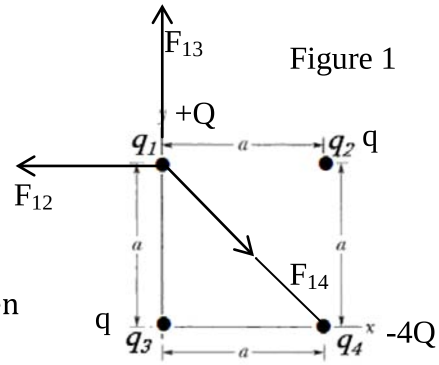
Q1.

As shown In **Figure 1** four particles form a square of side length *a*. The charges $q_1 = +Q$, $q_2 = q_3 = q$, $q_4 = -4.00\ Q$. What is the ratio q/ Q if the net electrostatic force on q_1 is zero?

A) 1.41
B) 0.707
C) 2.82
D) 1.00
E) Zero



Ans:

if net electrostatic force is zero then

$$|F_{13}| = |F_{14-y}|$$

$$|F_{13}| = |F_{14-y}|$$

$$\frac{kq_1q_3}{a^2} = \frac{kq_1q_4}{2a^2}\cos 45$$

$$|q_3| = \frac{|q_4|}{2} \times cos45 \Rightarrow q = \frac{4Q}{2} cos45$$

$$q = 2Qcos45$$

$$\frac{q}{Q} = 2cos45 = 1.41$$

Q2.

Consider two neutral point particles of mass 5.0 g each. A total of 4.0×10^{12} electrons are transferred from one neutral particle to the other particle. How far apart must the two particles be if the magnitude of the electrostatic force between them is equal to the magnitude of the weight of one of the particles on earth surface?

A) 27 cm
B) 31 cm
C) 33 cm
D) 25 cm
E) 39 cm

Ans:

$$mg = \frac{kq^2}{d^2} \quad \Rightarrow \quad d = \sqrt{\frac{kq^2}{mg}}$$

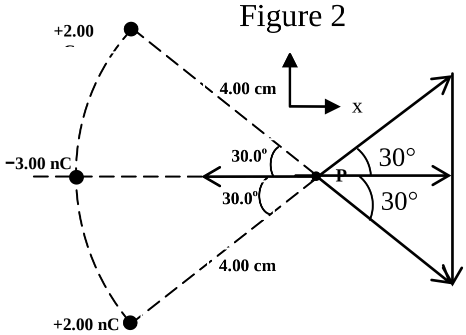
$$d = \sqrt{\frac{9 \times 10^9 \times (4 \times 10^{12} \times 1.6 \times 10^{-19})^2}{5 \times 10^{-3} \times 9.8}} = \sqrt{\frac{9 \times 16 \times 1.6 \times 1.6 \times 10^{-2}}{5 \times 9.8}}\ m$$

$$d = 0.27\ \text{m} = 27\ cm$$

Q3.

Three point charges are located on a circular arc as shown in **Figure 2.** What is the magnitude of net electric field at point P, the center of the arc?

Figure 2



A) 2.61×10^3 N/C
B) 2.08×10^4 N/C
C) 1.64×10^3 N/C
D) 3.64×10^3 N/C
E) 2.25×10^5 N/C

Ans:

$$F_{net-y} = 0$$

$$F_{net-x} = \frac{2 \times k \times q_+ \cos 30^\circ}{(0.04)^2} - \frac{k \times q_-}{(0.04)^2}$$

$$F_{net-x} = \frac{k}{(0.04)^2}[2 \times 10^{-9} \times 2 \times cos30 - 3 \times 10^{-9}]$$

$$F_{net} = \frac{9 \times 10^9 \times 10^{-9}}{(0.04)^2}[4cos30 - 3]$$

$$= \frac{9 \times 0.464}{(0.04)^2} = 2.61 \times 10^3 \text{ N/C}$$

Q4.

