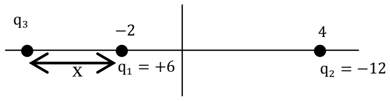
Q1.

Two charges $q_1 = +6.00\ \mu C$ and $q_2 = -12.0\ \mu C$ are placed at (−2.00 cm, 0) and (4.00 cm, 0), respectively. If a third unknown charge q_3 is to be located such that the net force on it from charges q_1 and q_2 is zero, what must be the coordinates of q_3?

A) (−16.5 cm, 0)
B) (−14.5 cm, 0)
C) (2.49 cm, 0)
D) (0, 0)
E) (−6.50 cm, 0)



Ans:

$$F_{13} = F_{23}$$

$$\frac{Kq_1q_3}{x^2} = \frac{Kq_2q_3}{(x+6)^2}$$

$$\frac{q_1q_3}{x^2} = \frac{q_2q_3}{(x+6)^2}$$

$$\frac{6\times10^{-6}}{x^2} = \frac{12\times10^{-6}}{(x+6)^2} \Rightarrow \frac{1}{x^2} = \frac{2}{(x+6)^2}$$

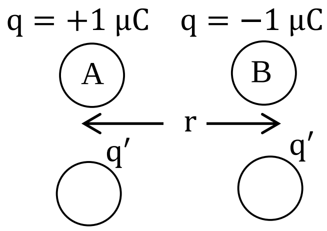
$$\Rightarrow x^2 + 12x + 36 = 2x^2$$

$$x^2 - 12x - 36 = 0 \Rightarrow x = 6 \pm 6\sqrt{2} = 6 + 6\sqrt{2} = 14.48 \therefore \text{Coordinate } (-16.48, 0)$$

Q2.

Two small metallic spheres A and B carry + 1.00 μC and −1.00 μC of charge, respectively, held fixed at a certain distance without touching each other. How many electrons must be transferred from one sphere to the other to reduce the force of attraction between them by a factor of four?

A) 3.13×10^{12} from B to A
B) 3.13×10^{12} from A to B
C) 7.23×10^{12} from B to A
D) 7.23×10^{12} from A to B
E) 1.71×10^{11} from B to A



Ans:

$$F = \frac{kqq}{r^2};\ F' = \frac{kq'q'}{r^2}$$

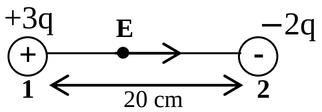
$$\frac{F}{4} = \frac{kq'q'}{r^2} \Rightarrow \frac{1}{4}\cdot k\frac{qq}{r^2} = k\frac{q'q'}{r^2} \Rightarrow \frac{q^2}{4} = (q')^2$$

$$q' = \frac{q}{2} \Rightarrow q' = 0.5\mu C = \frac{0.5\times10^{-6}}{1.6\times10^{-9}} = 3.13\times10^{12}$$

Q3.

The electric field midway between two charges of +3q and −2q is 98.0 N/C and the distance between the charges is 20.0 cm. What is the value of the charge q?

A) 2.18×10^{-11} C
B) 4.67×10^{-6} C
C) 1.09×10^{-10} C
D) 1.05×10^{-5} C
E) 5.73×10^{-11} C



Ans:

$$E = E_1 + E_2$$

$$98 = \frac{K(3q)}{(0.1)^2} + \frac{K(2q)}{(0.1)^2}$$

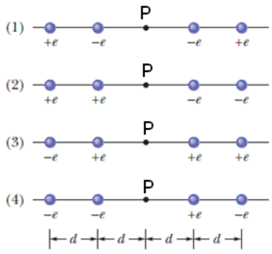
$$98 = \frac{K.5q}{0.01} \Rightarrow q = \frac{98 \times 0.01}{5 \times 9 \times 10^9} = 2.177 \times 10^{-11} C$$

Q4.

FIGURE 1 shows four situations in which four charged particles are evenly spaced to the left and right of a central point P. The charge values are indicated. Rank the situations according to the magnitude of the net electric field at the central point, **GREATEST FIRST**.

A) 2, 4, 3, 1
B) 4, 3, then 1 and 2 tie
C) 3 and 4 tie, then 1 and 2 tie
D) 4, 3, 1, 2
E) 1,4, 3, 2

Figure 1



Ans:

A

Q5.

