ECE329: Tutorial Session 4

September 24th, 2024

Share any thoughts on anything, including the exam!

Agenda

1. Exam 1
2. Quick content review
3. One example problem

4. Office Hours

Exam 1

Bound charges

Poisson’s Equation

Laplace’s Equation

Capacitance

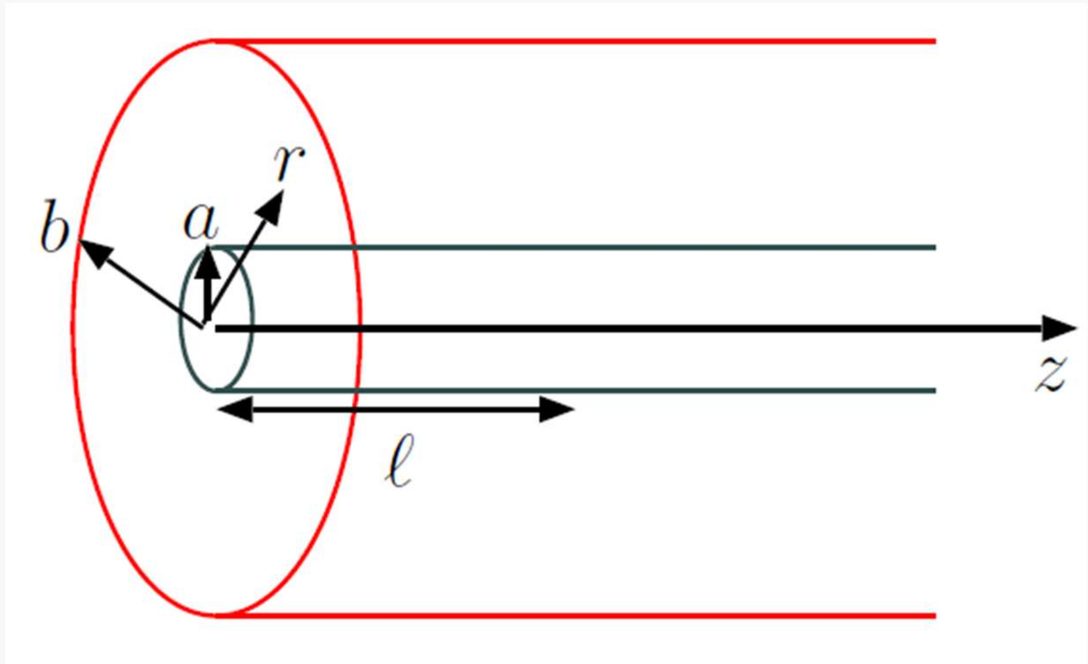
Capacitance: the ability of something to collect and store energy in the form of electrical charge.

This energy is stored as opposite electric charges being held apart (and thus creating a difference in electric potential, aka a voltage drop).

$$Q = CV \qquad G = \frac{\sigma}{\epsilon} C \qquad R = \frac{1}{G}$$

Problem 1

The central cylindrical volume with cross-sectional radius a is a conductor.
The pipe (drawn in red) is also a conductor and is grounded.
A dielectric with permittivity $\epsilon = 4\epsilon_0$ fills the space in between.



What is the capacitance, conductance, and resistance <u>per unit length</u> in the middle of the coaxial cable?

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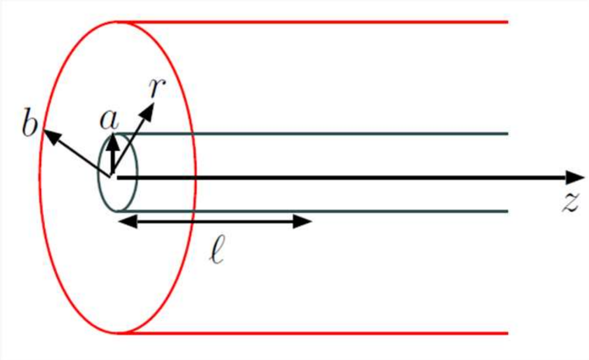