An electron enters a region of uniform electric field $\vec{E} = (60\,\hat{i})$ N/C with a velocity $\vec{v}_i = (50\,\hat{i})$ km/s. How far does the electron travel in the first 2.0×10^{-9} s time interval after entering the field?

A) 7.9×10^{-5} m
B) 1.1×10^{-5} m
C) 2.7×10^{-4} m
D) 1.3×10^{-6} m
E) 4.2×10^{-5} m

Ans:

$$\Delta X = V_0 t + \frac{1}{2}at^2 \Rightarrow |a| = \frac{q_e E}{m_e} = \frac{1.6 \times 10^{-14} \times 60}{9.11 \times 10^{-31}} = 1.054 \times 10^{13}$$

$$|V_0| = 50\text{ km/s} = 50 \times 10^3\, m/s = 5 \times 10^4\, m/s$$

$$\Delta X = 5 \times 10^4 \times 2 \times 10^{-9} - \frac{1}{2} \times (1.054 \times 10^{13}) \times (2 \times 10^{-9})^2$$

$$= 10 \times 10^{-5} - \frac{1}{2} \times 1.054 \times 4 \times 10^{-5}$$

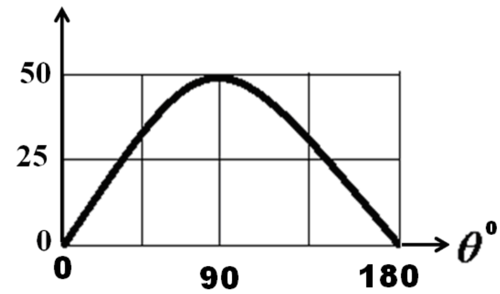
$$= 7.9 \times 10^{-5} m$$

Q5.

A certain electric dipole is placed in a uniform electric field $\vec{E}$ of magnitude 10 N/C**.** The magnitude of torque on the dipole plotted as a function of the angle between $\vec{E}$ and the dipole moment $\vec{p}$ is shown in **Figure 3**. How much work is needed by an external agent to turn the electric dipole from 30^0 to 60^0 with respect to $\vec{E}$ field?

A) $+1.83 \times 10^{-1}$ J
B) -1.83×10^{-1} J
C) $+2.66 \times 10^{-1}$ J
D) -2.66×10^{-1} J
E) $+9.20 \times 10^{-2}$ J

Figure 3



Ans:

$$W_{ext} = \Delta U = pE\left(cos\theta_i - cos\theta_f\right)$$

$$from\ graph\ pE = 50 \times 10^{-2}$$

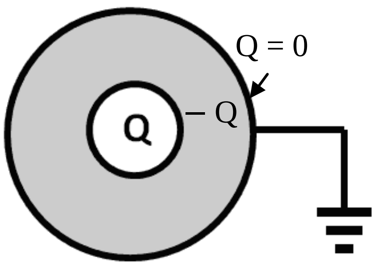
$$W_{ext} = 50 \times 10^{-2}(cos30 - cos60)$$

$$W_{ext} = 1.83 \times 10^{-1}\text{J}$$

Q6.

A metallic sphere contains a cavity at the center as shown in **Figure 4**. The outer surface of the sphere is grounded by connecting a conducting wire between it and the earth. A negative point charge Q = − 5.4 $\times 10^{-9}$ C is placed inside the cavity of the sphere. What is the net electric flux through the outer surface of the metallic sphere?

Figure 4



A) 0
B) $+6.1\times10^{2}$ N.m^2/C
C) -6.1×10^{2} N.m^2/C
D) $+3.1\times10^{2}$ N.m^2/C
E) -3.1×10^{2} N.m^2/C

Ans:

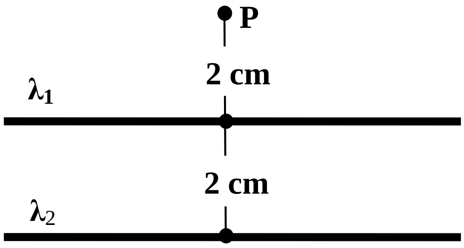
$$On\ the\ sphere\ Q_{net} = 0$$

$$\phi_{net} = 0$$

Q7.

