Q1. Two point charges, with charges q_1 and q_2, are placed a distance *r* apart. Which of the following statements is **TRUE** if the electric field due to the two point charges is zero at a point *P* between the charges?

A) q_1 and q_2 must have the same sign but may have different magnitudes.
B) q_1 and q_2 must have the same sign and magnitude.
C) *P* must be exactly midway between particles.
D) q_1 and q_2 must have opposite signs and may have different magnitudes.
E) q_1 and q_2 must have equal magnitudes but opposite signs.

Ans:

A

Q2. Two identical conducting spheres A and B carry charge $Q_A = +2Q$ and $Q_B = -3Q$. They are separated by a distance much larger than their diameters. The magnitude of the initial electrostatic force between spheres A and B is F. A third, identical uncharged conducting sphere C is first touched to A, then to B, and finally removed. As a result, the magnitude of the electrostatic force between A and B after touching is:

A) F/6
B) F/4
C) F/3
D) 3F
E) 2 F

Ans:

$$F_0 = \frac{k(2Q)(-3Q)}{d^2} = \frac{-6kQ^2}{d^2}$$

$$q_{Af} = \frac{2Q + 0}{2} = Q$$

$$q_{Bf} = \frac{-3Q + Q}{2} = -Q$$

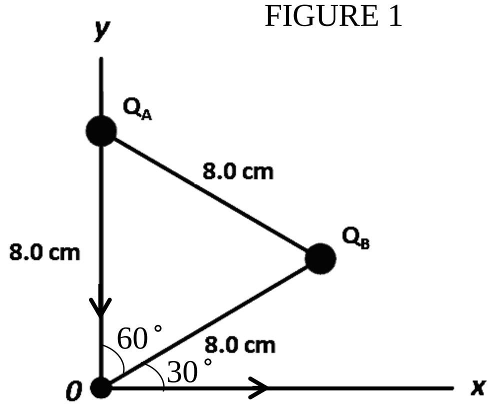
$$q_{Bf} = \frac{1}{6}\left(\frac{-6kQ^2}{d^2}\right) = -\frac{kQ^2}{d^2}$$

$$F_f = \frac{kq_{Af} \cdot q_{Bf}}{d^2} = \frac{kQ(-Q)}{d^2} = -\frac{kQ^2}{d^2} = \frac{F}{6}$$

Q3. Two charges Q_A and Q_B are placed in the x-y plane, as shown in **FIGURE 1**. The resultant electric field at the origin O due to the two charges is $\vec{E} = 6.3\times10^{7}$ N/C $\hat{i}$. Determine the magnitude and sign of the charge Q_B.

A) −52 μC
B) −16 μC
C) +72 μC
D) −66 μC
E) +26 μC

FIGURE 1



Ans:

$$\vec{E}_{net} = \vec{E}_A + \vec{E}_B$$

$$E_{net} = E_x = E_B cos\theta = \frac{kQ_B}{d^2} \cdot cos30$$

$$E_{net} = 6.3 \times 10^7 = \frac{kQ_B}{d^2} \cdot cos30$$

$$|Q_B| = \frac{6.3 \times 10^7 \times (0.08)^2}{9 \times 10^9 \times cos30} = 52\mu C$$

$$Q_B = -52\ \mu C$$

Q4. An electron enters a region of uniform electric field with its velocity opposite to the field. The electron's speed increases from 2.0×10^{7} m/s to 4.0×10^{7} m/s over a distance of 1.2 cm. What is the magnitude of electric field?

A) 2.9×10^{5} N/C
B) 1.4×10^{5} N/C
C) 2.0×10^{7} N/C
D) 4.0×10^{7} N/C
E) 1.0×10^{5} N/C

Ans:

$$v^2 = v_0^2 + 2ad \Rightarrow a = \frac{v^2 - v_0^2}{2d} = \frac{(16-4)\times 10^{14}}{2 \times 1.2 \times 10^{-2}} = 5 \times 10^{16}\ m/s^2$$

$$eE = ma \Rightarrow E = \frac{ma}{e} = \frac{9.11 \times 10^{-31}}{1.6 \times 10^{-19}} \times 5 \times 10^{16} = 2.9 \times 10^5\ N/C$$

Q5. An electric dipole of dipole moment $|\vec{p}|$ = 2.0×10^{-8} C.m is initially placed in an electric field of magnitude1.0×10^{2} N/C in a direction perpendicular to the field. If the dipole is rotated to align it in the same direction as the field, find the work done by the field to rotate the dipole.

