

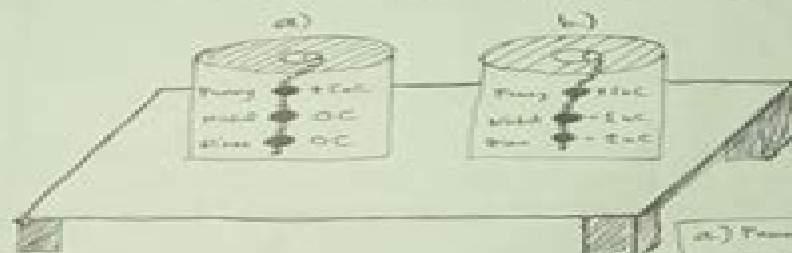
**ENGINEERING ELECTROMAGNETICS by William H. Hayt, Jr.  
FIFTH EDITION (ANSWER TO ODD-NUMBERED QUESTIONS)**

# 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 coins hang above all walls, and the lid is removed. The center of the cable is again touched eventually 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?



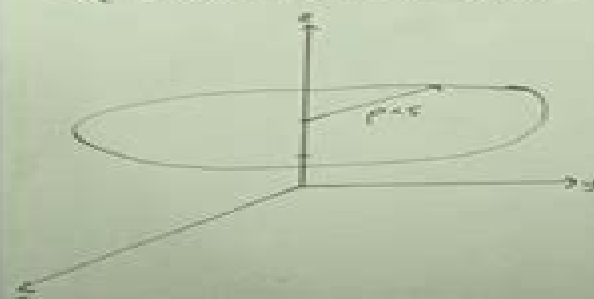
a) Penny =  $+5 \mu\text{C}$   
 Nickel =  $0 \text{ C}$   
 Dime =  $0 \text{ C}$   
 $Q_{\text{inner}} = -Q_{\text{outer}}$   
 $5 \mu\text{C} = -Q_{\text{outer}}$   
 $Q_{\text{outer}} = -5 \mu\text{C}$   
 lid + coin =  $+5 \mu\text{C}$

b. Penny =  $+5 \mu\text{C}$   
 Nickel =  $-2 \mu\text{C}$   
 Dime =  $-3 \mu\text{C}$   
 $Q_{\text{inner}} = -Q_{\text{outer}}$   
 $5 \mu\text{C} - 2 \mu\text{C} - 3 \mu\text{C} = -Q_{\text{outer}}$   
 $Q_{\text{outer}} = +0 \mu\text{C}$   
 lid + coin =  $-2 \mu\text{C}$

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

b) Penny:  $+5 \mu\text{C}$ , Nickel:  $-2 \mu\text{C}$ , Dime:  $-3 \mu\text{C}$ , lid + coin =  $+0 \mu\text{C}$

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)  $\Psi = \int_V \rho \, dV$   
 $= \int_0^{2\pi} \int_0^5 \frac{5\rho}{r^2+1} \rho \, d\rho \, d\phi$   
 $= \int_0^{2\pi} \int_0^5 \frac{5\rho^2}{r^2+1} \, d\rho \, d\phi$   
 $= \int_0^{2\pi} \frac{5\rho^2}{r^2+1} \left[ \frac{r^2}{2} \right]_0^5 \, d\phi$   
 $= 10\pi \int_0^5 \frac{r^2}{r^2+1} \, dr$   
 $= 10\pi \int_0^5 \left( 1 - \frac{1}{r^2+1} \right) dr$

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

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