Section	Group	Name	Signature
	5		
Grade			
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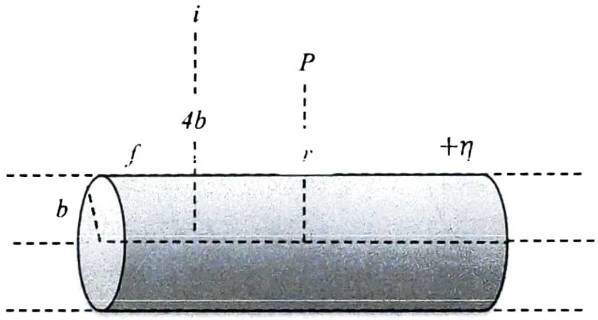
After this activity you should know:. • *Know when to integrate the electric field to find voltages* • *Know the directions in which the voltage increases/decreases* • *Know how to obtain the electric field from the electric potential.*

1. Using $\Delta V = -\int_i^f \vec{E} \cdot d\vec{s}$ to find ΔV is often very difficult because we need to know the electric field $\vec{E}$ everywhere between initial and final points. However, this can be done if there is enough symmetry to use Gauss's Law to find $\vec{E}$ as a function of position.

   A very long (treat as infinte) solid metal cylinder of radius b has uniform charge per area $+\eta$ on its surface. Find the voltage difference between an initial point $4b$ from the axis and a final point on the cylinder.

   a. What is the charge on a length L of the cylinder?

   $2\pi b\eta L$



   b. What is the charge per length λ of the cylinder?

   $2\pi b\eta$

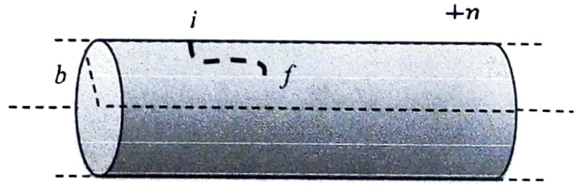
   c. What is the electric field E as a function of r $(r > b)$?

   $$E = \frac{\lambda}{2\pi\epsilon_0 r} = \frac{b\eta}{\epsilon_0 r}$$

   d. Use $\Delta V = -\int_i^f \vec{E} \cdot d\vec{s}$ to find the voltage difference where the initial point is $4b$ from the axis and the final point is on the surface of the cylinder.

   $$-\int_{4b}^{b} \frac{\lambda}{2\pi\epsilon_0 r} ds = \frac{\eta b}{\epsilon_0}\int_{b}^{4b} \frac{d\vec{r}}{r} = \frac{\eta b}{\epsilon_0}(\ln(4))$$

   e. Consider an initial point on the surface of the cylinder and a second point in the interior of the conducting cylinder. What is the voltage difference between these two points? Assume the cylinder is in electrostatic equilibrium. *Think: what is E inside the conductor?* 0



   $$\Delta V = -V_i + V_f = -V_i = -\frac{\eta b}{\epsilon_0}\ln(b)$$

f. What is true of the voltage inside a solid conductor in electrostatic equilibrium? Choose one!

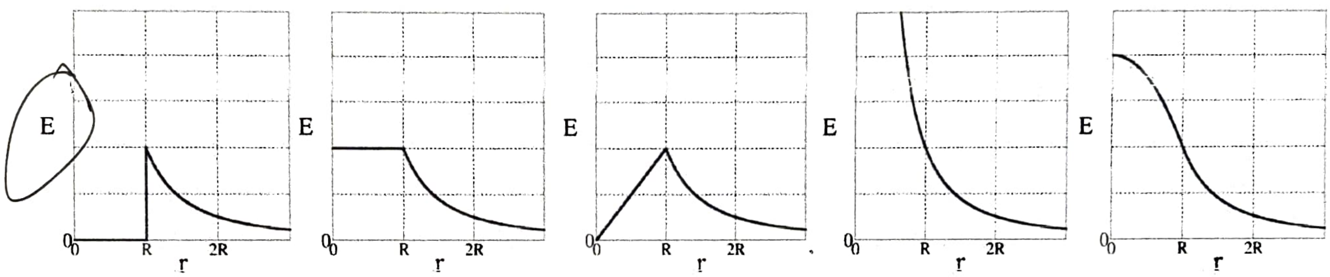
- The voltage inside a positively charged conductor increases as one approaches the center.
- The voltage inside a positively charged conductor decreases as one approaches the center.
- The voltage inside a conductor must be zero.
- The voltage inside a conductor is the same everywhere inside and is equal to the voltage at the surface.

g. What is the voltage difference between an initial point at a distance $4b$ from the central axis and a final point at the center axis of the metal cylinder? *No new calculation should be required.*

