

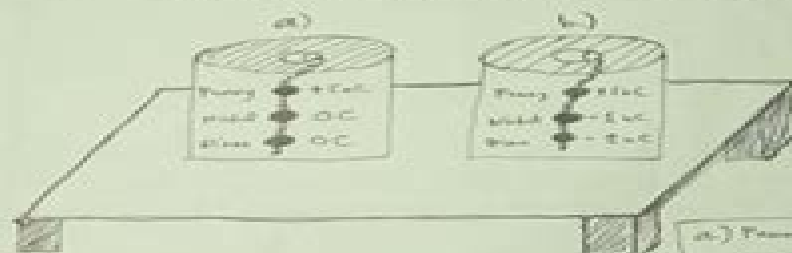
**ENGINEERING ELECTROMAGNETICS by William H. Hayt, Jr.
FIFTH EDITION (ANSWER TO ODD-NUMBERED QUESTIONS)**

CHAPTER 3

ELECTRIC FLUX DENSITY, GAUSS'S LAW, AND DIVERGENCE

PROBLEMS

1. An empty metal coax cable is placed on a marble table, the lid is removed, and both parts are discharged (chemically) by touching them to ground. An insulating nylon thread is glued to the center of the lid, and a penny, a nickel, and a dime are glued to the thread so that they are not touching each other. The penny is given a charge of $+5 \mu\text{C}$, and the nickel and dime are discharged. The assembly is lowered into the cable so that the coin is being above all walls, and the lid is removed. The center of the coin is again touched separately to ground. The dime is carefully separated with insulating gloves and held. (a) What charges are found on each of the five metallic pieces? (b) If the penny had been given a charge of $+8 \mu\text{C}$, the dime a charge of $-8 \mu\text{C}$, and the nickel a charge of $-2 \mu\text{C}$, what would the final arrangement have been?



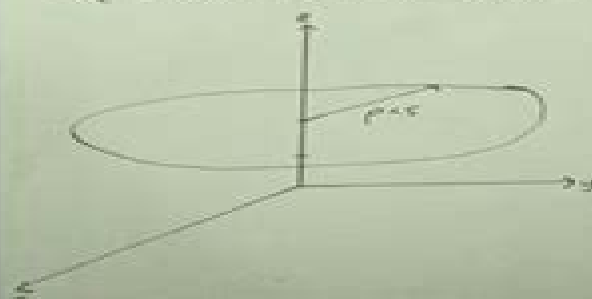
a) Penny = $5 \mu\text{C}$
 Nickel = 0 C
 Dime = 0 C
 $Q_{\text{inner}} = -Q_{\text{outer}}$
 $5 \mu\text{C} = -Q_{\text{outer}}$
 $Q_{\text{outer}} = -5 \mu\text{C}$
 lid + coin = $+5 \mu\text{C}$

b) Penny = $8 \mu\text{C}$
 Nickel = $-2 \mu\text{C}$
 Dime = $-2 \mu\text{C}$
 $Q_{\text{inner}} = -Q_{\text{outer}}$
 $8 \mu\text{C} - 2 \mu\text{C} - 2 \mu\text{C} = -Q_{\text{outer}}$
 $Q_{\text{outer}} = +4 \mu\text{C}$
 lid + coin = $-4 \mu\text{C}$

a) Penny: $5 \mu\text{C}$, Nickel: 0 C , Dime: 0 C , lid + coin = $+5 \mu\text{C}$

b) Penny: $8 \mu\text{C}$, Nickel: $-2 \mu\text{C}$, Dime: $-2 \mu\text{C}$, lid + coin = $+4 \mu\text{C}$

3. A nonuniform surface charge density of $5\rho/(r^2+1) \text{ nC/m}^2$ lies in the plane $z=0$ where $\rho \leq 5$; $\rho=0$ for $\rho > 5$. (a) How much electric flux leaves the circular region $\rho \leq 5$, $z=0$? (b) How much electric flux crosses the $z=0$ plane in the $+\hat{z}$ direction? (c) How much electric flux leaves the cylinder $\rho=5$ in the $+\hat{\phi}$ direction?



a) $\Psi = \int \rho \, dS$
 $= \int_0^{2\pi} \int_0^5 \frac{5\rho}{\rho^2+1} \rho \, d\rho \, d\phi$
 $= \int_0^{2\pi} \int_0^5 \frac{5\rho^2}{\rho^2+1} \, d\rho \, d\phi$
 $= \int_0^{2\pi} \frac{5\rho^2}{\rho^2+1} \left[\frac{1}{\rho} \right]_0^5 \, d\phi$
 $= 10\pi \int_0^5 \frac{\rho}{\rho^2+1} \, d\rho$
 $= 10\pi \int_0^5 \left(\frac{1}{\rho} - \frac{1}{\rho^2+1} \right) \, d\rho$

$= 10\pi \left[\rho - \tan^{-1}(\rho) \right]_0^5$
 $= 10\pi \left[(5 - \tan^{-1}(5)) - (0 - \tan^{-1}(0)) \right]$
 $= 10\pi \left[5 - \tan^{-1}(5) \right]$
 a) $\Psi = 117.9 \text{ nC}$

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Table of Contents Solution Manual Engineering Electromagnetics Hayt 5th Edition

1. Understanding the eBook Solution Manual Engineering Electromagnetics Hayt 5th Edition
 - The Rise of Digital Reading Solution Manual Engineering Electromagnetics Hayt 5th Edition
 - Advantages of eBooks Over Traditional Books
2. Identifying Solution Manual Engineering Electromagnetics Hayt 5th Edition
 - 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 Solution Manual Engineering Electromagnetics Hayt 5th Edition
 - User-Friendly Interface
4. Exploring eBook Recommendations from Solution Manual Engineering Electromagnetics Hayt 5th Edition
 - Personalized Recommendations
 - Solution Manual Engineering Electromagnetics Hayt 5th Edition User Reviews and Ratings
 - Solution Manual Engineering Electromagnetics Hayt 5th Edition and Bestseller Lists

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 - Highlighting and Note-Taking Solution Manual Engineering Electromagnetics Hayt 5th Edition
 - Interactive Elements Solution Manual Engineering Electromagnetics Hayt 5th Edition
8. Staying Engaged with Solution Manual Engineering Electromagnetics Hayt 5th Edition
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Solution Manual Engineering Electromagnetics Hayt 5th Edition
9. Balancing eBooks and Physical Books Solution Manual Engineering Electromagnetics Hayt 5th Edition
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection Solution Manual Engineering Electromagnetics Hayt 5th Edition
10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
11. Cultivating a Reading Routine Solution Manual Engineering Electromagnetics Hayt 5th Edition
 - Setting Reading Goals Solution Manual Engineering Electromagnetics Hayt 5th Edition
 - Carving Out Dedicated Reading Time
12. Sourcing Reliable Information of Solution Manual Engineering Electromagnetics Hayt 5th Edition
 - Fact-Checking eBook Content of Solution Manual Engineering Electromagnetics Hayt 5th Edition
 - 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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