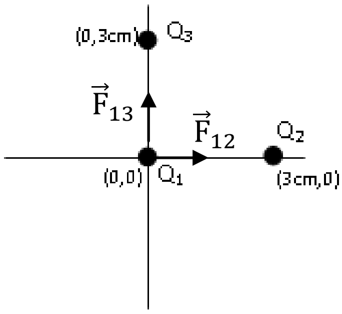
Q1.

Three fixed point charges are arranged as shown in **Figure 1**, where initially Q_1 = 10 μC, Q_2 = –15 μC, and Q_3 = –25 μC. If charges Q_2 and Q_3 are connected by a very thin conducting wire and then disconnected, the net electric force that now acts on charge Q_1 is:

A) $(+2000\,\hat{i} + 2000\,\hat{j})$ N
B) $(-2000\,\hat{i} - 2000\,\hat{j})$ N
C) $(+1500\,\hat{i} + 2500\,\hat{j})$ N
D) $(-1500\,\hat{i} - 2500\,\hat{j})$ N
E) $(+2000\,\hat{i} + 2500\,\hat{j})$ N



Ans:

$*$ The two forces are shown
$*$ if Q_2 and Q_3 are connected, their charges are equal.
$\Rightarrow F_{12} = F_{13}$
$\Rightarrow$ only choice A is possible.

Q2.

A particle of charge $q_1 = -14.4 \times 10^{-19}$ C is placed at the origin of the x-axis. Two other particles of charges q_2 and q_3 are placed at x_2 = 1 cm and x_3 = 3 cm, respectively, as shown in **Figure 2**. How many electrons or protons should charge q_2 have in order to create a zero net electric force on charge q_3?

A) Four protons
B) Four electrons
C) Six protons
D) Six electrons
E) Three electrons

Ans:

Assume q_3 is $+ \Rightarrow$ q_2 must be $+$

$F_{31} = F_{32}: \dfrac{kq_1q_3}{9} = \dfrac{kq_2q_3}{4}$

$\Rightarrow q_2 = \frac{4q_1}{9} = \frac{4\times 14.4}{9} \times 10^{-19}$

$= 6.4 \times 10^{-19} = 4$ protons

Answer is the same if q_3 is (-).

Q3.

A proton of initial velocity 2.0×10^3 m/s enters a uniform electric field of strength 3.0 N/C. The initial velocity of the proton and the electric field are in the same direction. The distance travelled by the proton in a time t = 2.0 μs is: (Ignore the gravitational force)

A) 4.6 mm
B) 3.7 mm
C) 1.0 mm
D) 2.8 mm
E) 6.8 mm

Ans:

$$a = \frac{qE}{m}$$

$$\frac{1}{2}at^2 = \frac{qEt^2}{2m} = \frac{1.6 \times 10^{-19} \times 3.0 \times 4.0 \times 10^{-12}}{2 \times 1.67 \times 10^{-27}} = 5.75 \times 10^{-4}\ \text{m}$$

$$v_i t = 2.0 \times 10^3 \times 2.0 \times 10^{-6} = 4.0 \times 10^{-3}\text{m}$$

$$x = v_i t + \frac{1}{2}at^2 = 4.6\ \text{mm}$$

Q4.

An electric dipole consists of two particles, each having a charge of magnitude 2.0 nC. It is placed in an external electric field of magnitude 500 N/C. The electric potential energy of the dipole is –2.0 nJ when it makes an angle of 60° with the field. What is the separation between the two charges of the dipole?

A) 4.0 mm
B) 2.0 mm
C) 8.0 mm
D) 6.0 mm
E) 10 mm

Ans:

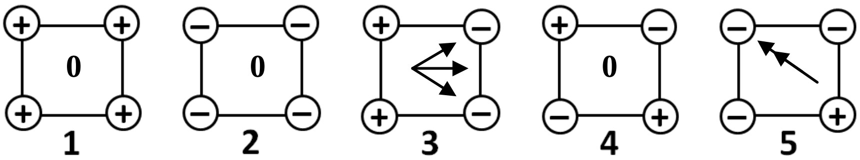
$$U = -\vec{P}.\vec{E} = -pE\cos\theta = -qdE\cos\theta$$

$$\Rightarrow d = -\frac{U}{qE\cos\theta} = \frac{2.0 \times 10^{-9}}{2.0 \times 10^{-9} \times 500 \times \frac{1}{2}} = 4.0 \times 10^{-3}\text{m}$$

Q5.

