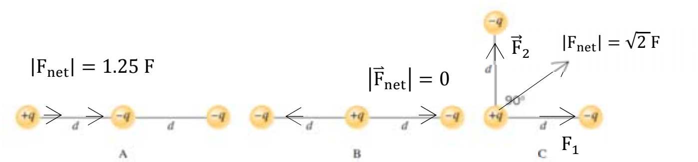
Q1.

FIGURE 1 shows three point charges arranged in three different ways. The charges are +*q*, -*q*, and -*q*. Rank the arrangements according to the magnitude of the net electrostatic force that acts on the positive charge, Smallest first.

Figure 1



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

Ans:

A

Q2.

A charged spherical water droplet of radius 0.018 mm remains stationary in the air. If the electric field of Earth is directed downward and of magnitude 150 N/C. Find the number of electrons making the net charge of the water droplet. [Ignore air friction]

A) 1.0×10^7
B) 2.3×10^7
C) 2.6×10^{19}
D) 1.6×10^7
E) 1.6×10^{19}

Ans:

$$qE = mg \Rightarrow q = \frac{mg}{E} \Rightarrow q = \frac{\rho V g}{E}$$

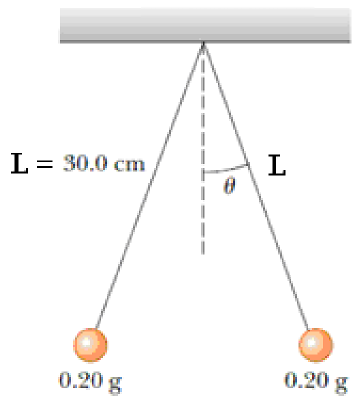
$$\Rightarrow q = \frac{(10)^3\left(\frac{4}{3}\pi(0.018 \times 10^{-3})\right)^3 (9.8)}{E}$$

$$\Rightarrow \#\, of electrons = \frac{q}{1.6 \times 10^{-19}} \cong 1 \times 10^7\; electrons$$

Q3.

Two small identical metallic spheres, each of mass m = 0.20 g, are suspended as pendulum by light strings as shown in **FIGURE 2**. The spheres are given the same electric charge q, and it is found that they come to equilibrium when each string is at angle of θ = 5° with the vertical. If each string is of length L = 30.0 cm, Find the magnitude of the charge on each sphere? [Ignore air friction]

Figure 2



A) 7.2 nC
B) 3.2 nC
C) 4.9 nC
D) 8.4 nC
E) 8.8 nC

Ans:

$$r = 2L sin\theta = 0.0523\ m$$

$$vertical \Rightarrow T = \frac{mg}{\cos 5°} = 1.967 \times 10^{-3}\ N$$

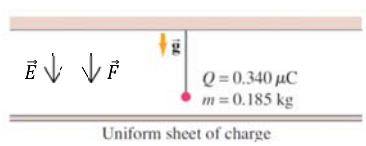
$$Horizontal \Rightarrow T = sin5° = \frac{kq^2}{r^2}$$

$$\Rightarrow q = \sqrt{\frac{r^2 T sin(5)}{k}} = 7.2 \times 10^{-9} C$$

Q4.

FIGURE 3 shows a point charge of mass 0.185 kg, and net charge +0.340 μC, hangs at rest at the end of an insulating cord above a large horizontal sheet of uniform charge distribution charge. If the tension in the cord is measured to be 5.18 N, then calculate the magnitude and direction of the electric field due to the sheet of charge.

Figure 3



A) 9.90×10^6 N/C in the downward direction
B) 9.90×10^6 N/C in the upward direction
C) 15.2×10^6 N/C in the downward direction
D) 15.2×10^6 N/C in the upward direction
E) 3.40×10^6 N/C down ward direction

Ans:

$$\sum F = 0$$

$$+T - mg - qE = 0$$

$$E = \frac{T - mg}{q} = \frac{5.18 - (0.185)(9.8)}{0.34 \times 10^{-6}} = 9.90 \times 10^6\ N/C\ \ downward$$

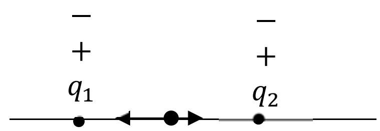
Q5.

Two point particles, with charges of q_1 and q_2, are placed a distance r apart. The electric field is zero at a point P somewhere between the particles on the line segment connecting them. Only one statement is CORRECT.

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

Ans:

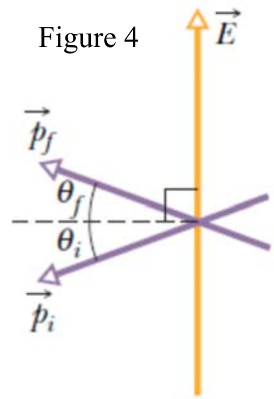
A



Q6.