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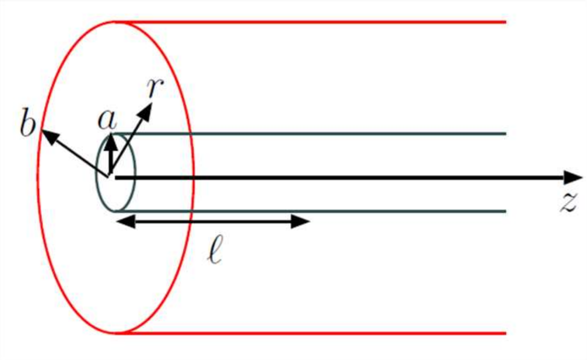

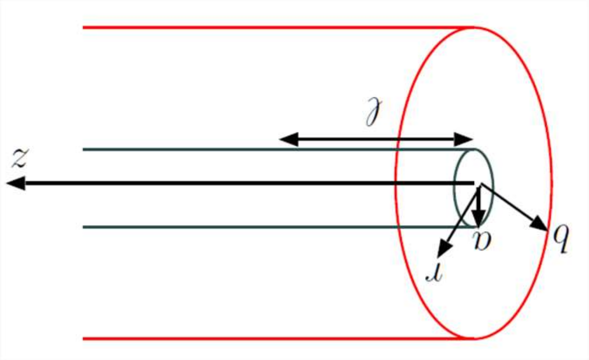

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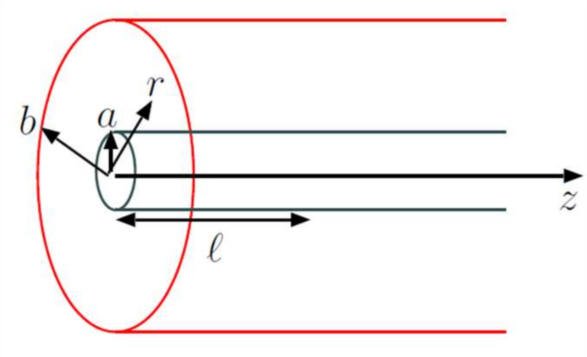

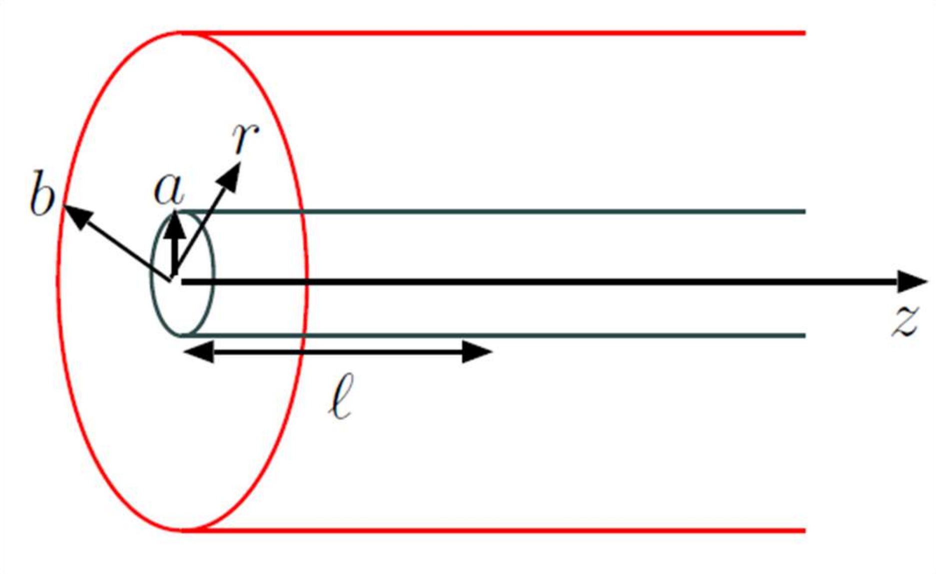

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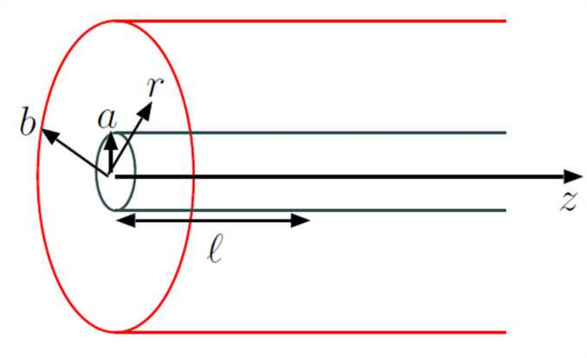