Four particles, with the same magnitude of charge, are placed at the corners of a square, as shown in **Figure 3**. Which configuration gives an electric field, at the center of the square, pointing to the right?

Figure 3



A) 3
B) 1
C) 4
D) 2
E) 5

Ans:

A

Q6.

The electric field at point P just outside the outer surface of a hollow spherical conductor of inner radius 10 cm and outer radius 20 cm has magnitude 450 N/C and is directed outward. When an unknown point charge Q is placed at the center of the sphere, the electric field at point P is still pointing outward but is now 180 N/C. What is the value of charge Q?

A) –1.2 nC
B) +1.2 nC
C) –3.4 nC
D) +3.4 nC
E) –5.0 nC

Ans:

$$q_{net} = \frac{Er^2}{k} = +\frac{450 \times 0.04}{9 \times 10^9} = +2.0 \text{ nC}$$

$$q_{tot} = \frac{E^* r^2}{k} = +\frac{180 \times 0.04}{9 \times 10^9} = +0.8 \text{ nC}$$

$$q_{tot} = q_{net} + Q$$

$$\Rightarrow Q = q_{tot} - q_{net} = +0.8 - 2.0 = -1.2 \text{ nC}$$

Q7.

A uniform electric field is given by: $\vec{\mathbf{E}} = 2\hat{\mathbf{i}} + 4\hat{\mathbf{j}} - 5\hat{\mathbf{k}}$ (N/C). A square plate, of side 10 cm, lies in the *xy* plane. What is the value of the electric flux through the plate?

A) 0.05 N.m^2/C
B) 0.02 N.m^2/C
C) 0.04 N.m^2/C
D) 0.06 N.m^2/C
E) 0.07 N.m^2/C

Ans:

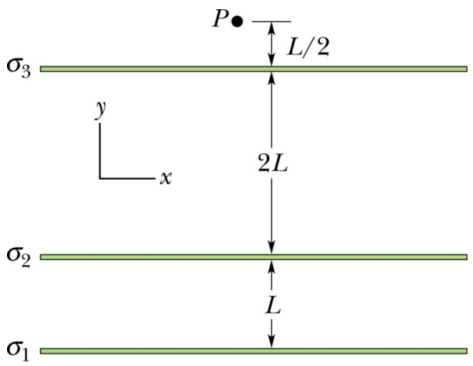
$$\vec{A} = \pm 0.01\ \hat{k}$$

$$\Phi = |\vec{E}.\vec{A}| = (0.01)(5) = 0.05\ \mathrm{N}.\frac{m^2}{C}$$

Q8.

Figure 9 shows, in cross section, three infinitely large parallel and flat non-conducting sheets on which charge is uniformly distributed. The surface charge densities are σ_1 = +2.00 μC/m^2, σ_2 = + 5.00 μC/m^2, and σ_3 = –3.00 μC/m^2, and distance *L* = 1.50 cm. In units of N/C, what is the net electric field at point P?

A) $+2.26 \times 10^5\ \hat{\mathbf{j}}$
B) $-2.26 \times 10^5\ \hat{\mathbf{j}}$
C) $+4.52 \times 10^5\ \hat{\mathbf{j}}$
D) $-4.52 \times 10^5\ \hat{\mathbf{j}}$
E) $+5.65 \times 10^5\ \hat{\mathbf{j}}$



Ans:

$$\sigma_{net} = +2 + 5 - 3 = +4\ \mu c/m^2$$

$$\Rightarrow \vec{E} \text{ is upward } (+\hat{j})$$

$$E_{net} = \frac{\sigma_{net}}{2\epsilon_0} = \frac{4 \times 10^{-6}}{2 \times 8.85 \times 10^{-12}}$$

$$= 2.26 \times 10^5\ \frac{N}{C}$$

Q9.