In **FIGURE 4**, an electric dipole swings from an initial orientation i (θ_i =20.0°) to a final orientation f (θ_f =20.0°) in a uniform external electric field of magnitude 3.00 × 10^6 N/C. The electric dipole moment is 1.00 × 10^{-27} C.m. Find the work done by the electric field on the dipole.

Figure 4



A) +2.05 × 10^{-21} J
B) +3.28 × 10^{-21} J
C) +5.56 × 10^{-21} J
D) +2.21 × 10^{-21} J
E) −5.56 × 10^{-21} J

Ans:

$$W = -\Delta U = U_i - U_f$$

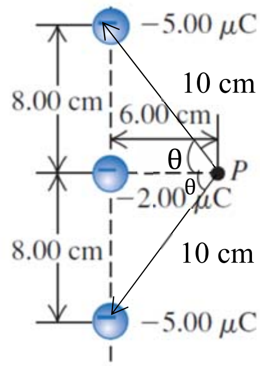
$$= -PEcos(110) + PEcos70$$

$$W = 2.05 \times 10^{-21}\ \text{J}$$

Q7.

Three negative point charges (−5.00 μC, −2.00 μC and −5.00 μC) lie along a line as in **FIGURE 5**. Find the electric field this combination of charges produces at point P which lies 6.00 cm from the −2.00 μC charge measured perpendicular to the line connecting the three charges.

Figure 5



A) -1.04×10^{7} N/C $\hat{i}$
B) -1.69×10^{7} N/C $\hat{i}$
C) -1.59×10^{7} N/C $\hat{i}$
D) $+1.04\times10^{7}$ N/C $\hat{i}$
E) $+1.69\times10^{7}$ N/C $\hat{i}$

Ans:

$$|E_{net}| = 9\times10^{9}\left[\frac{2\times10^{-6}}{(0.06)^2}+\frac{(2)(5\times10^{-6})}{(0.01)^2}\cos(80)\right]$$

$$|E_{net}| = 1.04\times10^{7}\ N/C\ Leftward\ direction$$

$$\tan\theta = \frac{8}{6} \Rightarrow \theta = 80°$$

$$\cos(80) = 0.164$$

Q8.

A point particle with charge $+q$ is at the center of a Gaussian surface in the form of a cube. The electric flux through the top and bottom faces of the cube, respectively.

A) $q/6\varepsilon_0$ and $q/6\varepsilon_0$
B) $q/4\varepsilon_0$ and $q/6\varepsilon_0$
C) $q/4\varepsilon_0$ and $q/4\varepsilon_0$
D) $q/6\varepsilon_0$ and $q/4\varepsilon_0$
E) $q/6\varepsilon_0$ and q/ε_0

Ans:

$$\Phi = \oint \vec{E}\cdot dA = \frac{q_{enc}}{\varepsilon_0}$$

$$6\Phi = \frac{q}{\varepsilon_0} \Rightarrow \Phi = \frac{q}{6\varepsilon_0}\ for\ each\ face\ of\ cube$$

Q9.

A very long uniform line of charge has charge per unit length 4.80 μC/m and lies along the *x*-axis. A second long uniform line of charge has charge per unit length –2.40 μC/m and is parallel to the *x*-axis at y = 0.400 m. Find the net electric field at point (0.000, 0.600 m).

A) -7.20×10^4 N/C $\hat{j}$
B) -3.65×10^4 N/C $\hat{j}$
C) -5.22×10^4 N/C $\hat{j}$
D) $+5.22\times10^4$ N/C $\hat{j}$
E) $+3.65\times10^4$ N/C $\hat{j}$

Ans:

$$\mathrm{E}_{net} = E_+ - E_-$$

$$= (2)(9\times10^9)\left[\frac{4.8\times10^{-6}}{0.6}\hat{j} - \frac{2.4\times10^{-6}}{0.2}\hat{j}\right]$$

$$= -7.2\ \times 10^4\frac{N}{C}\,\hat{j}$$

Q10.

The magnitude of electric field at a distance of 0.145 m from the surface of a solid insulating sphere with radius 0.355 m is 1750 N/C. Assuming the sphere's charge is uniformly distributed, find the magnitude of the electric field inside the sphere at a distance of 0.200 m from the center.