A) +2.0 μJ
B) −2.0 μJ
C) +4.0 μJ
D) −4.0 μJ
E) +1.0 μJ

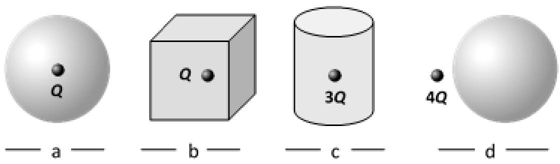
Ans:

$$W = -\Delta U = U_i - U_f;\ U_i = 0; U_f = -pE$$

$$W = -U_f = pE = 2 \times 10^{-8} \times 1.0 \times 10^{2} = 2 \times 10^{-6}\ \text{J} = +2\ \mu\text{J}$$

Q6. Rank the electric fluxes through each of four Gaussian surfaces shown in **FIGURE 2** from **largest to smallest**.

FIGURE 2



A) c, a and b tie, d
B) a and c tie, d, b
C) b, c and a tie, d
D) d, b, c and a tie
E) a and d tie, c, b

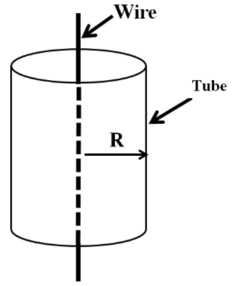
Ans:

$$\phi_E \propto q_{encl};\ q_{encl-a} = Q;\ q_{encl-b} = Q;\ q_{encl-c} = 3Q;\ q_{encl-d} = 0$$

$$C, a\ and\ b\ tie, d$$

Q7. A long thin walled metal tube with radius R=1.00 cm has a charge per unit length $\lambda = -4.20$ nC/m. A long thin wire carrying 5.60 nC/m charge passes through the center of the tube as shown in the **FIGURE 3**. Find the magnitude of the electric field at a distance of 1.50 cm from the wire center in the direction perpendicular to the wire axis.

FIGURE 3



A) 1.68×10^3 N/C
B) 1.01×10^3 N/C
C) 2.33×10^3 N/C
D) 3.51×10^3 N/C
E) 1.05×10^3 N/C

Ans:

$$\lambda_{net} = \lambda_{wire} - \lambda_{tube} = (5.6 - 4.2) \times 10^{-9} = 1.4\, nC/m$$

$$E_r = \frac{2k\lambda_{net}}{r} = \frac{2 \times 9 \times 10^9 \times 1.4 \times 10^{-9}}{1.5 \times 10^{-2}} = 1680\, N/C$$

Q8. A conducting uniform thin spherical shell of radius 14.0 cm carries a uniform surface charge density $\sigma = 2.60 \times 10^{-4}$ C/m^2. Find the magnitude of the electric field at a point at a distance of 20.0 cm from the center of the shell.

A) 1.44×10^7 V/m
B) 3.15×10^7 V/m
C) 5.22×10^7 V/m
D) 1.01×10^7 V/m
E) 1.05×10^7 V/m

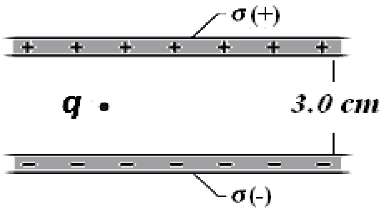
Ans:

$$E = \frac{kq}{r^2} = \frac{k}{r^2}\sigma A = \frac{k\sigma}{r^2} \cdot 4\pi R^2$$

$$E = \frac{9 \times 10^9 \times 2.6 \times 10^{-4}}{(0.2)^2} \times 4\pi \times (0.14)^2 = 1.44 \times 10^7 \text{ V/m}$$

Q9. Two horizontal infinite non-conducting sheets carry uniform surface charge densities $\sigma_+ = +3.0 \times 10^{-6}$ C/m^2 and $\sigma_- = -5.0 \times 10^{-6}$ C/m^2 on their surfaces, as shown in **FIGURE 4**. A point charge particle *q* with 1.6×10^{-6} C charge is released from rest between the plates. Determine the magnitude of the electrostatic force on the particle *q*. Ignore the force of gravity on the particle.