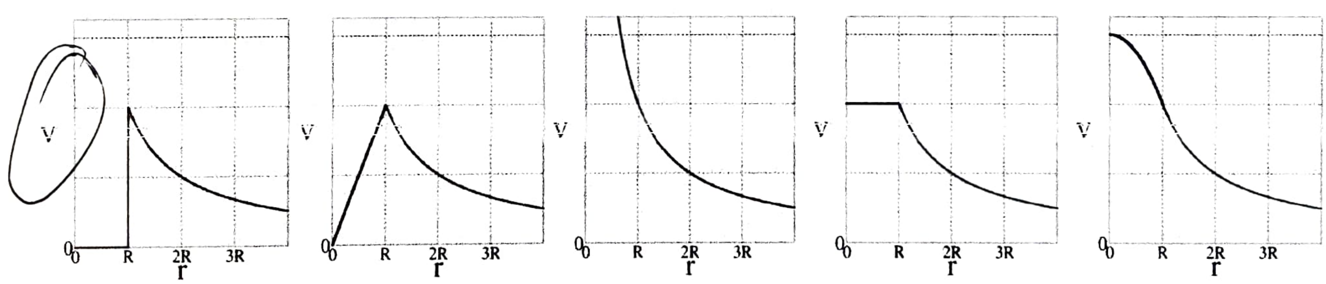
$$-\frac{\eta b}{\epsilon_0} \ln(4b)$$

2. A solid conducting sphere has charge Q uniformly distributed over it surface.

a. Which graph best represents the magnitude of the electric field as a function of r?



b. Which graph best represents the voltage as a function of r? *Think about your result from 1f.*



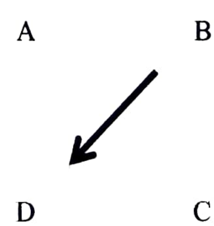
3. The electric field in a region of space points in the direction shown.

a. Which point (A, B, C, or D) is at the highest voltage?

B

b. Which points are at the same voltage?

A C



4. Having found the voltage difference from knowing the electric field, we can also do the inverse, find the electric field if we know the voltage as a function of position. Since the inverse of integration is differentiation, we have:

$$E_x = -\frac{\partial V}{\partial x}, \quad E_y = -\frac{\partial V}{\partial y}, \quad E_z = -\frac{\partial V}{\partial z}$$

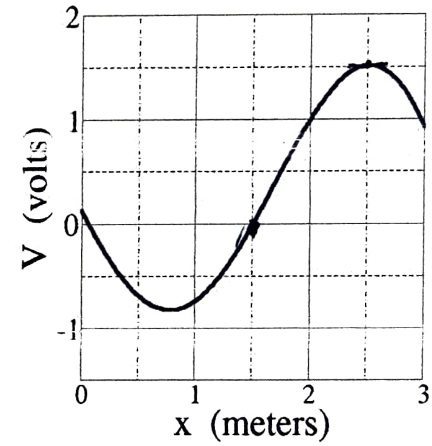
The partial derivative $\partial V/\partial x$ means that to take the derivative with respect to x while treating y and z as constant. The electric potential in a region of space is given by

$$V(x,y,z) = V_0\left(\left(\frac{x}{L}\right)^2 - \frac{5y}{L}\right)$$

What is the electric field in this region?

$$\vec{E} = -V_0 \left\langle \frac{2x}{L^2} - \frac{5y}{L},\ \left(\frac{x}{L}\right)^2 - \frac{5}{L},\ \left(\frac{x}{L}\right)^2 - \frac{5y}{L} \right\rangle$$

5. The graph shows the voltage as a function of x.



a. What is E_x at $x = 2.5\,m$?

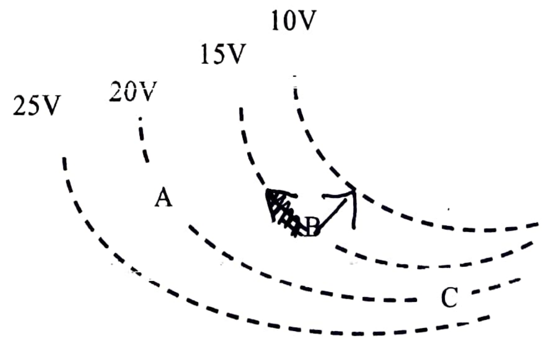
0

b. What is E_x at $x = 1.5\,m$?

≈ -2

6. The plot shows a series equipotential surfaces (surfaces where all the points have the same voltage). *Hint: think about your results from (3).*

a. Draw an arrow showing the direction of the electric field at point B.



b. At which point (A, B or C) is the magnitude of the electric field the smallest?

A