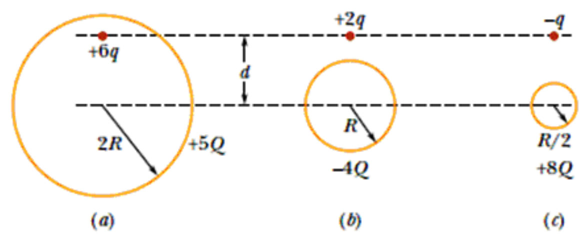
Q1.

Figure 1 shows three situations involving a charged particle and a uniformly charged spherical shell. The charges are given, and radii of the shells are indicated. Rank the situations according to the magnitude of the force on the particle due to the presence of the shell, **GREATEST FIRST**.

Figure 1



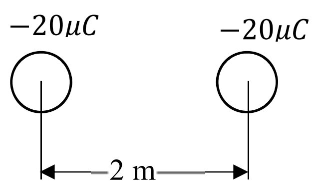
A) b and c tie, then a
B) a, b, c
C) b, a, c
D) c, a, b
E) b, c, a

Ans:

A

Q2.

Consider two identical conducting spheres each of radius 10 cm. Initially, sphere 1 has a charge of – 60 μC, and sphere 2 has a charge of + 20.0 μC. They are touched and then separated by a distance (center to center) of 2.0 m. What is the magnitude of the electrostatic force between them after separation?



A) 0.90 N
B) 2.7 N
C) 0.43 N
D) 0.37 N
E) 0.12 N

Ans:

Total charge on two spheres = –60 +40 = –40 μC

$$F = K\,\frac{q_1 q_2}{r^2}$$

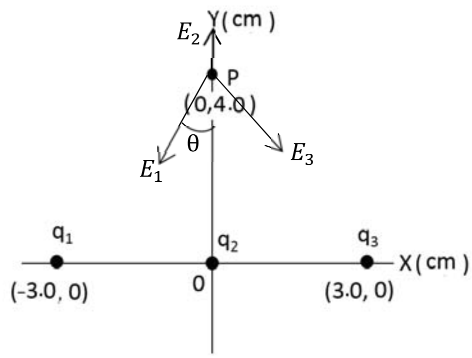
$$= \frac{9\times 10^{9}\times (20\times 10^{-6})^2}{2^2}$$

$$= \frac{9\times 10^{9}\times 4\times 10^{-10}}{4} = 0.9\ N$$

Q3.

Three charges $q_1 = q_3 = -2.0$ μC and $q_2 = +4.0$ μC are placed along the x-axis as shown in **Figure 2**. Find the magnitude of the resultant electric field at point P (0, 4.0 cm).

Figure 2



A) 1.1×10^7 N/C
B) 8.1×10^6 N/C
C) 3.4×10^7 N/C
D) 7.8×10^6 N/C
E) 2.9×10^7 N/C

Ans:

$$|\vec{E}_1| = |\vec{E}_3|$$

$$E_{net} = E_2 - 2E_1 cos\theta$$

$$= \frac{kq_2}{(4\times10^{-2})^2} - 2\frac{kq_1}{(5\times10^{-2})^2}\cdot\frac{4}{5}$$

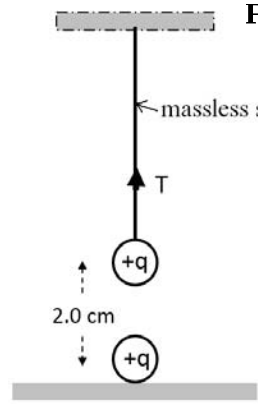
$$= \frac{9\times10^9\times4\times10^{-6}}{16\times10^{-4}} - \frac{2\times9\times10^9\times2\times10^{-6}}{25\times10^{-4}}\cdot\frac{4}{5}$$

$$= 2.25\times10^7 - 1.152\times10^7 = -1.098\times10^7\ N/C$$

Q4.

Two small identical insulating charged spheres each of mass 0.20 kg, one is fixed on the floor and the other is hanging vertically above the first with a massless string with a center to center distance of 2.0 cm, as shown in **Figure 3**. Charge q is uniformly distributed on each sphere. If the tension in the string is 0.52 N, find the value of q.

