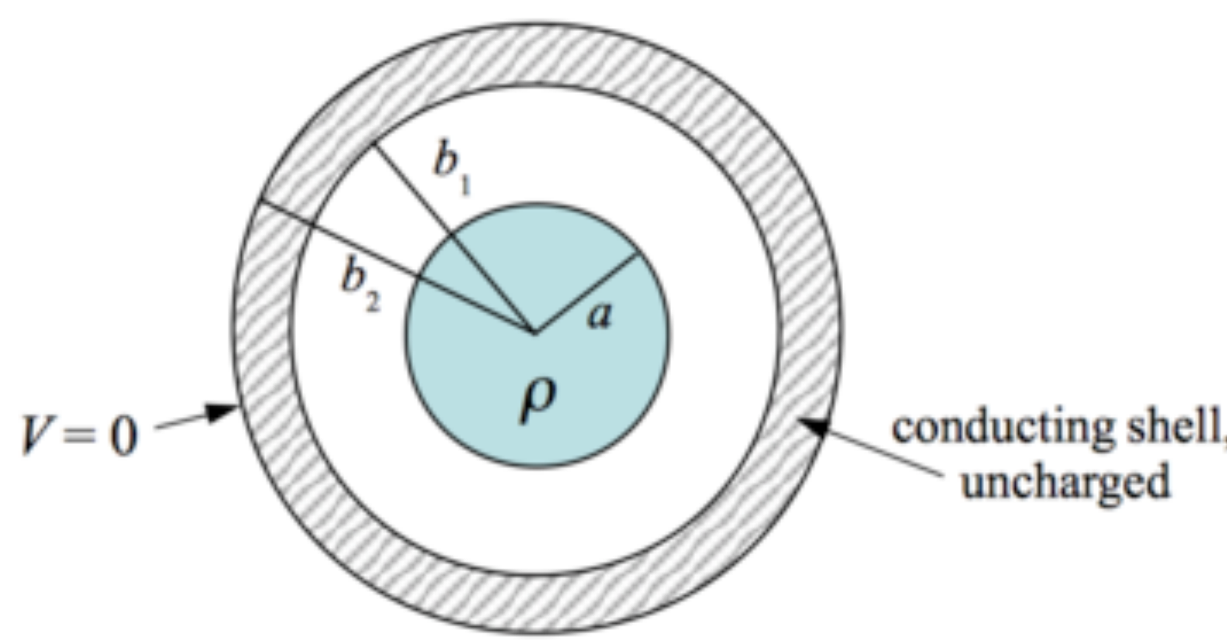
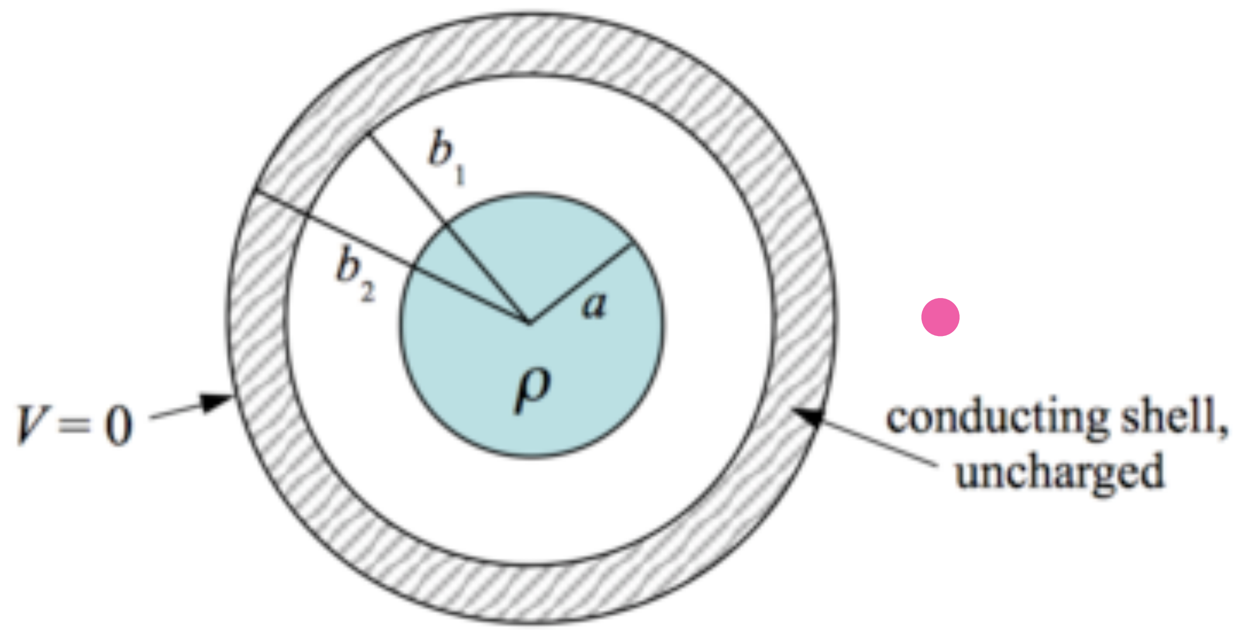
Electric Potential in a System with Cylindrical Symmetry