At some instant the velocity components of an electron moving between two parallel plates are $v_x = 1.5\times10^5\, m/s$ and $v_y = 3.0\times10^5\, m/s$. The uniform electric field between the plates is $\vec{E} = (1.2\,\hat{j})N/C$. In unit vector notation find the velocity of the electron after 2.0 μs. (ignore the effect of gravity)

A) $\left(1.5\times10^5\,\hat{i} - 1.2\times10^5\,\hat{j}\right)m/s$
B) $\left(1.5\times10^5\,\hat{i} + 7.2\times10^5\,\hat{j}\right)m/s$
C) $\left(5.7\times10^5\,\hat{i} - 1.2\times10^5\,\hat{j}\right)m/s$
D) $\left(1.2\times10^5\,\hat{i} - 1.2\times10^5\,\hat{j}\right)m/s$
E) $\left(1.5\times10^5\,\hat{i} + 3.0\times10^5\,\hat{j}\right)m/s$

Ans:

$v_x = 1.5\times10^5\, m/s$ will remain the same

Electric filed is upward therefoe electron will deaccelerate

$$a_y = \frac{qE}{m_e} = \frac{1.6\times10^{-19}\times1.2}{9.11\times10^{-31}} = 2.1075\times10^{11}\, m/s^2$$

$$V = U + at$$

$$V = 3\times10^5 - 2.1075\times10^{11}(2\times10^{-6}) = -121514.8 = 1.215\times10^5(-\hat{j})\ m/s$$

Q6.

An electric dipole is placed in a uniform electric field $\vec{E} = (4000\,\hat{i})N/C$. What is the change in dipole's potential energy if the initial and the final electric dipole moments $\vec{p}_i$ and $\vec{p}_f$ respectively, are given by

$\vec{p}_i = (3.72\times10^{-30}\,\hat{i} + 4.96\times10^{-30}\,\hat{j})\, C.m$

$\vec{p}_f = (6.20\times10^{-30}\,\hat{i})\, C.m$

A) -9.92×10^{-27} J
B) $+1.45\times10^{-27}$ J
C) $+3.97\times10^{-26}$ J
D) $+9.92\times10^{-27}$ J
E) -3.97×10^{-26} J

Ans:

$$U = -P\cdot E$$

$$\Delta U = U_f - U_i = -\bar{P}_f\cdot\bar{E} - (-\bar{P}_i\cdot\bar{E})$$

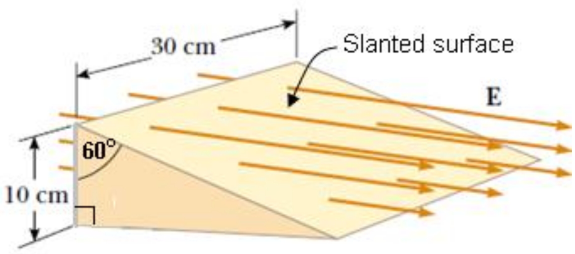
$$= -[3.72\times10^{-30}\times4000] + [6.2\times10^{-30}\times4000]$$

$$= +1.488\times10^{-26} - 2.48\times10^{-26} = -9.92\times10^{-27} J$$

Q7.

Consider a closed triangular box resting within a horizontal electric field of magnitude E = 7.80 × 10^4 N/C, as shown in **FIGURE 2**. Calculate the electric flux through the slanted surface.

Figure 2



A) 2.34 × 10^3 N.m^2/C
B) 1.17 × 10^3 N.m^2/C
C) 4.34 × 10^3 N.m^2/C
D) 7.34 × 10^3 N.m^2/C
E) 1.65 × 10^3 N.m^2/C

Ans:

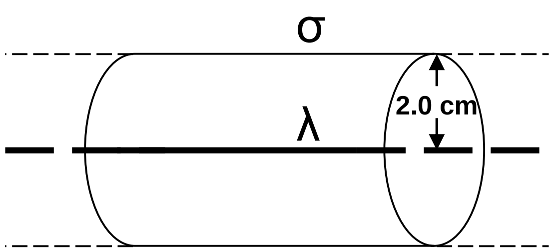
$$\Phi = \bar{E}\cdot\bar{A} = E\,A\,cos0 = EA$$

$$= 7.8\times10^4\times0.1\times0.3 = 2340\;N.m^2/C$$

Q8.

A long, straight wire has a linear charge density λ = −7.8 nC/m. The wire is enclosed by a coaxial, thin-walled non-conducting cylindrical shell of radius 2.0 cm, as shown **FIGURE 3**. Find the surface charge density σ, on the outer surface of the shell that makes the net electric field zero outside the shell.