Figure 3



A) 2.5×10^{-7} C
B) 3.0×10^{-7} C
C) 1.3×10^{-7} C
D) 4.3×10^{-7} C
E) 8.7×10^{-7} C

Ans:

$$F_e + T = mg$$

$$\frac{Kq^2}{(2\times10^{-2})^2} + 0.52 = 0.2\times9.8$$

$$q^2 = \frac{1.44\times4\times10^{-4}}{9\times10^9} = 2.53\times10^{-7}C$$

Q5.

An electron moving with a velocity 8.00×10^6 m/s parallel to positive x-axis enters a region of uniform electric field parallel to the x-axis. Find the electric field needed to stop the electron momentarily at a distance of 40.0 cm after entering the field.

A) $456\ \hat{i}$ N/C
B) $456(-\hat{i})$N/C
C) $246\ \hat{i}$ N/C
D) $246(-\hat{i})$ N/C
E) $540\ \hat{i}$ N/C

Ans:

$$2ax = V^2 - U^2$$

$$2a(0.4) = 0 - (8 \times 10^6)^2$$

$$a = 8 \times 10^{13}\ m/s^2$$

$$F = eE \Rightarrow ma = eE$$

$$E = \frac{ma}{e} = \frac{9.1 \times 10^{-31} \times 8 \times 10^{13}}{1.6 \times 10^{-19}} = 455.5\ \ N/C$$

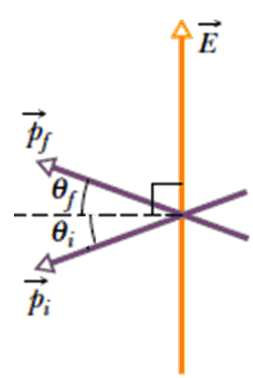
In the direction of motion of electron

Q6.

In **Figure 4** an electric dipole swings from an initial orientation $\theta_i = 25^o$ to a final orientation $\theta_f = 25^o$ in a uniform electric field of magnitude $E = 3.0 \times 10^6$ N/C. The electric dipole moment is 1.6×10^{-27} C.m. What is the change in the dipole's potential energy?

A) -4.1×10^{-21} J
B) $+3.1 \times 10^{-21}$ J
C) -3.1×10^{-21} J
D) $+4.1 \times 10^{-21}$ J
E) -5.2×10^{-21} J

Figure 4



Ans:

$$U = -\overline{P} \cdot \overline{E}$$

$$\Delta U = U_f - U_i = -PECos\theta_f - (-PECos\theta_i)$$

$$= -PE\left[Cos\theta_f - Cos\theta_i\right]$$

$$= -1.6 \times 10^{-27} \times 3 \times 10^6 [Cos65 - Cos115]$$

$$= -4.057 \times 10^{-21}\ \text{J}$$

Q7.

A charge Q is uniformly distributed throughout the volume of an insulating sphere of radius 6.0 cm. If the electric field at a distance of 6.0 cm from the center of the sphere is 4.2 $\times 10^7$ N/C, find the magnitude of electric field at a distance of 2.0 cm from the center of the sphere.

A) 1.4×10^7 N/C
B) 4.2×10^7 N/C
C) Zero
D) 9.2×10^7 N/C
E) 3.5×10^7 N/C

Ans:

Inside the sphere $E \propto r$

$$E_1 = kr_1$$

$$\frac{E_1}{E_2} = \frac{r_1}{r_2}$$

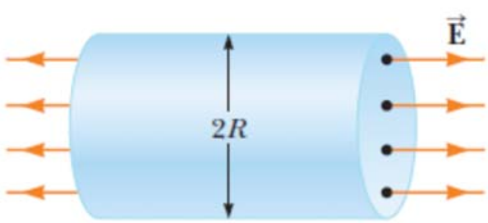
$$\frac{E_1}{4.2 \times 10^7} = \frac{2}{6}$$

$$E_1 = 1.4 \times 10^7\ N/C$$

Q8.

An unknown charge is located inside a cylindrical shell of radius R = 20.0 cm produces a uniform electric field of magnitude E = 42.0 N/C parallel to its axis, as shown in the **Figure 5**. Find the net charge inside the shell.

