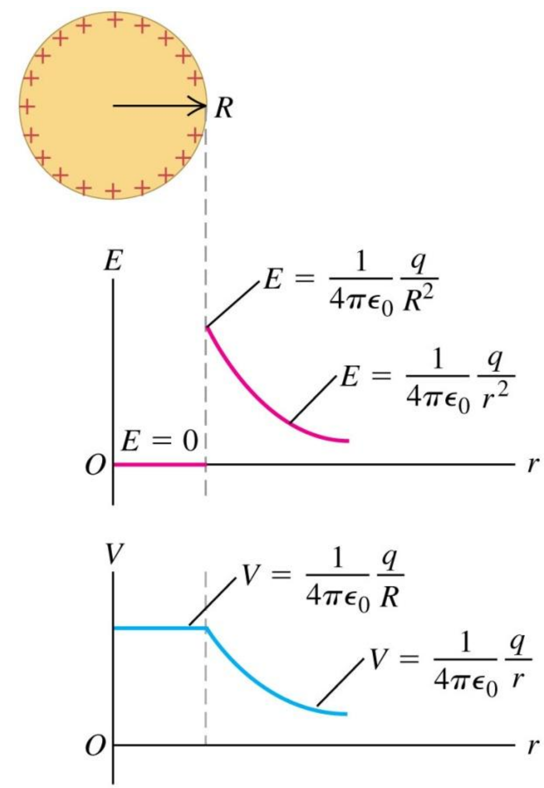
- Notice that we don't have to worry about components for this calculation – we are integrating a scalar.

Potential Calculations Using the Electric Field

- In general, to calculate the potential, all you need to do is to choose a reference potential and then integrate the electric field.

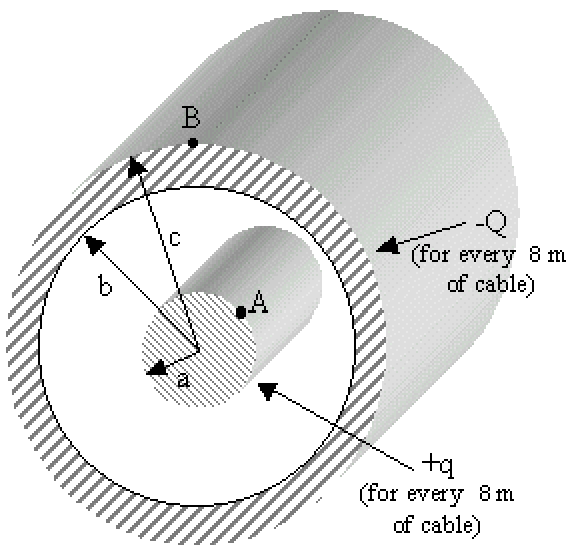
$$\Delta V = V(r_2) - V(r_1) = -\int_{r_1}^{r_2} \vec{E} \cdot d\vec{r}$$

- Notice that where the electric field is zero, the potential is constant, so, everywhere in and on a conductor, the electric potential is the same.

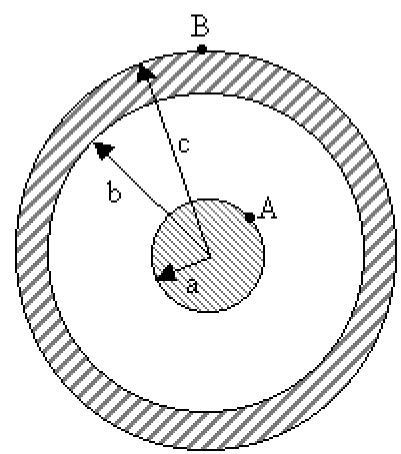


Potential Calculations

- The diagram above shows a coaxial cable. The inner conductor has radius *a* = 0.0025 m. The outer conductor is a cylindrical shell with inner radius *b* = 0.0075 m, and outer radius *c* = 0.008 m from the center. Both conductors are coaxial and they are infinitely long. For every *L* = 8 m length of cable, there is a total charge *q* = 2.8e-008 C on the inner conductor and a total charge of *Q* = -5.6e-006 C on the outer conductor.
- Determine the electric potential difference between the labeled points A and B.



Perspective View



Front View

Electric Potential and Electric Field Lines

- Notice a couple of things:
  - Locations in space that have the same potential form surfaces (equipotential surfaces).
  - These surfaces are everywhere perpendicular to the electric field.