Consider two infinitely long thin wires carrying uniform linear charge densities λ_1 and λ_2. The wires are arranged as shown in **Figure 5** and λ_2 = +5.50 nC/m**.** If the net electric field at P is zero, determine the magnitude of λ_1.

Figure 5



A) 2.75 nC/m
B) 1.50 nC/m
C) 1.75 nC/m
D) 2.00 nC/m
E) 0.50 nC/m

Ans:

$$E_p = 0 \Rightarrow |E_2| = |E_1| \Rightarrow \left|\frac{\cancel{2}k\lambda_2}{r_2}\right|\left|\frac{\cancel{2}k\lambda_1}{r_1}\right|$$

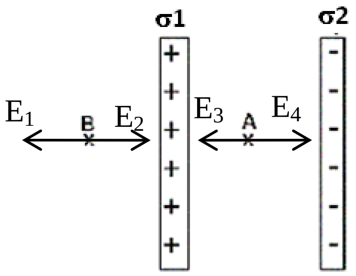
$$|\lambda_1| = \frac{|\lambda_2|}{r_2} \times r_1$$

$$= 5.5 \times 10^{-9} \times \left(\frac{2}{4}\right) = 2.75\ nC/m$$

Q8.

Figure 6 shows two large, parallel, non-conducting sheets, each with fixed uniform charge density: $\sigma_1 = +2.0\times10^{-6}$ C/m^2, $\sigma_2 = -4.0\times10^{-6}$ C/m^2. The ratio of the magnitude of the electric field at point A to that at point B, (E_A/E_B), is:

Figure 6



A) 3.0
B) 0.5
C) 1.0
D) 3.5
E) 1.5

Ans:

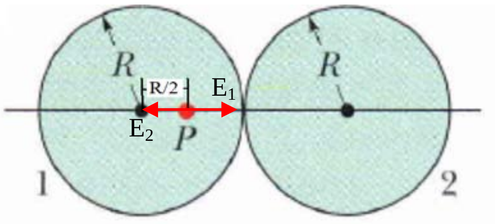
$$\frac{E_A}{E_B} = \frac{|\sigma_1| + |\sigma_2|}{|\sigma_1| - |\sigma_2|} = \frac{|4.0 + 2.0| \times 10^{-6}\ c/m^2}{|2.0 - 4.0| \times 10^{-6}\ c/m^2}$$

$$= 3.0$$

Q9.

Figure 7 shows the cross sectional area of two identical charged solid spheres, 1 and 2, of radius *R*. The charge is uniformly distributed throughout the volumes of both the spheres. The net electric field is zero at point P, which is located on a line connecting the centers of the spheres, at radial distance R/2 from the center of sphere 1. If the charge on sphere 1 is $q_1 = 7.8\ \mu$C, determine the magnitude of the charge q_2 on sphere 2.

Figure 7



A) 8.8 μC
B) 3.2 μC
C) 9.3 μC
D) 3.5 μC
E) 6.8 μC

Ans:

$$Net\ electric\ field\ at\ P\ E_P = 0$$

$$\vec{E}_P = \vec{E}_2 + \vec{E}_1 = 0$$

$$|\vec{E}_2| = |\vec{E}_1|$$

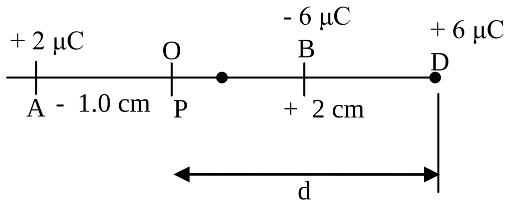
$$\frac{kq_2}{\left(\frac{3R}{2}\right)^2} = \frac{kq_1}{R^3} \times \frac{R}{2} = \frac{kq_1}{2R^2}$$

$$\frac{4q_2}{9R^2} = \frac{q_1}{2R^2} \Rightarrow q_2 = \frac{9q_1}{8} = 8.8\ \mu C$$

Q10.