A solid isolated charged conductor is in electrostatic equilibrium. Choose the **TRUE** statement:

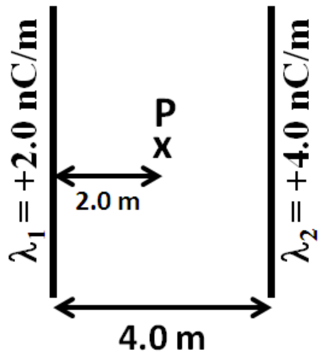
A) Any excess charge is confined to the surface of the conductor.
B) Excess charge is distributed throughout the volume of the conductor.
C) There is an electric field inside the conductor.
D) There is no electric field at the surface of the conductor.
E) Electric flux through a Gaussian surface inside the conductor is non-zero.

Ans:

A

Q10.

Two infinitely long lines of charge are shown in **Figure 5**. What is the electric field at P?



A) 18 (N/C), to the left
B) 18 (N/C), to the right
C) 9.0 (N/C), to the left
D) 9.0 (N/C), to the right
E) Zero

Ans:

$$E = \frac{2k\lambda}{r}$$

$$E_1 = \frac{2 \times 9 \times 10^9 \times 2 \times 10^{-9}}{2} = 18 \left(\frac{N}{C}\right) \rightarrow \text{to the right}$$

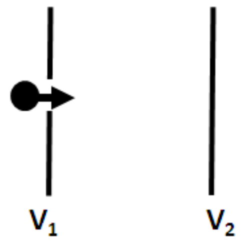
$$E_2 = \frac{2 \times 9 \times 10^9 \times 4 \times 10^{-9}}{2} = 36 \left(\frac{N}{C}\right) \rightarrow \text{to the left}$$

$$\Rightarrow E_{net} = E_2 - E_1 = 18 \left(\frac{N}{C}\right) \rightarrow \text{to the left}$$

Q11.

Figure 4 shows an electron moving to the right between two parallel charged plates. The electric potentials of the plates are V_1 = –70 V and V_2 = –50 V. What is the change in the kinetic energy of the electron as it moves from the left to the right plate?

A) $+3.2 \times 10^{-18}$ J
B) -3.2×10^{-18} J
C) -19×10^{-18} J
D) $+19 \times 10^{-18}$ J
E) $+8.0 \times 10^{-18}$ J



Ans:

$$\Delta U = q.\Delta V$$

$$= -1.6 \times 10^{-19} \times (-50 + 70) = -3.2 \times 10^{-18}\ \text{J}$$

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

$$\Rightarrow \Delta K = -\Delta U = +3.2 \times 10^{-18}\ \text{J}$$

Q12.

Consider two conducting spheres A and B. Sphere A has radius R_A and carries charge q. Sphere B has radius $R_B = 3R_A$ and initially uncharged. Sphere A is far from sphere B. The spheres are connected with a thin conducting wire. After the connection, what is the ratio of the charge on A to that on B (q_A/q_B)?

A) 1/3
B) 1
C) 1/9
D) 3
E) 9

Ans:

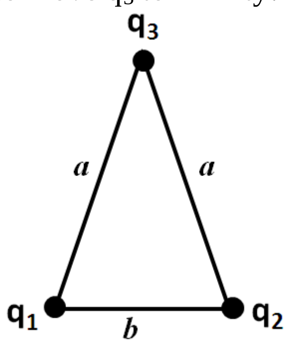
$$V_A = k.q_A / R_A$$

$$V_B = k.q_B / R_B = k.q_B / \mathbf{3}R_A$$

$$\text{After connection: } V_A = V_B \Rightarrow \frac{k.q_A}{R_A} = \frac{k.q_B}{3R_A} \Rightarrow \frac{q_A}{q_B} = \frac{1}{3}$$

Q13.

Three charged particles, q_1 = +10 nC, q_2 = –20 nC, and q_3 = +30 nC, are positioned at the corners of a triangle, as shown in **Figure 6**. If a = 10 cm and b = 6.0 cm, how much work must be done by an external agent to move q_3 to infinity?