Figure 5



A) 9.34×10^{-11} C
B) 5.37×10^{-11} C
C) 7.38×10^{-11} C
D) 2.79×10^{-11} C
E) 3.76×10^{-11} C

Ans:

$$\int E \cdot dA = \frac{1}{\varepsilon_0} q_{enc}$$

$$\int_{S_1} E \cdot dA + \int_{S_2} E \cdot dA = \frac{1}{\varepsilon_0} q_{enc}$$

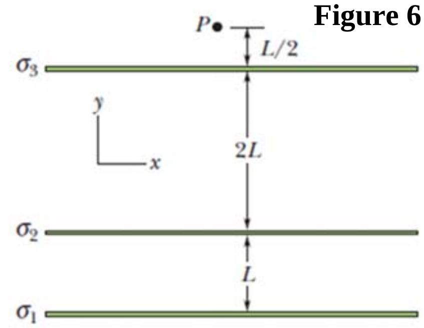
$$2EA = \frac{1}{\varepsilon_0} q_{enc}$$

$$q_{enc} = \varepsilon_0 (2 \times E \cdot A) = 8.85 \times 10^{-12} \times 2 \times 42 \times \pi (0.2)^2 = 9.34 \times 10^{-11} C$$

Q9.

Figure 6 shows, in cross section, three large non-conducting sheets on which charge is uniformly distributed. The surface charge densities are σ_1 = +4.0 μC/m^2 and σ_2 = −5.0 μC/m^2. Find the surface charge density σ_3 if the net electric field at point P is $7.2\times10^4(\hat{j})N/C$.

Figure 6



A) +2.3 μC/m
B) −2.3 μC/m
C) +3.7 μC/m
D) −3.7 μC/m
E) +9.0 μC/m

Ans:

$$E_{net} = E_1 + E_3 - E_2$$

$$= \frac{\sigma_1}{2\epsilon_0} + \frac{\sigma_3}{2\epsilon_0} - \frac{\sigma_2}{2\epsilon_0}$$

$$2\epsilon_0(7.2\times10^4) = 4\times10^{-6} + \sigma_3 - 5\times10^{-6}$$

$$\sigma_3 = 2\times8.85\times10^{-12}(7.2\times10^4) + 1\times10^{-6}$$

$$\sigma_3 = 1.2744\times10^{-6} + 1\times10^{-6} = 2.27\times10^{-6}\ C/m$$

Q10.

When a point charge q = +5.0 μC is placed at the center of a thick conducting spherical shell, the net charge on the outer surface of the shell is +15 μC. If the inner radius of the shell is 6.0 cm find the surface charge density on the inner surface of the shell.

A) -1.1×10^{-4} C/m^2
B) $+1.1\times10^{-4}$ C/m^2
C) $+3.3\times10^{-3}$ C/m^2
D) -2.7×10^{-4} C/m^2
E) -9.4×10^{-4} C/m^2

Ans:

$$\sigma = \frac{Charge}{area}$$

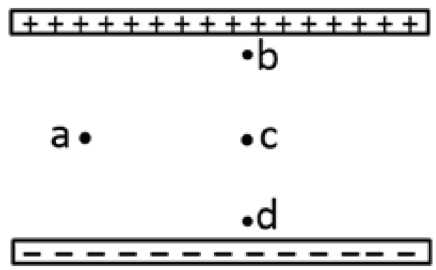
$$\sigma = \frac{-5\times10^{-6}}{4\pi R^2}$$

$$\sigma = \frac{-5\times10^{-6}}{4\pi\times(0.06)^2} = -1.1\times10^{-4}\ C/m^2$$

Q11.

Four points a, b, c and d are marked in a uniform electric field generated by oppositely charged plates as shown in **Figure 7**. An electron is transferred from its initial position 'a' to new final positions b, c and d. Rank the change in electrical potential energy of the electron at new positions b, c and d, **MOST POSITIVE FIRST**.

Figure 7



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

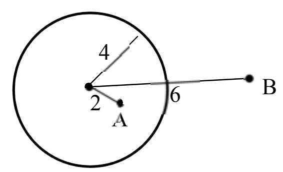
Ans:

A

Q12.

A solid conducting sphere of radius 4.0 cm has a charge of 50 nC distributed uniformly over its surface. A and B are points at a distance of 2.0 cm and 6.0 cm from the center of the sphere, respectively. What is the electric potential difference between points A and B ($V_A - V_B$)?