Figure 3



A) 6.21 × 10^{-8} C/m^2
B) 3.82 × 10^{-8} C/m^2
C) 1.24 × 10^{-8} C/m^2
D) 9.37 × 10^{-8} C/m^2
E) 5.31 × 10^{-8} C/m^2

Ans:

$$\mathrm{E}_{line} = \mathrm{E}_{Shell}$$

$$\mathrm{E}_{line} = \frac{\lambda}{2\pi\varepsilon_o r}$$

For Shell

$$\int \bar{\mathrm{E}}_{shell}\,d\bar{a} = \frac{1}{\varepsilon_o}q_{enc}$$

$$\bar{\mathrm{E}}_{shell}2\pi r\cdot l = \frac{1}{\varepsilon_o}(\sigma\cdot2\pi rl)$$

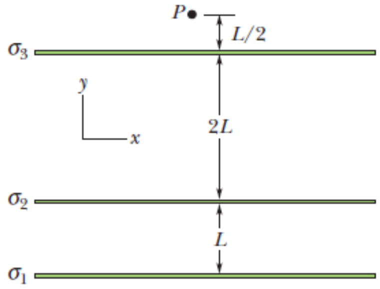
$$E_{shell} = \frac{\sigma}{\varepsilon_o}$$

$$\frac{\sigma}{\varepsilon_o} = \frac{\lambda}{2\pi\varepsilon_o r} \Longrightarrow \sigma = \frac{7.8\times10^{-9}}{2\pi\times0.02} = 6.207\times10^{-8}\;C/m^2$$

Q9.

FIGURE 4 shows, in cross section, three infinity large non-conducting sheets with uniform charge densities σ_1 = +3.0 μC/m^2, σ_2 = +5.0 μC/m^2, and σ_3 = − 7.0 μC/m^2, and L = 2.5 cm. In unit vector notation, what is the net electric field at point P?

Figure 4



A) $(+5.6\times10^{4}\,\hat{j})N/C$
B) $(-6.8\times10^{5}\,\hat{j})N/C$
C) $(-5.6\times10^{4}\,\hat{j})N/C$
D) $(+6.8\times10^{5}\,\hat{j})N/C$
E) $(-1.1\times10^{5}\,\hat{j})N/C$

Ans:

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

$$= \frac{\sigma_1}{2\varepsilon_0} + \frac{\sigma_2}{2\varepsilon_0} - \frac{\sigma_3}{2\varepsilon_0}$$

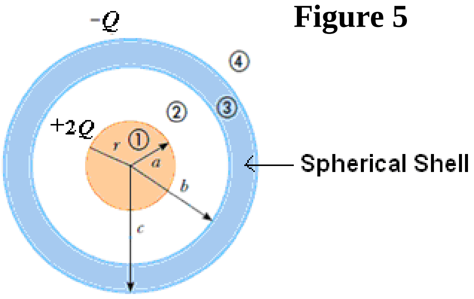
$$= \frac{1}{2\varepsilon_0}[\sigma_1 + \sigma_2 - \sigma_3] = \frac{1}{2\varepsilon_0}[3 + 5 - 7] \times 10^{-6}$$

$$= \frac{1}{2\varepsilon_0} \times 10^{-6} = 5.6497 \times 10^4\ N/C\ \hat{j}$$

Q10.

A solid conducting sphere of radius a carries a net charge of +2*Q*. A conducting spherical shell of inner radius b and outer radius c is concentric with the solid sphere and carries a net charge −*Q* as shown in **FIGURE 5**. Arrange the electric field in four regions labeled 1, 2, 3, and 4, **GREATEST FIRST**.

Figure 5



A) 2, 4 then 1 and 3 tie
B) 1, 2, 3, 4
C) 2, 3, 4, 1
D) 1, 3, 2, 4
E) 4 and 2 tie, then 3, 1

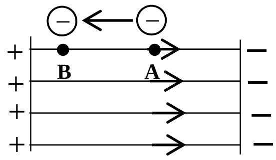
Ans:

A

Q11.

Work done by the ***electric field*** in moving a charge q = −4.0 mC from point A to point B is +20 mJ. What is the potential difference between points A and B, i.e. $V_B - V_A$=?