Two charges, Q_A = +2 μC and Q_B = − 6 μC, are located on the x-axis at x_A= −1 cm and x_B= +2 cm, respectively. Where should a third charge, Q_C = + 6 μC, be placed on the positive x-axis so that the potential at the origin is equal to zero?

A) x = 6 cm
B) x = 4 cm
C) x = 7 cm
D) x = 3 cm
E) x = 1 cm



Ans:

$$V_P = \not{k}\left[\frac{q_A}{0.01} + \frac{q_B}{0.02} + \frac{q_D}{d}\right] = 0$$

$$\frac{q_D}{d} = -\frac{q_A}{0.01} - \frac{q_B}{0.02} = -\frac{2\times10^{-6}}{0.01} + \frac{6\times10^{-6}}{0.02} = \frac{2\times10^{-6}}{0.02}$$

$$\frac{q_D}{d} = \frac{\overset{3}{\not{6}}\times \not{10}^{-6}}{d} = \frac{\not{2}\times\not{10}^{-6}}{0.02} \Rightarrow \frac{3}{d} = \frac{1}{0.02}$$

$$d = 3\times 0.02 = 0.06\,m = 6\,cm$$

Q11.

The electric potential over a particular region is given by V(x,y)= 9 − 7x − 5y^2. Determine the angle between the electric field $\vec{E}$ at point P and the positive x axis. The coordinates of the point P are x=1.00 m and y=2.00 m.

A) 70.7 °
B) 43.6 °
C) 46.6 °
D) 83.6 °
E) 53.6 °

Ans:

$$E_x\,(x = 1.00\,m) = -\frac{\partial v}{\partial x} = 7$$

$$E_y\,(y = 2.00\,m) = -\frac{\partial v}{\partial y} = 10\,y = 20$$

$$\theta = \tan^{-1}\left(\frac{E_y}{E_x}\right) = \tan^{-1}\left(\frac{20}{7}\right) = 70.7°$$

Q12.

A metallic isolated sphere of diameter 3.5 cm, fixed in space, carries +9.0 nC charge. A proton was released from rest at the sphere's surface. Determine the maximum speed of the proton. (Assume V=0 at infinity)

A) 9.4×10^5 m/s
B) 1.2×10^5 m/s
C) 3.1×10^3 m/s
D) 4.2×10^7 m/s
E) 3.2×10^7 m/s

Ans:

$$\Delta K = W = -\Delta U = U_i - U_f \; but \;\; K_i = U_f = 0 \; Then$$

$$K_{max} = K_f = U_i \Rightarrow \frac{1}{2} m_p v_{max}^2 = \frac{kq_pQ}{R}$$

$$v_{max} = \sqrt{\frac{2}{1amp} \times \frac{kq_pQ}{R}} = \sqrt{\frac{2 \times 9 \times 10^9 \times 9 \times 10^{-9} \times 1.6 \times 10^{-16}}{1.67 \times 10^{-27} \times 0.0175}}$$

$$= 9.4 \times 10^5 \; m/s$$

Q13.

Two metal spheres 1 and 2 with radii r_1 = 1.0 cm and r_2=2.0 cm carry charges q_1= +22 nC, and q_2= −10 nC, respectively. Initially both spheres are far apart. Then the spheres are connected by a thin wire, how much charge is lost by sphere 1 when the electrostatic equilibrium is reached?