A) 3.8×10^3 V
B) 1.5×10^4 V
C) 7.5×10^3 V
D) 4.3×10^4 V
E) 5.4×10^3 V



Ans:

Potential at point 'A' is same as on the surface of the sphere

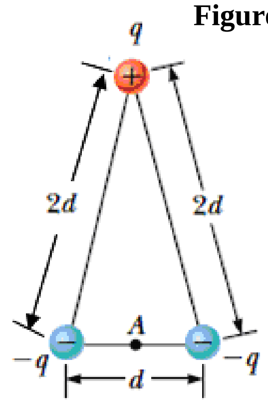
$$V_A = \frac{KQ}{0.04}; \ \ V_B = \frac{KQ}{0.06}$$

$$V_A - V_B = KQ\left(\frac{1}{0.04} - \frac{1}{0.06}\right) = 9 \times 10^9 \times 50 \times 10^{-9}\left(\frac{25}{3}\right) = 3750\ V$$

Q13.

The three charged particles shown in **Figure 8** are at the vertices of a triangle (where d = 2.00 cm). If q = 7.00 μC, calculate the electric potential at point A, the midpoint of the base.

Figure 8



A) −1.10 × 10⁷ V
B) −3.95 × 10⁷ V
C) −8.16 × 10⁷ V
D) −5.26 × 10⁷ V
E) +2.39 × 10⁷ V

Ans:

First the distance r from +q to point A

$$\mathbf{4}d^2 = \frac{d^2}{4} + r^2$$

$$4d^2 - \frac{d^2}{4} = r^2 \Rightarrow r^2 = \frac{15}{4}d^2$$

$$V_A = \frac{-Kq}{\frac{d}{2}} - \frac{Kq}{\frac{d}{2}} + \frac{Kq}{\frac{\sqrt{15}}{2}d}$$

$$V_A = \frac{2kq}{d}\left[-1 - 1 + \frac{1}{\sqrt{15}}\right] = \frac{2 \times 9 \times 10^9 \times 7 \times 10^{-6}}{0.02}\left(-2 + \frac{1}{\sqrt{15}}\right)$$

$$V_A = -1.097 \times 10^7 V$$

Q14.

An electron is projected with an initial kinetic energy of 1.0×10^{-19} J directly towards a proton that is fixed in place. If the electron is initially far away from the proton, at what distance from the proton the kinetic energy of the electron is twice its initial kinetic energy? (Assume potential zero at infinity)

A) 2.3×10^{-9} m
B) 5.2×10^{-9} m
C) 1.1×10^{-9} m
D) 7.3×10^{-9} m
E) 3.7×10^{-9} m

Ans:

$\Delta K \cdot E = \Delta U$

Change in K.E is same as initial K.E

$1 \times 10^{-19} = U_f - U_i$

$$= \frac{Kq_1q_2}{x} - 0 \Rightarrow x = \frac{9 \times 10^9 \times (1.6 \times 10^{-19})^2}{1 \times 10^{-19}} = 2.304 \times 10^{-19}\, m$$

Q15.

A parallel plate capacitor C = 100 μF is charged to a potential difference of 100 V and then disconnected from the battery. If you fill the space between the plates with dielectric κ = 10, which of the following statements is **CORRECT**?

A) The voltage across the capacitor is reduced to 10 V.
B) The voltage across the capacitor remains 100 V.
C) The charge stored by the capacitor increases by a factor of 10.
D) The new capacitance of the capacitor is 10 μF.
E) The charge stored by the capacitor decreases by a factor of 10.

Ans:

$A; \quad \theta - remainst\ constant$

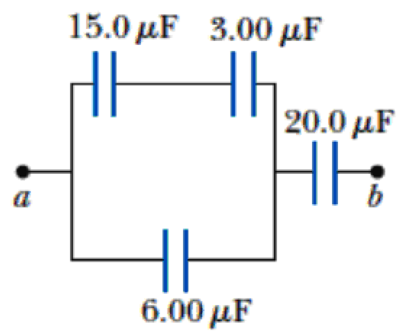
$$C' = 10\,C = 1000\,\mu F$$

$$V = \frac{Q}{C} \Longrightarrow C' = \frac{V}{10}$$

Q16.

Four capacitors are connected as shown in **Figure 9**. Find the equivalent capacitance between points a and b.