Consider a non-conducting cylinder of infinite length and radius a, which carries a volume charge density ρ. Surrounding this object is an uncharged conducting cylindrica shell. The metal tube is also of infinite length, and its inner and outer radii are b_1 and b_2 respectively. In this problem, we will define the potential to be zero at the outer surface of the conducting shell.

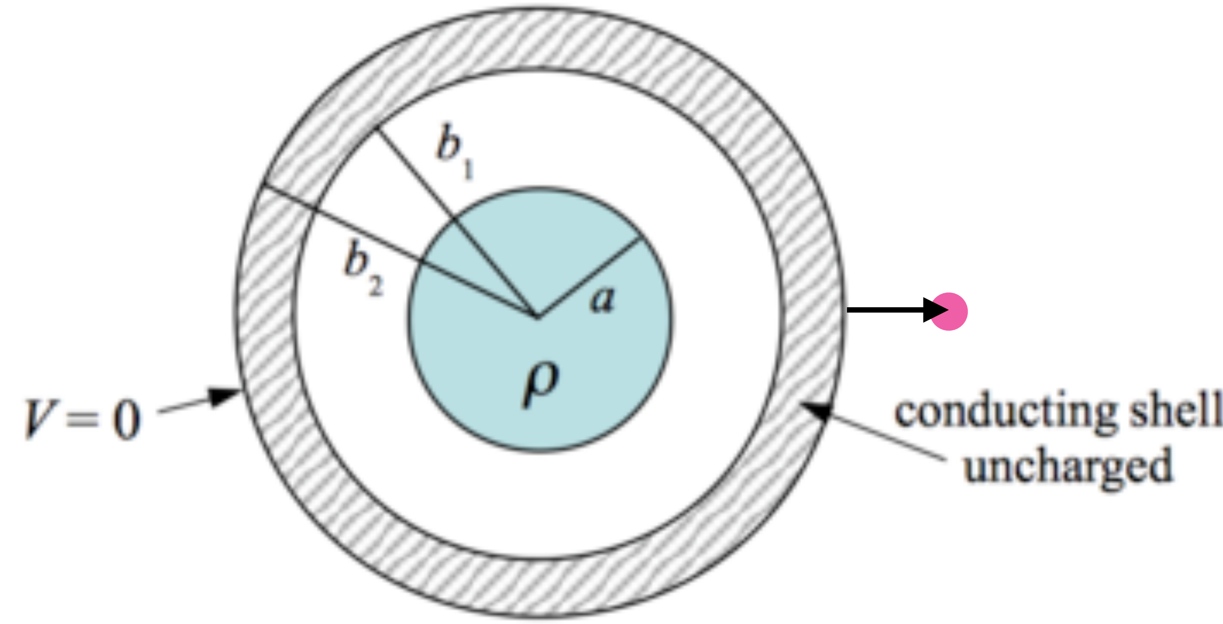
(a) What is the electric potential at a radius of 10 cm from the center of the cylinders?



