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 q1 and q2 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 next 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. (a)

$$\mathbf{E}_1 = \frac{k_e|q_1|}{r_1^2}(-\mathbf{j}) = \frac{(8.99\times10^9)(3.00\times10^{-9})}{(0.100)^2}(-\mathbf{j}) = -(2.70\times10^3 \text{ N/C})\mathbf{j}$$

$$\mathbf{E}_2 = \frac{k_e|q_2|}{r_2^2}(-\mathbf{i}) = \frac{(8.99\times10^9)(6.00\times10^{-9})}{(0.300)^2}(-\mathbf{i}) = -(5.99\times10^2 \text{ N/C})\mathbf{i}$$

$$\mathbf{E} = \mathbf{E}_2 + \mathbf{E}_1 = \boxed{-(5.99\times10^2 \text{ N/C})\mathbf{i} - (2.70\times10^3 \text{ N/C})\mathbf{j}}$$

(b)

$$\mathbf{F} = q\mathbf{E} = (5.00\times10^{-9}\text{ C})(-599\mathbf{i} - 2700\mathbf{j})\text{N/C}$$

$$\mathbf{F} = (-3.00\times10^{-6}\mathbf{i} - 13.5\times10^{-6}\mathbf{j})\text{N} = \boxed{(-3.00\mathbf{i} - 13.5\mathbf{j})\,\mu\text{N}}$$

2. $\mathbf{\Phi}_E = EA\cos\theta = (2.00\text{ x}10^4 \text{ N/C})(18.0 \text{ m}^2)\cos 10.0 = \boxed{355 \text{ kN}\cdot\text{m}^2/\text{C}}$

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. $\sigma/\varepsilon_0 = E$ $\sigma = (8.00 \times 10^4)(8.85 \times 10^{-12})$ $= 7.08 \times 10^{-7}$ C/m^2

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

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

$Q = 1.77 \times 10^{-7}$ C = $\boxed{177 \text{ nC}}$, 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 m.

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

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

(b) Draw a gaussian surface at r = 0.5 m.
We take Q' to be the net charge on the hollow sphere. Outside c,

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

$Q + Q' = +5.56 \times 10^{-9}$ C, so $Q' = +9.56 \times 10^{-9}$ 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, $Q_2 = Q' - Q_1 = 9.56 \text{ nC} - 4.00 \text{ nC} = \boxed{+5.56 \text{ nC}}$