Figure 9



A) 5.96 μF
B) 20.5 μF
C) 26.0 μF
D) 3.56 μF
E) 1.03 μF

Ans:

$$\frac{1}{C_{12}} = \frac{1}{15} + \frac{1}{3} = \frac{1+5}{15} = \frac{6}{15}$$

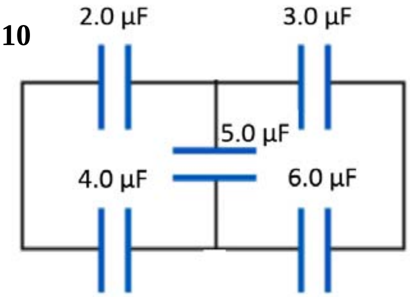
$$C_{123} = \frac{15}{6} + 6 = \frac{51}{6}$$

$$C_{1234} = \frac{1}{\frac{51}{6}} + \frac{1}{20} = \frac{6}{51} + \frac{1}{20} = 5.96\,\mu F$$

Q17.

In the circuit shown in **Figure 10** if the charge stored by the 2.0 μF capacitor is 40 μC, find the voltage across the 5.0 μF capacitor.

Figure 10



A) 30 V
B) 20 V
C) 10 V
D) 40 V
E) 45 V

Ans:

$$Q_2 = Q_4 = 40\ \mu C$$

$$Q_{24} = C_{24} V_{24}$$

$$\frac{1}{C_{24}} = \frac{1}{2} + \frac{1}{4} = \frac{3}{4} \Rightarrow C_{24} = \frac{4}{3} \mu F$$

voltage across 5 μF is same as across series combination of 2 μF and 4 μF capacitors

$$Q_2 = C_{24} V \Longrightarrow 40 \times 10^{-6} = \frac{4}{3} \times 10^{-6} \cdot V$$

$$V = \frac{40 \times 3}{4} = 30\ V$$

Q18.

Initially an air filled 10.0 mF parallel plate capacitor is fully charged by connecting it to a 200 V battery. Then, the battery is disconnected. Now if we double the separation between the plates (without touching the plates), what is the new energy stored in the capacitor?

A) 400 J
B) 100 J
C) 800 J
D) 200 J
E) 600 J

Ans:

$$Q = CV = 10 \times 10^{-3} \times 200 = 2C$$

$$C = \varepsilon_0 \frac{A}{d} \quad and \quad C' = \varepsilon_0 \frac{A}{2d} \Longrightarrow C' = \frac{1}{2} C$$

$$E = \frac{1}{2} \frac{Q^2}{C} \quad E' = \frac{1}{2} \frac{Q^2}{C/2}$$

$$E' = 2 \cdot \frac{1}{2} \frac{Q^2}{C} = \frac{2^2}{10 \times 10^{-3}} = 400\ \text{J}$$

Q19.

A high voltage copper transmission line with a diameter of 2.0 cm and a length of 200 km carries a steady current of 1.0×10^3 A. If copper has a free charge density of 8.5×10^{28} electrons/m^3, over what time interval does one electron travel the full length of the line?

A) 8.5×10^8 s
B) 3.5×10^8 s
C) 9.7×10^8 s
D) 2.6×10^8 s
E) 7.7×10^8 s

Ans:

$$I = AJ = neAv_d$$

$$v_d = \frac{I}{neA} = \frac{10^3}{8.5\times10^{28}\times\pi(.01)^2\times1.6\times10^{-19}}$$

$$v_d = 2.3405\times10^{-4}\,m/s$$

$$x = v_d \cdot t$$

$$t = \frac{200\times10^3}{2.3405\times10^{-4}} = 8.545\times10^8 s$$

Q20.

Two cylindrical wires A and B made of the same material and having the same lengths are connected across the same voltage source. If the power dissipated in wire A is three times the power dissipated in wire B, what is the ratio of their diameters d_A/d_B?

A) 1.7
B) 3.0
C) 4.2
D) 3.5
E) 9.0

Ans:

$$P = \frac{V^2}{R} = \frac{V^2}{\rho\frac{l}{A}} = \frac{V^2 A}{\rho l} = \frac{V^2\frac{\pi}{4}d^2}{\rho l}$$

$$P \propto d^2$$

$$\frac{P_A}{P_B} = \frac{d_A^2}{d_B^2} \Longrightarrow \frac{d_A}{d_B} = \sqrt{\frac{P_A}{P_B}} = \sqrt{\frac{3P_B}{P_B}} = \sqrt{3} = 1.7$$