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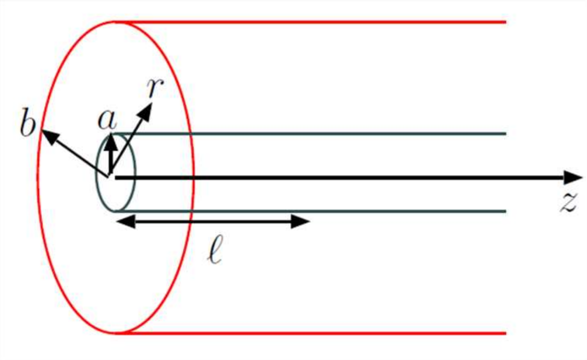
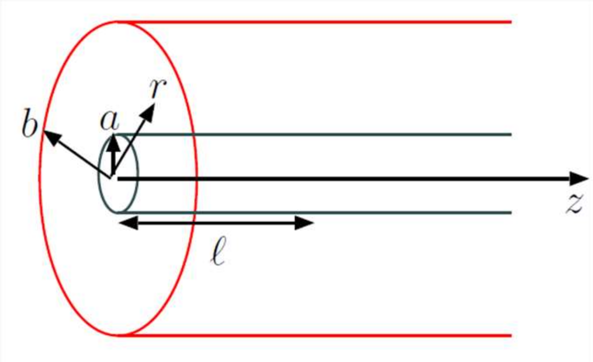


Problem 1 Extended



Where is Laplace's equation satisfied?
What is the free charge density within the dielectric?
What is the free surface charge density at $r = a$ and $r = b$?
What is the bound charge density within the dielectric?
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Recall $\epsilon = 4\epsilon_0$ in the dielectric.

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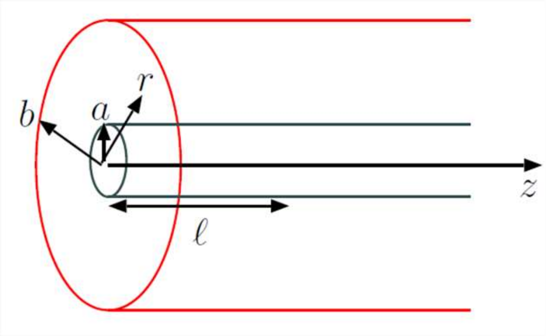

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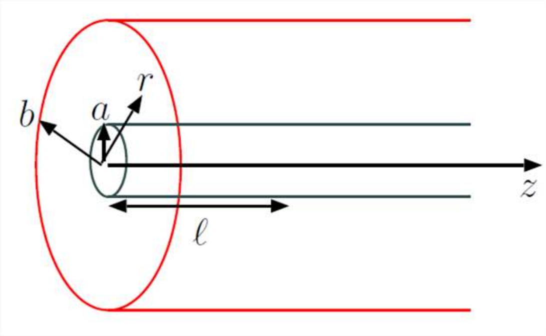

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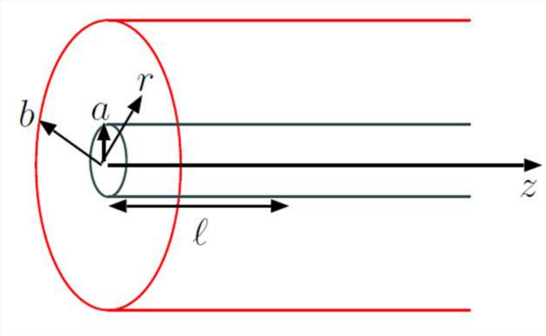

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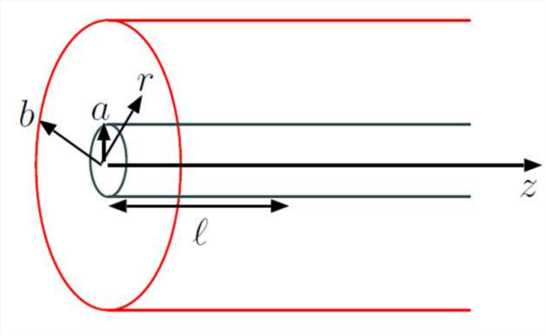