A) 1.96×10^3 N/C
B) 2.55×10^3 N/C
C) 1.12×10^3 N/C
D) 6.18×10^3 N/C
E) 0

Ans:

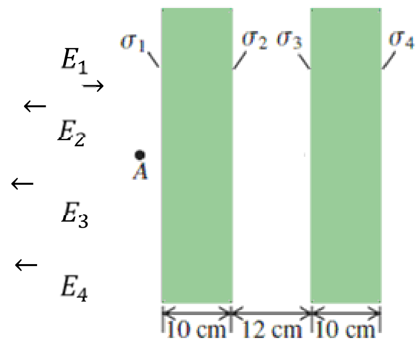
$$\mathrm{E}_{outside} = \frac{kQ}{r^2} \Longrightarrow Q = \frac{Er^2}{R} = 4.86\times10^{-8}\ C$$

$$\Rightarrow \mathrm{E}_{inside} = \frac{kQr}{R^3} = \frac{(9\times10^9)(4.86\times10^{-8})(0.2)}{(0.355)^3} = 1.96\times10^3\,\frac{N}{C}$$

Q11.

Two very large, nonconducting plastic sheets, each 10.0 cm thick, carry uniform charge densities $\sigma_1 = -6.00\ \mu C/m^2$, $\sigma_2 = +5.00\ \mu C/m^2$, $\sigma_3 = +2.00\ \mu C/m^2$, and $\sigma_4 = +4.00\ \mu C/m^2$ on their surfaces, as shown in **FIGURE 6**. Find the electric field at point *A* locatd 5.00 cm from the left face of the left-hand sheet.

Figure 6



A) 2.82×10^5 N/C to the left
B) 1.37×10^5 N/C to the left
C) 3.11×10^5 N/C to the left
D) 1.37×10^5 N/C to the right
E) 3.11×10^5 N/C to the right

Ans:

$$|E_{net}| = E_2 + E_3 + E_4 - E_1$$

$$= \frac{1}{2\varepsilon_0}[\sigma_2 + \sigma_3 + \sigma_4 - \sigma_1]$$

$$= 2.82 \times 10^5 \ \frac{N}{C}$$

$$\vec{E} = -2.82 \times 10^5 \ \frac{N}{C} \ \hat{\imath}$$

Q12.

A charge of -3.00 μC is fixed in place. From a horizontal distance of 0.0450 m, a particle of mass 7.20×10^{-3} kg and charge –8.00 μC is fired horizontally with an initial speed of 65.0 m/s directly toward the fixed charge. Find the distance the particle travel before its speed is zero. [Ignore air friction]

A) 0.0342 m
B) 0.0931 m
C) 0.0065 m
D) 0.00931 m
E) 0.0217 m

Ans:

$$\Delta K + \Delta U = 0$$

$$\frac{1}{2} m \left(V_f - V_i^2\right) + \frac{kq_1q_2}{r_f} - \frac{kq_1q_2}{r_i} = 0$$

$$\Longrightarrow r_f = 0.0108\, m$$

$$\Longrightarrow distance\ before\ speed\ zero = 0.0450 - 0.0108 = 0.0342\, m$$

Q13.

Determine the electric potential energy for the array of three charges **FIGURE 7**, relative to its value when the charges are infinitely far away and infinitely far apart.

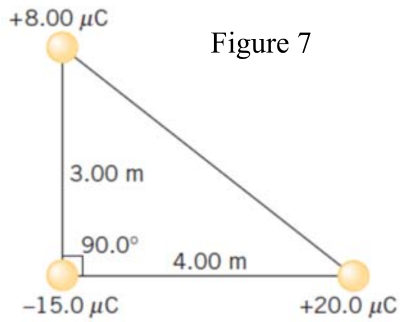


Figure 7

A) –0.747 J
B) –0.544 J
C) –0.891 J
D) –0.911 J
E) –0.501 J

Ans:

$$U = U_{12} + U_{23} + U_{13}$$

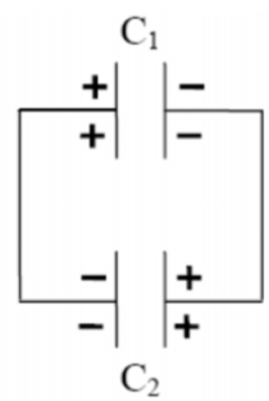
$$= 9 \times 10^9 \left[\frac{-8 \times 15 \times 10^{-12}}{3} \frac{-15 \times 20 \times 10^{-12}}{4} + \frac{8 \times 20 \times 10^{-12}}{5} \right]$$

$$= -0.747\, J$$

Q14.

When the two capacitors C1 and C2 are each charged to a 25.0 V, and then disconnected from the battery, they were found to store charges of 100 μC and 300 μC, respectively. The two capacitors are then connected with opposite polarity as shown in **FIGURE 8**. What then is the potential difference across the capacitors?