$a = 3$ cm, $b_1 = 6$ cm, $b_2 = 8$ cm, $\rho = +7.5$ C/m^3

Notice that V=0 point is not at infinity.

We have to integrate the electric field from a point where we know the potential to the point we are interested in



$$E_r = \frac{\lambda}{2\pi\epsilon_0 r} = \frac{\rho\pi a^2}{2\pi\epsilon_0 r}$$

$$V(r) - 0 = -\int_{b_2}^{r} E_r dr$$

$$V(r) = -\frac{\rho\pi a^2}{2\pi\epsilon_0}\int_{b_2}^{r}\frac{dr}{r} = \frac{\rho a^2}{2\epsilon_0}\ln\frac{r}{b_2}$$

use something like Python to evaluate:

$a = 3$ cm, $b_2 = 8$ cm, $\rho = +7.5$ C/m^3
$\varepsilon_0 = 8.854\times10^{-12}$ F/m

$$V(r) = -\frac{\rho\pi a^2}{2\pi\epsilon_0}\int_{b_2}^{r}\frac{dr}{r} = \frac{\rho a^2}{2\epsilon_0}\ln\frac{r}{b_2}$$

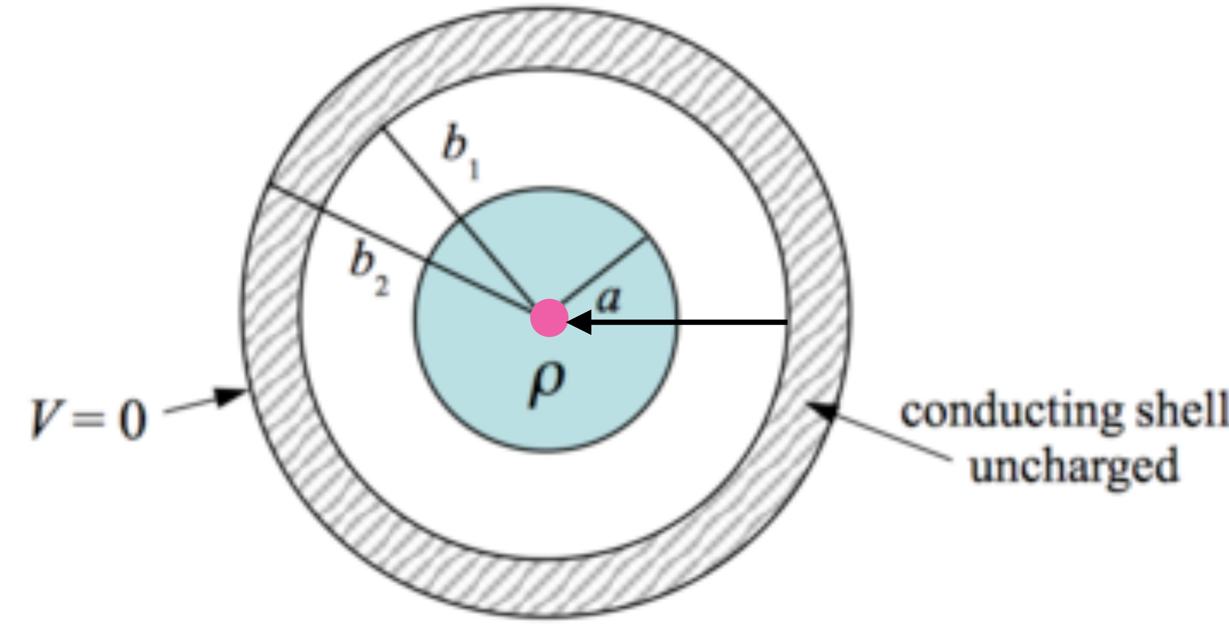
$a = 3$ cm, $b_2 = 8$ cm, $\rho = +7.5$ C/m^3
$\varepsilon_0 = 8.854\times10^{-12}$ F/m

Python

```
>>> from math import *

>>> eps0= 8.854e-12
>>> b2=8e-2
>>> rho=7.5
>>> r=10e-2
>>> a=3e-2

>>> rho*(a**2)*log(r/b2)/(2*eps0)

85058672.42889746
```

$= -8.5 \times 10^7$ V

What is the electric potential at the center of the non-conducting cylinder?