A) +5.0 V
B) −5.0 V
C) −20 V
D) +20 V
E) −4.0 V



Ans:

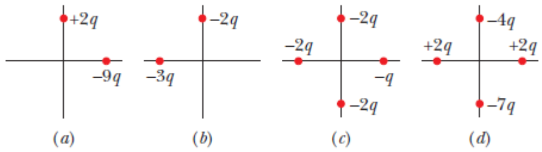
$$\Delta V = -\frac{W}{q}$$

$$= \frac{-20 \times 10^{-3}}{-4 \times 10^{-3}} = 5\ V$$

Q12.

FIGURE 6 shows four arrangements of charged particles (where $q > 0$), all located at the same distance from the origin. Rank the situations according to the net electric potential at the origin, **MOST POSITIVE FIRST** (take the potential to be zero at infinity).

Figure 6



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

Ans:

A

Q13.

The electric potential in xy plane is given by $V = \left(2.0\,x^2 - 3.0\,y^2\right)$, where V is in volts and x and y are in meters. In unit vector notation, what is the electric field at point $\left(5.0\,m, 7.0\,m\right)$?

A) $\left(-20\hat{i} + 42\hat{j}\right)V/m$
B) $\left(+20\hat{i} - 42\hat{j}\right)V/m$
C) $\left(-50\hat{i} + 95\hat{j}\right)V/m$
D) $\left(-20\hat{i} + 95\hat{j}\right)V/m$
E) $\left(-30\hat{i} + 42\hat{j}\right)V/m$

Ans:

$$E_x = -\frac{dv}{dx} = -4x = -4(5) = -20\hat{\imath}$$

$$E_y = -\frac{dv}{dy} = -[-6y] = 6(7) = 42\hat{\jmath}$$

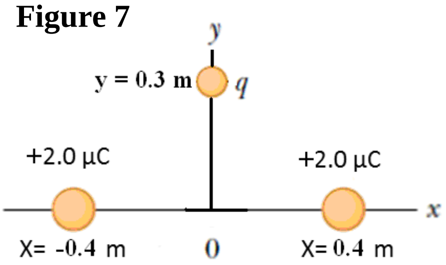
$$= (-20\hat{\imath} + 42\hat{\jmath})\ N/C\ \ or\ V/m$$

Q14.

Two charges each of +2.0 μC are fixed along the x axis at x = −0.40 m and x = +0.40 m, as shown in **FIGURE 7**. A third charge q = +4.0 μC is released from rest from y = 0.3 m. Find the maximum kinetic energy attained by the third charge after the release.

A) 0.29 J
B) 0.54 J
C) 0.24 J
D) 0.73 J
E) 0.13 J

Figure 7



Ans:

$$\Delta U = \frac{k2 \times 10^{-6} \times 4 \times 10^{-6}}{0.5} + \frac{k \times 2 \times 10^{-6} \times 4 \times 10^{-6}}{0.5}$$

$$\frac{1}{2}mv^2 = \frac{2 \times 9 \times 10^9 \times 8 \times 10^{-12}}{0.5} = 0.288\,J$$

Q15.

An air filled parallel plate capacitor is charged to a potential difference of 10 V and then disconnected from the battery. Now if you fill the space between the plates with dielectric material of k = 2, which of the following statements is correct

A) The voltage across the capacitor reduces to 5.0 V.
B) The voltage across the capacitor remains at 10 V.
C) The capacitance remains the same.
D) The energy stored by the capacitor remains the same.
E) The charge stored reduces to half of its initial value.

Ans:

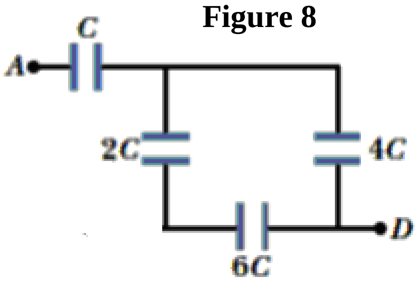
A

Q16.

If C = 50.0 μF in **FIGURE 8**, what is the equivalent capacitance between points A and D?

