

## Exam 1 Physics 114 Solutions

1(a) All four contribute. Any electric field polarizes a neutral object; the field then exerts forces on the oppositely charged ends of the object. In a uniform field, however, the magnitudes of the forces on either end are equal and because they are directed in opposite directions, these forces add up to zero. In a nonuniform field, the forces are not equal in magnitude and/or in opposite directions and so the sum is nonzero.

(b) Only  $q_1$  and  $q_2$  contribute. Only the enclosed charge contributes to the flux through a Gaussian surface. Field lines from any charged particle outside the Gaussian surface that enter the surface must also re-exit and so they do not contribute to the net flux.

2. Yes, any electric field polarizes a neutral object; the field then exerts forces on the oppositely charged ends of the object. In a uniform field, however, the magnitudes of the forces on either end are equal and because they are directed in opposite directions, these forces add up to zero. In a nonuniform field, the forces are not equal in magnitude and/or in opposite directions and so the sum is nonzero.

3. The correct answer is: 5. The magnitude of the electrostatic force exerted by 2 on 1 is equal to the magnitude of the electrostatic force exerted by 1 on 2. If the charges are of the same sign, the forces are repulsive; if the charges are of opposite sign, the forces are attractive.

4. The correct answer is: 2. The repulsive electrostatic force exerted by particle 2 on particle 3 is up and to the left. The attractive electrostatic force exerted by particle 1 on particle 3 is down and to the left. Because the two forces are equal in magnitude, the vector sum points horizontally toward the left, i.e., in the  $-x$  direction.

### Problems

$$1. \quad (a) \quad \mathbf{E}_1 = \frac{k_e |q_1|}{r_1^2} (-\mathbf{j}) = \frac{(8.99 \times 10^9)(3.00 \times 10^{-9})}{(0.100)^2} (-\mathbf{j}) = -(2.70 \times 10^3 \text{ N/C}) \mathbf{j}$$

$$\mathbf{E}_2 = \frac{k_e |q_2|}{r_2^2} (-\mathbf{i}) = \frac{(8.99 \times 10^9)(6.00 \times 10^{-9})}{(0.300)^2} (-\mathbf{i}) = -(5.99 \times 10^2 \text{ N/C}) \mathbf{i}$$

$$\mathbf{E} = \mathbf{E}_2 + \mathbf{E}_1 = \boxed{-(5.99 \times 10^2 \text{ N/C}) \mathbf{i} - (2.70 \times 10^3 \text{ N/C}) \mathbf{j}}$$

$$(b) \quad \mathbf{F} = q\mathbf{E} = (5.00 \times 10^{-9} \text{ C})(-599 \mathbf{i} - 2700 \mathbf{j}) \text{ N/C}$$

$$\mathbf{F} = (-3.00 \times 10^{-6} \mathbf{i} - 13.5 \times 10^{-6} \mathbf{j}) \text{ N} = \boxed{(-3.00 \mathbf{i} - 13.5 \mathbf{j}) \mu\text{N}}$$

$$2. \quad \Phi_E = EA \cos \theta = (2.00 \times 10^4 \text{ N/C})(18.0 \text{ m}^2) \cos 10.0 = \boxed{355 \text{ kN} \cdot \text{m}^2/\text{C}}$$

3. (a) The net field in the conductor is zero. The electric field set up by the conductor has to cancel that of the external field.  $\sigma/\epsilon_0 = E$   $\sigma = (8.00 \times 10^4)(8.85 \times 10^{-12})$   
 $= 7.08 \times 10^{-7} \text{ C/m}^2$

$$\boxed{\sigma = 708 \text{ nC/m}^2}, \text{ positive on one face and negative on the other.}$$

(b)  $\sigma = \frac{Q}{A}$   $Q = \sigma A = (7.08 \times 10^{-7})(0.500)^2 \text{ C}$

$$Q = 1.77 \times 10^{-7} \text{ C} = \boxed{177 \text{ nC}}, \text{ positive on one face and negative on the other.}$$

4.  $\oint \mathbf{E} \cdot d\mathbf{A} = E(4\pi r^2) = \frac{q_{\text{in}}}{\epsilon_0}$

- (a) Draw a gaussian surface at  $r = 0.1 \text{ m}$ .

$$(-3.60 \times 10^3 \text{ N/C})4\pi(0.100 \text{ m})^2 = \frac{Q}{8.85 \times 10^{-12} \text{ C}^2/\text{N} \cdot \text{m}^2} \quad (a < r < b)$$

$$Q = -4.00 \times 10^{-9} \text{ C} = \boxed{-4.00 \text{ nC}}$$

- (b) Draw a gaussian surface at  $r = 0.5 \text{ m}$ .

We take  $Q'$  to be the net charge on the hollow sphere. Outside  $c$ ,

$$(2.00 \times 10^2 \text{ N/C})4\pi(0.500 \text{ m})^2 = \frac{Q + Q'}{8.85 \times 10^{-12} \text{ C}^2/\text{N} \cdot \text{m}^2} \quad (r > c)$$

$$Q + Q' = +5.56 \times 10^{-9} \text{ C}, \text{ so } Q' = +9.56 \times 10^{-9} \text{ C} = \boxed{+9.56 \text{ nC}}$$

- (c) For  $b < r < c$ :  $E = 0$  and  $q_{\text{in}} = Q + Q_1 = 0$  where  $Q_1$  is the total charge on the inner surface of the hollow sphere. Thus,  $Q_1 = -Q = \boxed{+4.00 \text{ nC}}$

Then, if  $Q_2$  is the total charge on the outer surface of the hollow sphere,

$$Q_2 = Q' - Q_1 = 9.56 \text{ nC} - 4.00 \text{ nC} = \boxed{+5.56 \text{ nC}}$$