First integrate from the inside surface at b_1 down to a

$$0 - V(r) = -\int_a^{b_1} E_r dr$$

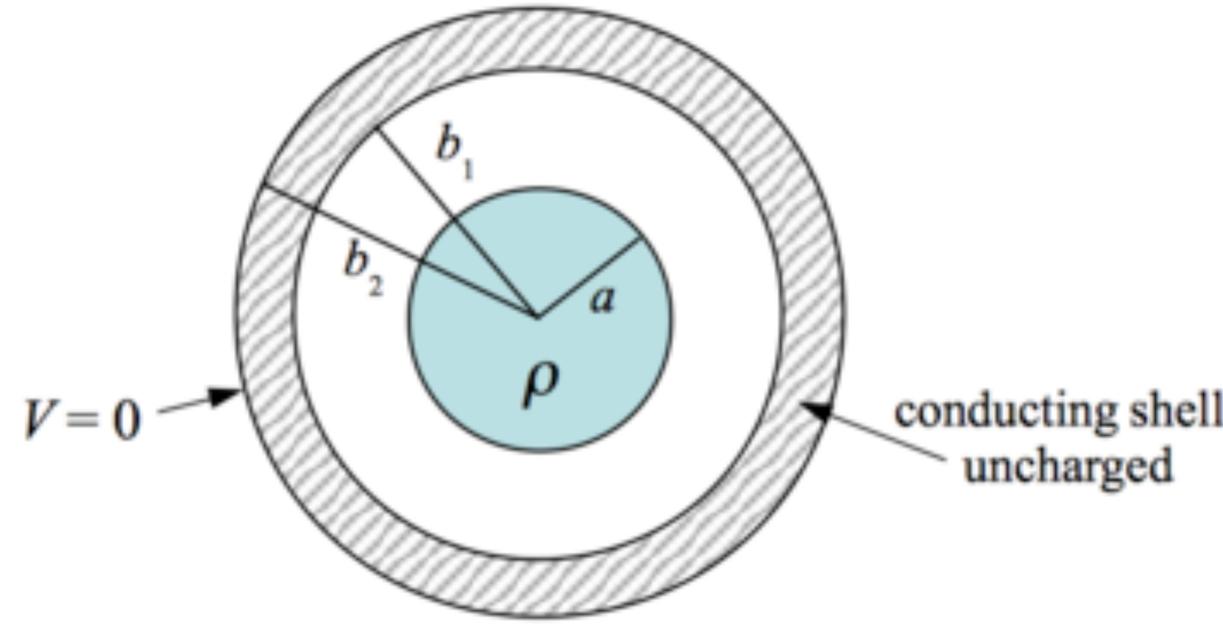
$$V(a) = -\frac{\rho\pi a^2}{2\pi\epsilon_0}\int_a^{b_1}\frac{dr}{r} = \frac{\rho a^2}{2\epsilon_0}\ln\frac{b_1}{a}$$

Inside the non-conductor ρ is constant. The field there is like this…

$$E_r = \frac{\rho\pi r^2}{2\pi\epsilon_0 r} = \frac{\rho r}{2\epsilon_0}$$

$$V(0) - V(r) = \frac{\rho}{2\epsilon_0}\int_0^a r dr = \frac{\rho a^2}{4\epsilon_0}$$

$a = 3$ cm, $b_1 = 6$ cm, $b_2 = 8$ cm, $\rho = +7.5\ C/m^3$
$\varepsilon_0 = 8.854\times10^{-12}$ F/m



$$V(0) = V(a) + \frac{\rho a^2}{4\epsilon_0} = \frac{\rho a^2}{2\epsilon_0}\ln\frac{b_1}{a} + \frac{\rho a^2}{4\epsilon_0}$$

$= 4.55 \times 10^8$ V

Why don't we choose V=0 at infinity like in other cases?

Cylindrical Potential

Is it clear?

A. Very Clear
B. Still have Questions
C. Don't understand