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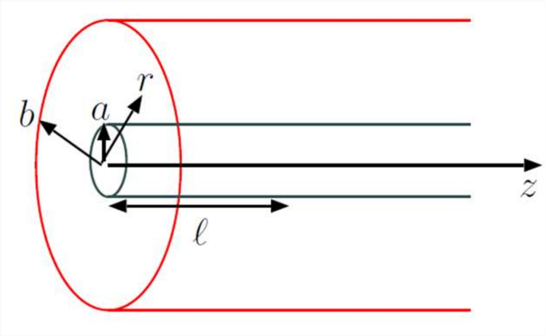

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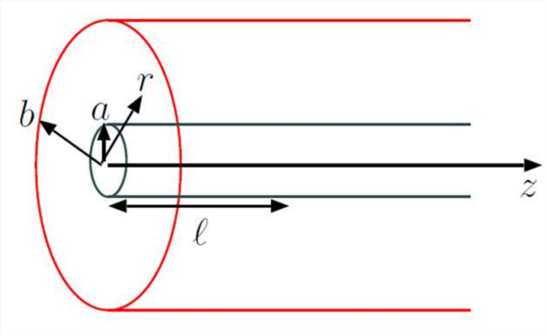

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Week 4 equations, in one place

$$\vec{F} = \frac{q_1 q_2}{4\pi\epsilon_0 r^2}\hat{r}$$

$$\vec{F} = q_1\vec{E} + q_1(\vec{v}_1 \times \vec{B})$$

$$\vec{E} = \frac{q_2}{4\pi\epsilon_0 r^2}\hat{r}$$

$$\epsilon \oiint \vec{E} \cdot d\vec{S} = Q_{\text{enclosed}}$$

$$\oiint \vec{D} \cdot d\vec{S} = Q_{\text{enclosed}}$$

$$\iiint \rho dV = Q_{\text{enclosed}}$$

$$\oiint \vec{B} \cdot d\vec{S} = 0$$

$$I = \oiint \vec{J} \cdot d\vec{S} = -\frac{\partial Q_{\text{enclosed}}}{\partial t}$$

$$\nabla \times \vec{E} = 0$$

$$\vec{E} = -\nabla V$$

$$\oint \vec{E} \cdot d\vec{l} = 0$$

$$V_{ab} = V(b) - V(a) = -\int_a^b \vec{E} \cdot d\vec{l}$$

$$\hat{n} \cdot \left(\vec{D}_1 - \vec{D}_2\right) = \rho_s$$

$$\hat{n} \times \left(\vec{E}_1 - \vec{E}_2\right) = 0$$

$$\hat{n} \cdot \left(\vec{P}_1 - \vec{P}_2\right) = -\rho_{b,s}$$

$$Q = CV$$

$$G = \frac{\sigma}{\epsilon}C \qquad R = \frac{1}{G}$$

$$\epsilon = \epsilon_0(1 + \chi_e)$$

$$\vec{P} = \epsilon_0\chi_e\vec{E}$$

$$\vec{D} = \epsilon_0\vec{E} + \vec{P} = \epsilon\vec{E}$$

$$\vec{J} = \sigma\vec{E}$$

$$\rho_b = -\nabla \cdot \vec{P}$$

$$\nabla \cdot \epsilon_0\vec{E} = \rho_f + \rho_b$$

$$\nabla \cdot \vec{D} = \rho$$

$$\nabla \cdot \vec{J} = -\frac{\partial \rho}{\partial t}$$

$$-\nabla^2 V = \frac{\rho}{\epsilon}$$

$$\oiint \vec{D} \cdot d\vec{S} = \iiint \nabla \cdot \vec{D} dV$$

$$\oint \vec{E} \cdot d\vec{l} = \iint \left(\nabla \times \vec{E}\right) \cdot d\vec{S}$$

$$\int_a^b \nabla V \cdot d\vec{l} = V(b) - V(a)$$

Units

Charge Q: C
Electric field $\vec{E}$: N/C or V/m
Displacement field $\vec{D}$: C/m^2
Polarization field $\vec{P}$: C/m^2
Electric potential V: V
Capacitance C: F
Magnetic field $\vec{B}$: T or Wb/m^2
Charge density ρ: C/m^3
Surface charge density ρ_S: C/m^2
Current density $\vec{J}$: A/m^2

Electric permittivity ϵ: F/m
Magnetic permeability μ: H/m
Conductivity σ: Si/m

Office Hours

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