A) +18 nC
B) −18 nC
C) +12 nC
D) −12 nC
E) +14 nC

Ans:

$$q_{net} = +22\, nc - lone = 12\, nC$$

After connection $V_1 = V_2 \Rightarrow \frac{\not{k} q_1}{r_1} = \frac{\not{k}(q_{net} - q_1)}{r_2}$

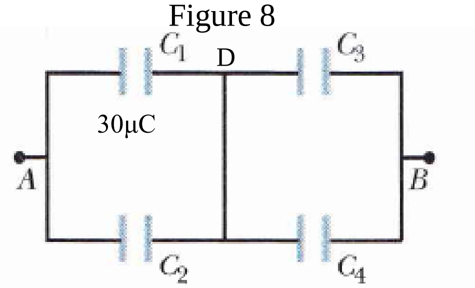
$$\frac{q_1}{r_1} = \frac{q_{net} - q_1}{r_2} \Rightarrow q_1 r_2 = r_1(q_{net} - q_1) \Rightarrow q_1 = \frac{r_1 q_{net}}{r_1 + r_2}$$

$$q_1 = \frac{1}{3} \times 12 \times 10^{-9} = 4.0 \times 10^{-9}\text{ C}, \qquad q_{lost} = (22 - 4.0) \times 10^{-9} = 18\, nC$$

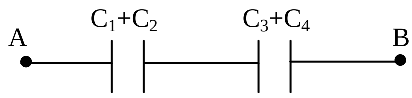
Q14.

Figure 8 shows a four-capacitor arrangement that is connected to a larger circuit at points A and B. The capacitances are C_1 = l0 μF, and C_2= C_3= C_4= 20 μF. The charge on capacitor C_1 is 30 μC. What is the magnitude of the potential difference $V_A - V_B$?

Figure 8



⇒



A) 5.3 V
B) 3.5 V
C) 2.2 V
D) 1.2 V
E) 7.2 V

Ans:

$$V_{C_1} = +\frac{Q_1}{C_1} = \frac{30\times10^{-6}}{10\times10^{-6}} = 3\ V, V_{C_2} = V_{c1}$$

$$Q_2 = C_2 V_{C_2} = 20\times10^{-6}\times3 = 60\times10^{-6}\ C$$

$$Q_{C_3+C_4} = Q_{C_1+C_2} = 60+30 = 90\ \mu C$$

$$Q_{C_3} = \frac{Q_{C_3+C_4}}{2} = \frac{90\times10^{-6}}{2} = 45\ \ \mu C$$

$$V_{C_3} = 4.5\times10^{-6}/20\times10^{-6} = \frac{45}{20} = 2.25\ V$$

$$V_A - V_B = 3 + 2.25 = 5.3\ V$$

Q15.

A 200 V battery is connected across 10 identical capacitors which are connected in series. The total energy stored in the combination is 0.0400 J. What is the capacitance of each capacitor?

A) 20.0 µF
B) 1.00 µF
C) 2.00 µF
D) 6.00 µF
E) 30.0 µF

Ans:

$$U_{tot} = \frac{1}{2} C_{eq} V^2 = \frac{1}{2}\frac{C}{n} V^2 \quad n = 10$$

$$0.04 = \frac{1}{2} \times \frac{C}{10} \times (200)^2 \Rightarrow C = \frac{0.04 \times 20}{(200)^2}$$

$$C = \frac{0.04 \times 20}{(200)^2} = 20.0\ \mu F$$

Q16.

A parallel-plate capacitor filled with a material of dielectric constant 3.60, has a capacitance of 1.25 nF. When 5500 V potential difference is applied across the capacitor, the electric field between the plates is 1.60×10^7 V/m. What is the area of the plates?