FIGURE 4



A) 0.72 N
B) 1.5 N
C) 0.11 N
D) 2.4 N
E) 0.33 N

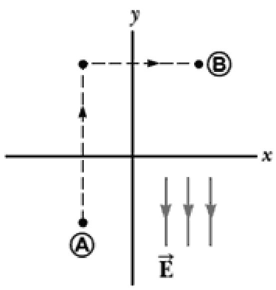
Ans:

$$E = \frac{|\sigma_1| + |\sigma_2|}{2\varepsilon_0}; \; F = qE$$

$$F = qE = 1.6 \times 10^{-6} \times \frac{(3+5) \times 10^{-6}}{2 \times 8.85 \times 10^{-12}} = 0.72 \text{ N}$$

Q10. A uniform electric field of magnitude 322 V/m is directed in a region as shown in **FIGURE 5**. Calculate the electric potential difference $V_B - V_A$ if the coordinates of point A are (-0.200, - 0.300) m, and those of point B are (0.400, 0.500) m. Assume V = 0 at infinity.

FIGURE 5



A) 258 V
B) 112 V
C) 361 V
D) 322 V
E) 105 V

Ans:

$$\Delta V = -\vec{E}_y \cdot \Delta\vec{r}_y = -\vec{E}_y \Delta\vec{r}_y$$

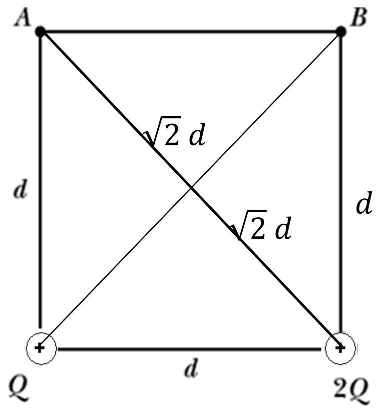
$$E_y = -322 \text{ v/m}$$

$$\Delta r_y = r_{By} - r_{Ay} = 0.5 - (-0.3) = 0.8 \text{ m}$$

$$\Delta V = -(-322) \times 0.8 = 257.6 \text{ V} \approx 258 \text{ V}$$

Q11. The two charges ***Q*** and **2*Q*** in the **FIGURE 6** are separated by a distance d = 15.0 cm. If the electric potential difference between B and A $(V_B - V_A)$ = +572 V, find the value of Q. Assume V = 0 at infinity.

FIGURE 6



A) 32.5 nC
B) 22.7 nC
C) 11.1 nC
D) 45.3 nC
E) 55.5 nC

Ans:

$$V_B = \frac{2kQ}{d} + \frac{kQ}{\sqrt{2}d} = \frac{kQ}{d}\left(2 + \frac{1}{\sqrt{2}}\right) = 2.707\,\frac{kQ}{d}$$

$$V_A = \frac{kQ}{d} + \frac{2kQ}{\sqrt{2}d} = \frac{kQ}{d}\left(1 + \sqrt{2}\right) = 2.414\,\frac{kQ}{d}$$

$$V_B - V_A = 2.707\,\frac{kQ}{d} - 2.414\,\frac{kQ}{d} = 0.293\,\frac{kQ}{d} = 572$$

$$Q = \frac{572 \times d}{0.293 \times k} = \frac{572 \times 0.15}{0.293 \times 9 \times 10^9} = 32.5 \times 10^{-9}\,C$$

Q12. Two protons, initially at rest and separated by 50.0 mm are released simultaneously from rest. What is speed of either proton at the instant when they are infinitely apart? Assume V = 0 at infinity.

A) 1.66 m/s
B) 1.01 m/s
C) 1.15 m/s
D) 3.42 m/s
E) 2.22 m/s

Ans:

$$K_i + U_i = K_f + U_f;\; K_i = U_f = 0 \;\Rightarrow U_i = K_f$$

$$K_f = 2 \times \frac{1}{2}mv^2 = \frac{kq^2}{d} \Rightarrow v = \sqrt{\frac{k}{md}} \times q$$

$$v = \sqrt{\frac{9 \times 10^9}{1.67 \times 10^{-27} \times 0.05}} \times 1.6 \times 10^{-19} = 1.66\,m/s$$

Q13. An isolated charged spherical conductor has a radius R. At a distance r from the center of the sphere (r>R), the magnitude of the electric field is 500 V/m and the electric potential is 23.0 kV. What is the value of the charge on the conductor? Assume V = 0 at infinity.

