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A very long insulating cylinder of radius  $R_1$  has a charge per unit length of  $\lambda$  distributed uniformly throughout the cylinder. The cylinder is surrounded by a concentric conducting shell of inner radius  $R_2$  and outer radius  $R_3$ , as shown in the diagram. The shell contains a charge per unit length of  $-5\lambda$ .

Determine the direction of the electric field and its magnitude as a function of  $r$ , the distance from the center of the cylinder for:

- $0 < r < R_1$
- $R_1 < r < R_2$
- $R_2 < r < R_3$
- $R_3 < r$
- What is the charge per unit length on the inner and outer surfaces of the conducting shell?



(a) choose cyl. G.S. of radius  $r$ , length  $L$

$$\epsilon_0 \Phi_E = q_{in}$$

$$\epsilon_0 \vec{E} \cdot \vec{A} = q_{in} = \rho V_{in}$$

$$\epsilon_0 E (2\pi r L) = \left( \frac{\lambda}{\pi R_1^2} \right) (\pi r^2 L)$$

$$\rho = \frac{Q}{L A} = \frac{Q}{L \pi R_1^2}$$

$$\lambda = Q/L$$

$$\rho = \frac{\lambda}{\pi R_1^2}$$

$$E = \frac{\lambda r}{2\pi \epsilon_0 R_1^2} \quad \begin{array}{l} \text{direction} \\ \text{radially out} \\ \text{since } \lambda \text{ is +} \end{array}$$

(b)  $\epsilon_0 \Phi_E = \epsilon_0 E A = q_{in}$

$$\epsilon_0 E (2\pi r L) = \lambda L$$

$$E = \frac{\lambda}{2\pi \epsilon_0 r} \quad \text{direction radially outward}$$

(c)  $E = 0$ , inside a conductor

(d)  $\epsilon_0 \Phi_E = q_{in}$

$$\epsilon_0 E A = \epsilon_0 E (2\pi r) L = (\lambda - 5\lambda) L = -4\lambda L$$

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

direction radially inward.

inner surface:  $-\lambda$

outer surface:  $-4\lambda$

Since charge inside G.S. within shell must = 0

Total charge/length on shell =  $-5\lambda$

# Physics 50520paper 4

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## **Table of Contents Physics 50520paper 4**

1. Understanding the eBook Physics 50520paper 4
  - The Rise of Digital Reading Physics 50520paper 4
  - Advantages of eBooks Over Traditional Books
2. Identifying Physics 50520paper 4
  - Exploring Different Genres
  - Considering Fiction vs. Non-Fiction
  - Determining Your Reading Goals
3. Choosing the Right eBook Platform
  - Popular eBook Platforms
  - Features to Look for in an Physics 50520paper 4
  - User-Friendly Interface
4. Exploring eBook Recommendations from Physics 50520paper 4
  - Personalized Recommendations
  - Physics 50520paper 4 User Reviews and Ratings
  - Physics 50520paper 4 and Bestseller Lists
5. Accessing Physics 50520paper 4 Free and Paid eBooks
  - Physics 50520paper 4 Public Domain eBooks
  - Physics 50520paper 4 eBook Subscription Services
  - Physics 50520paper 4 Budget-Friendly Options
6. Navigating Physics 50520paper 4 eBook Formats

- ePub, PDF, MOBI, and More
- Physics 50520paper 4 Compatibility with Devices
- Physics 50520paper 4 Enhanced eBook Features
- 7. Enhancing Your Reading Experience
  - Adjustable Fonts and Text Sizes of Physics 50520paper 4
  - Highlighting and Note-Taking Physics 50520paper 4
  - Interactive Elements Physics 50520paper 4
- 8. Staying Engaged with Physics 50520paper 4
  - Joining Online Reading Communities
  - Participating in Virtual Book Clubs
  - Following Authors and Publishers Physics 50520paper 4
- 9. Balancing eBooks and Physical Books Physics 50520paper 4
  - Benefits of a Digital Library
  - Creating a Diverse Reading Collection Physics 50520paper 4
- 10. Overcoming Reading Challenges
  - Dealing with Digital Eye Strain
  - Minimizing Distractions
  - Managing Screen Time
- 11. Cultivating a Reading Routine Physics 50520paper 4
  - Setting Reading Goals Physics 50520paper 4
  - Carving Out Dedicated Reading Time
- 12. Sourcing Reliable Information of Physics 50520paper 4
  - Fact-Checking eBook Content of Physics 50520paper 4
  - Distinguishing Credible Sources
- 13. Promoting Lifelong Learning
  - Utilizing eBooks for Skill Development
  - Exploring Educational eBooks
- 14. Embracing eBook Trends
  - Integration of Multimedia Elements
  - Interactive and Gamified eBooks

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