A) 42.3 μF
B) 325 μF
C) 59.1 μF
D) 28.3 μF
E) 13.7 μF

Figure 8



Ans:

$$\frac{1}{C_{12}} = \frac{1}{2C} + \frac{1}{6C} = \frac{3+1}{6C}$$

$$\frac{1}{C_{12}} = \frac{4}{6C} \Longrightarrow C_{12} = \frac{3}{2}\,C$$

$$C_{123} = \frac{3}{2}C + 4C$$

$$C_{123} = \frac{11}{2}C$$

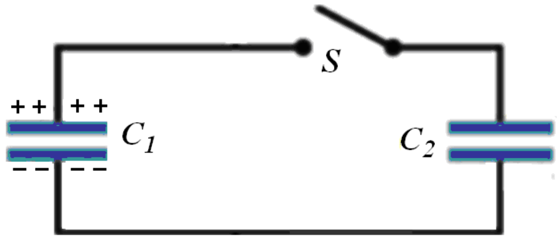
$$C_{1234} = \frac{1}{C} + \frac{1}{11\,\frac{C}{2}} = \frac{1}{C} + \frac{2}{11C} = \frac{11+2}{11\,C}$$

$$C_{1234} = \frac{11}{13}C = \frac{11}{13} \times 50\mu F = 42.3\mu F$$

Q17.

In **FIGURE 9**, the capacitors C_1 = 2.0 μF and C_2 = 4.0 μF. The capacitor C_1 is charged to a potential difference of 10 V and C_2 is initially uncharged. After closing the switch *S*, find the total energy stored by the two capacitors.

Figure 9



A) 3.3×10^{-5} J
B) 1.0×10^{-4} J
C) 3.0×10^{-4} J
D) 1.5×10^{-5} J
E) 5.0×10^{-5} J

Ans:

$$Q_1 = C_1 V = 2 \times 10^{-6} \times 10 = 20\mu C$$

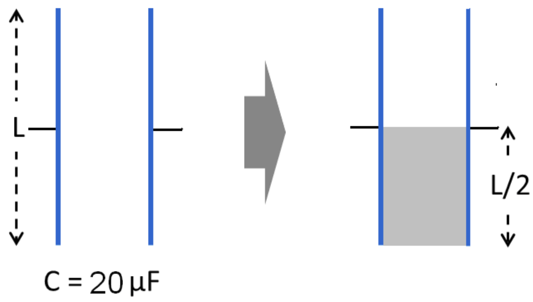
$$Q_T = Q_1 = 20\mu C$$

$$E_T = \frac{1}{2}\frac{q^2}{C_T} = \frac{1}{2}\frac{(20 \times 10^{-6})^2}{6 \times 10^{-6}} = 3.33 \times 10^{-5} J$$

Q18.

An air filled parallel plate capacitor has capacitance of C = 20.0 μF. If lower half of the capacitor is filled with dielectric material κ = 10, as shown in **FIGURE 10**, find the capacitance of the new capacitor.

Figure 10



A) 110 μF
B) 9.09 μF
C) 440 μF
D) 73.5 μF
E) 173 μF

Ans:

$$C = 20\mu F = \varepsilon_0 A/d$$

$$C_T = C_1 + C_2$$

$$= \varepsilon_0 \frac{A/2}{d} + k\varepsilon_0 \frac{A/2}{d}$$

$$= \frac{1}{2}\varepsilon_0 \frac{A}{d} + \frac{k}{2}\varepsilon_0 \frac{A}{d}$$

$$= \frac{1}{2} \times 20 + \frac{10}{2}(20) = 10 + 100 = 110\mu F$$

Q19.

When 115 V is applied across a 10 m long wire with a 0.30 mm radius, the magnitude of the current density is 1.4×10^{8} A/m^{2}. Find the resistivity of the wire.

A) 8.21×10^{-8} Ω.m
B) 9.33×10^{-7} Ω.m
C) 5.72×10^{-8} Ω.m
D) 2.38×10^{-8} Ω.m
E) 4.16×10^{-8} Ω.m

Ans:

$$V = IR$$

$$V = I \cdot \rho \frac{l}{A}$$

$$V = \frac{I}{A} \cdot \rho \cdot l$$

$$V = J \cdot \rho \cdot l$$

$$115 = 1.4 \times 10^{8} \times \rho \times 10 \Longrightarrow \rho = \frac{115}{1.4 \times 10^{8} \times 10} = 8.214 \times 10^{-8} \Omega \cdot m$$

Q20.

A heater element with potential difference of 400 V across it transfers electrical energy to thermal energy at the rate of 3000 W. At what rate the heater will transfer the energy if it is connected across a potential difference 300 V.

A) 1.69 kW
B) 2.25 kW
C) 3.57 kW
D) 1.13 kW
E) 2.92 kW

Ans:

$$P = \frac{V^2}{R} \Rightarrow R = \frac{(400)^2}{3000} = 53.333$$

$$P' = \frac{(300)^2}{53.33} = 1.6875 \times 10^{3} W = 1.69\ kW$$