A) 118 μC
B) 50.8 μC
C) 221 μC
D) 88.7 μC
E) 355 μC

Ans:

$$E = \frac{KQ}{r^2}; V = \frac{KQ}{r}; \frac{E}{V} = \frac{KQ}{r^2} \times \frac{r}{kQ} = \frac{1}{r} \Rightarrow r = \frac{V}{E}$$

$$r = \frac{V}{E} = \frac{23 \times 10^3}{500} = 46\, m$$

$$Q = \frac{Vr}{k} = \frac{23 \times 10^3 \times 46}{9 \times 10^9} = 117.6 \times 10^{-6} C = 118\, \mu C$$

Q14. The initial energy density of an air-filled parallel-plate capacitor, connected to a battery of potential difference V, is u_i. If the capacitor plates separation is doubled, while the battery is still connected, the ratio of the initial energy density u_i to the final energy density u_f of the capacitor (u_i/ u_f) is:

A) 4
B) 3
C) 2
D) 1
E) None of the given values

Ans:

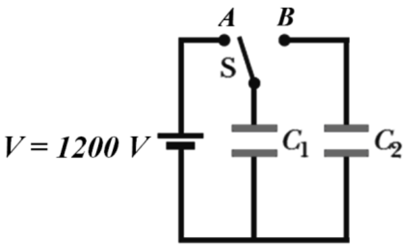
$$u = \frac{\varepsilon_0}{2} E^2 = \frac{\varepsilon_0}{2} \left(\frac{V}{d}\right)^2 = \frac{\varepsilon_0 V^2}{2} \cdot \frac{1}{d^2}$$

$$u_i = \frac{\varepsilon_0 V^2}{2} \frac{1}{d_i^2}; \; u_f = \frac{\varepsilon_0 V^2}{2} \cdot \frac{1}{d_f^2}$$

$$\frac{u_i}{u_f} = \frac{d_f^2}{d_i^2} \; but \; d_f = 2d_i \; \Rightarrow 4\frac{d_i^2}{d_i^2} = 4$$

Q15. Two capacitors $C_1=5.00 \times 10^{-10}$ F and $C_2=3.00 \times 10^{-10}$ F are connected to a battery $V=1.20 \times 10^3$ V, as shown in **FIGURE 7**. The switch is first connected to A, and the capacitor C_1 is fully charged. Then, the switch is connected to B and the circuit is allowed to reach equilibrium. Find the charge stored in capacitor C_2 after the equilibrium is reached.

FIGURE 7



A) 225 nC
B) 375 nC
C) 125 nC
D) 455 nC
E) 112 nC

Ans:

$$Q_{1i} = C_1 V = 5 \times 10^{-10} \times 1.2 \times 10^3 = 6 \times 10^{-7}\ C$$

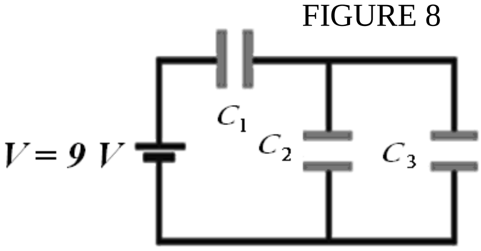
$$C_{eq} = C_1 + C_2 = (5+3) \times 10^{-10} = 8 \times 10^{-10}\ F$$

$$V_f = \frac{Q_{1i}}{C_{eq}} = \frac{6 \times 10^{-7}}{8 \times 10^{-10}} = 0.75 \times 10^3 = 750\ V$$

$$Q_{2f} = 3 \times 10^{-10} \times 0.75 \times 10^3 = 2.25 \times 10^{-7} = 225\ nC$$

Q16. **FIGURE 8** shows three capacitors $C_1 = 6.00$ μF, $C_2 = 4.00$ μF and $C_3 = 2.00$ μF connected to a 9.00 V battery. What is the total energy stored in the three capacitors?