A) 0.0135 m^2
B) 0.102 m^2
C) 0.0194 m^2
D) 0.0498 m^2
E) 0.387 m^2

Ans:

$$C_0 = \frac{C_k}{k}, \qquad C_0 = \frac{\varepsilon_0 A}{d} \quad but\ d = \frac{V}{E}$$

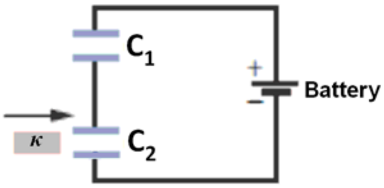
$$Then\ A = \frac{C_0}{\varepsilon_0} \cdot d = \frac{1}{\varepsilon_0} \cdot \frac{C_k}{k} \cdot \frac{V}{E} = \frac{1}{8.85 \times 10^{-12}} \times \frac{1.25 \times 10^{-9}}{3.60} \times \frac{5500}{1.60 \times 10^7}$$

$$A = 0.0135\ m^2$$

Q17.

When a dielectric slab is inserted between the plates of one of the two identical capacitors, as shown in **Figure 9**, which of the following statements describe the situation of C_2 **correctly**?

Figure 9



A) Potential energy stored in C_2 decreases
B) Capacitance of C_2 decreases
C) Charge on C_2 decreases
D) Potential difference across C_2 increases
E) Potential energy stored in C_2 increases

Ans:

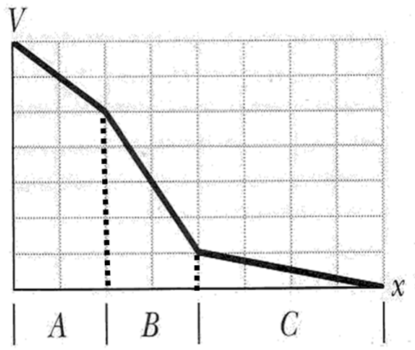
$$V_k = \frac{Q}{C_\kappa} \Rightarrow V_\kappa \text{ decrease}$$

$$U = \frac{1}{2} C_\kappa V_\kappa^2 \Rightarrow \text{ decreases}$$

Q18.

The electric potential V(x) versus the position x along a copper wire carrying current is shown in **Figure 10**. The wire consists of three sections, A, B, and C that differ in radius. Rank the three sections according to the magnitude of the current density**, least first**.

Figure 10



A) C, A, B
B) A, B, C
C) C, B, A
D) B, A, C
E) A, C, B

Ans:

$$J = \sigma E = \sigma \frac{\Delta V}{\Delta x} \Rightarrow J \propto \frac{\Delta V}{\Delta x}$$

$$\left(\frac{\Delta V}{\Delta x}\right)_c < \left(\frac{\Delta V}{\Delta x}\right)_A < \left(\frac{\Delta V}{\Delta x}\right)_B$$

Q19.

The resistance of a wire at 0°C is 70.0 Ω. If temperature of the wire increases to 100° C, its resistance increases by 50 %. What is resistance of the wire at 120°C? (Ignore changes in the dimensions of the wire)

A) 112 Ω
B) 211 Ω
C) 101 Ω
D) 181 Ω
E) 150 Ω

Ans:

$$R(100°) = R(0°) \times 1.5 = 70 \times 1.5 = 105\ \Omega$$

$$\Delta R = R_0 + \alpha + \Delta T \Rightarrow \alpha = \frac{\Delta R}{R_0 \times \Delta T} = \frac{(105 - 70)}{70 \times (100 - 0)} = 0.005$$

$$R(120°) = R(0°)(1 + \alpha \times 120) = 70(1 + 0.005 \times 120) = 112\ \Omega$$

Q20.

A copper wire of cross sectional area 2.00×10^{-6} m^2 and length 4.00 m has a current of 2.00 A uniformly distributed across its area. How much electrical energy is transferred into thermal energy in 1.00 hour (resistivity of copper = 1.69×10^{-8} Ω.m)

A) 487 J
B) 319 J
C) 727 J
D) 559 J
E) 996 J

Ans:

$$\text{Electrical Energy} = P \times t = i^2 \times R \times t = \frac{i^2 \times \rho \times l}{A} \times 3600$$

$$= (2)^2 \times 1.69 \times 10^{-8} \times \frac{4}{2 \times 10^{-6}} \times 3600$$

$$= 487\ \text{J}$$