Figure 8



A) 12.5 V
B) 25.0 V
C) 57.1 V
D) 30.0 V
E) 50.0 V

Ans:

$$C_1 = \frac{100}{25} \mu C = 4 \mu F$$

$$C_2 = \frac{300}{25} \mu C = 12 \mu F$$

$$C_{eq} = C_1 + C_2 = 16\, \mu F$$

$$Q_{net} = 200\, \mu C = (C_1 + C_2)(V)$$

$$V = \frac{200 \times 10^{-6}}{16 \times 10^{-6}} = 12.5\, V$$

Q15.

The electric potential V in a region of space is given by

$$V(X,Y,Z) = A(x^2 - 3y^2 + z^2)$$

where A is a constant. If the work done by the field when a 1.50 μC test charge is moved from the point $(x, y, z) = (0\ m, 0\ m, 0.250\ m)$ to the origin is 6.00×10^{-5} J, then find the constant A.

A) 640 V/m^2
B) 450 V/m^2
C) 523 V/m^2
D) 357 V/m^2
E) 553 V/m^2

Ans:

$W = -q\Delta V$

$6 \times 10^{-5}\, J = -1.5 \times 10^{-6}\, A[0 - (0 - 0 + (0.25)^2]$

$\Rightarrow A = 640\ \dfrac{V}{m^2}$

Q16.

A parallel plate capacitor is connected to a battery. The capacitor has a certain energy density. While the battery is still connected to the capacitor, and the distance between the capacitor plates is doubled, the capacitor energy density

A) decreases by a factor of four.
B) increases by a factor of four.
C) increases by a factor of two.
D) decreases by a factor of two.
E) does not change.

Ans:

$u_i = \dfrac{1}{2}\varepsilon_0 E_i^2$

$d_f = 2di \longrightarrow E_f = \dfrac{1}{2}\ E_i$

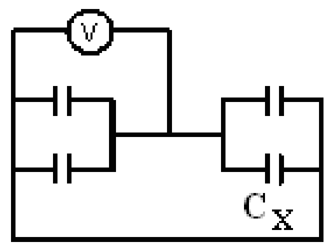
$u_f = \dfrac{1}{2}\varepsilon_0 \left(\dfrac{E_i}{2}\right)^2$

$u_f = \dfrac{1}{4}\left(\dfrac{1}{2}\varepsilon_0 E_i^2\right)$

Q17.

Each of the four capacitors shown in **FIGURE 9** is 500.0 μF. If the voltmeter reading is 1000V, then find the magnitude of the charge on the capacitor plate C_X.

Figure 9



A) 0.5000 C
B) 0.2000 C
C) 20.00 C
D) 50.00 C
E) 100.00 C

Ans:

All capacitors connected in parallel

$\Rightarrow Q = CV = 500 \times 10^{-6} \times 1000 = 0.5000\ C$

Q18.

A parallel plate capacitor filled with dielectric material between its plates has a capacitance of 50 pF. If the plate separation is 0.20 mm, find the maximum operating potential difference. (For the dielectric: dielectric constant = 6.0, dielectric strength = 150×10^{6} V/m)

A) 30 kV
B) 15 kV
C) 80 kV
D) 50 kV
E) 100 kV

Ans:

$$E = \frac{\Delta V}{\Delta d}$$

$$150 \times 10^{6} = \frac{\Delta V}{0.2 \times 10^{-3}} \Longrightarrow \Delta V = 30\ kV$$

Q19.

A 120 V potential difference is applied to a heater. There are 2.6×10^{19} electrons flowing through any cross section of the heater every second. How much energy is consumed by the heater every minute?

A) 3.0×10^4 J
B) 1.8×10^6 J
C) 1.8×10^4 J
D) 4.9×10^5 J
E) 2.5×10^5 J

Ans:

$$J = neV_g; \quad I = \frac{q}{t} = 4.16\ A$$

$$P = VI \ \Rightarrow E = VIt$$

$$\Rightarrow E = (120)(4.16)(60) = 3 \times 10^4\ J$$

Q20.

Copper has resistivity ρ_o at room temperature. Find the temperature at which copper has resistivity $2\rho_o$. Assume room temperature is 24.4 °C and temperature coefficient of resistivity
$\alpha_{cu} = 4.30 \times 10^{-3}\ K^{-1}$

A) 257 °C
B) 223 °C
C) 217 °C
D) 298 °C
E) 273 °C

Ans:

$$\rho = \rho_0[1 + \alpha(T - T_0)]$$

$$2\rho_0 = \rho_0[1 + 4.3 \times 10^{-3}(T - 297.4)]$$

$$T = 530\ K \ \Longrightarrow T = 257℃$$