FIGURE 8



A) 122 μJ
B) 80.8 μJ
C) 50.5 μJ
D) 221 μJ
E) 331 μJ

Ans:

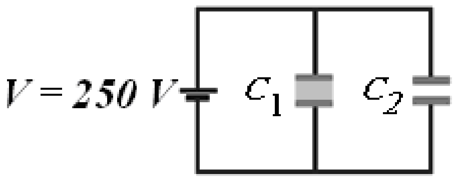
$$U = \frac{1}{2} C_{eq} V^2; \quad C_{23} = C_2 + C_3 = (4+2)\mu F = 6\ \mu F$$

$$C_{eq} = \frac{C_1 \times C_{23}}{C_1 + C_{23}} = \frac{6 \times 6}{6+6}\ \mu F = 3 \mu F$$

$$U = \frac{1}{2} C_{eq} V^2 = \frac{1}{2} \times 3 \times 10^{-6} \times (9)^2 = 121.5\ \mu J \approx 122\ \mu J$$

Q17. How much total charge is stored in the two parallel-plate capacitors C_1 and C_2 of the circuit shown in **FIGURE 9**? C_1 is filled with material of dielectric constant κ= 3.00 while C_2 is filled with air. Each capacitor has a plate area of 5.00×10^{-3} m^2 and a plate separation of 2.00 mm.

FIGURE 9



A) 22.1 nC
B) 12.7 nC
C) 5.55 nC
D) 32.5 nC
E) 52.9 nC

Ans:

$$Q_{net} = (C_1 + C_2)V$$

$$C_1 = \frac{k\varepsilon_0 A}{d} = \frac{3 \times 8.85 \times 10^{-12} \times 5 \times 10^{-3}}{2 \times 10^{-3}} = 6.637 \times 10^{-11}\ F$$

$$C_2 = \frac{\varepsilon_0 A}{d} = \frac{8.85 \times 10^{-12} \times 5 \times 10^{-3}}{2 \times 10^{-3}} = 2.2125 \times 10^{-11}\ F$$

$$Q_{net} = (6.637 + 2.213) \times 10^{-11} \times 250$$

$$Q_{net} = 2212.5 \times 10^{-11} C = 22.1 \times 10^{-9} C$$

Q18. A copper wire with diameter d carries a current I. If we double the diameter of the wire, and also double the current in the wire, what is ratio of new drift speed v_{d2} to the old drift speed v_{d1} (v_{d2}/ v_{d1}) of the charge carriers?

A) 1/2
B) 1/4
C) 2
D) 4
E) 1/3

Ans:

$$v_d = \frac{J}{ne} = \frac{I/A}{ne} = \frac{I/\pi\left(\frac{d^2}{4}\right)}{ne} = \frac{4I}{\pi n e d^2}$$

$$\frac{v_{d_2}}{v_{d_1}} = \frac{\frac{4I_2}{\pi n e d_2^2}}{\frac{4I_1}{\pi n e d_1^2}} = \frac{I_2 d_1^2}{I_1 d_2^2} = \frac{2I_1}{I_1} \times \frac{d_1^2}{4d_1^2} = \frac{1}{2}$$

Q19. Copper has resistivity ρ_o at room temperature. Find the temperature at which copper has resistivity $2\rho_o$. Assume room temperature is 20.0 °C and temperature coefficient of resistivity α_{cu} = 4.30 ×10^{-3} K^{-1}.

A) 253 °C
B) 171 °C
C) 111 °C
D) 355 °C
E) 422 °C

Ans:

$$\rho = \rho_0(1+\alpha\Delta T) \ but \ \rho = 2\rho_0$$

$$2\rho_0 = \rho_0(1+\alpha\Delta T) \Rightarrow 2 = 1+\alpha\Delta T \Rightarrow 1 = \alpha\Delta T$$

$$\Delta T = \frac{1}{\alpha} = \frac{1}{4.3\times 10^{-3}} = 232.6\ ℃$$

$$T_f = T_i + \Delta T = 20 + 232.6 = 252.3℃ = 253℃$$

Q20. A water heater operate at 120 V and carries a current 2.00 A. Assuming the water absorbs all the energy delivered by the heater, how long does it take to raise the temperature of 0.500 kg of liquid water from 23.0 °C to 100 °C?

A) 672 s
B) 433 s
C) 272 s
D) 755 s
E) 981 s

Ans:

$$\text{Heat required} = \Delta Q = mc\Delta T = 0.5\times 4190\times 77 = 161315\ J$$

$$\text{Power Available P} = IV = 2\times 120 = 240\ \text{W}$$

$$\text{Then } \Delta Q = P\times t \Rightarrow t = \frac{\Delta Q}{P} = \frac{161315}{240} = 672\ s$$