A) $+2.7 \times 10^{-5}$ J
B) $+3.2 \times 10^{-5}$ J
C) -3.2×10^{-5} J
D) -2.7×10^{-5} J
E) zero

Ans:

$$U_i = \frac{kq_1q_2}{b} + \frac{kq_1q_3}{a} + \frac{kq_2q_3}{a}$$

$$U_f = \frac{kq_1q_2}{b}$$

$$\Delta U = U_f - U_i = -\frac{kq_3}{a}(q_1 + q_2)$$

$$= -\frac{9 \times 10^9 \times 30 \times 10^{-9}}{0.1} \times (-10) \times 10^{-9}$$

$$= +2.7 \times 10^{-5} \text{ J}$$

$$W_{ext} = \Delta U = +2.7 \times 10^{-5} \text{ J}$$

Q14.

The electric potential (in volts) in a certain region of space is given by $V = 3xy$. What is the magnitude of the electric field (in units of V/m) at the point (1.0 m, 1.0 m)?

A) 4.2
B) 2.3
C) 3.0
D) 6.0
E) 5.5

Ans.

$$E_x = -\frac{\partial V}{\partial x} = -3y$$

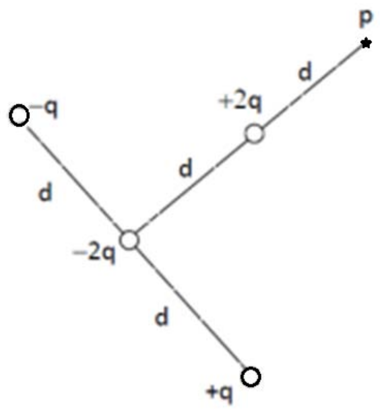
$$E_y = -\frac{\partial V}{\partial y} = -3x$$

$$\text{at } (1.0, 1.0): \vec{E} = -3\hat{i} - 3\hat{j} \implies E = 3\sqrt{2} = 4.2 \left(\frac{V}{m}\right)$$

Q15.

Consider the four charges distributed as shown in **Figure 8**. What is the net electric potential at point *P* due to the four charges, if *V* = 0 at infinity, *q* = 10 nC, and *d* = 10 cm?

A) +900 V
B) –900 V
C) Zero
D) +300 V
E) –300 V



Ans:

The (+q)and (− q) cancel each other

$$\therefore\ V_p = -\frac{2kq}{zd} + \frac{2kq}{d} = \frac{kq}{d}$$

$$= \frac{9\times10^{9}\times10\times10^{-9}}{0.1} = +900\ \text{V}$$

Q16.

Two conductors, insulated from each other, are charged by transferring electrons from one conductor to the other. After 2.5×10^{12} electrons have been transferred, the potential difference between the conductors is 12 V. What is the capacitance of the system?

A) 33 nF
B) 12 nF
C) 2.5 nF
D) 4.8 nF
E) 18 nF

Ans:

$$Q = 2.5\times10^{12}\times1.6\times10^{-19} = 4.0\times10^{-7}\text{C}$$

$$C = \frac{Q}{V} = \frac{4.0\times10^{-7}}{12} = 33\ \text{nF}$$

Q17.

Consider an isolated charged parallel plate capacitor. If the plate separation is decreased while the plate area is fixed, which of the following quantities will **decrease**?

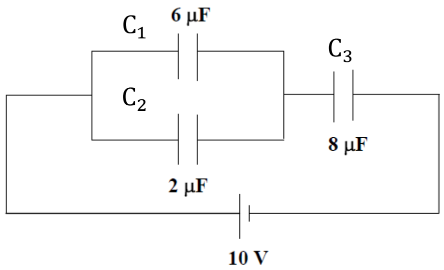
A) the energy stored by the capacitor
B) the charge on the capacitor (X → isolated)
C) the capacitance of the capacitor (X → increase)
D) the electric field between the plates$(X \to E = \frac{V}{d} = \frac{q}{\epsilon_0 A} \to \text{constant})$
E) the energy density of the electric field $(X \to u = \frac{1}{2}\epsilon_0 E^2 = \text{constant})$

Ans:

A

Q18.

Determine the equivalent capacitance of the circuit shown in **Figure 7**.



A) 4.0 μF
B) 9.5 μF
C) 16 μF
D) 7.6 μF
E) 1.3 μF

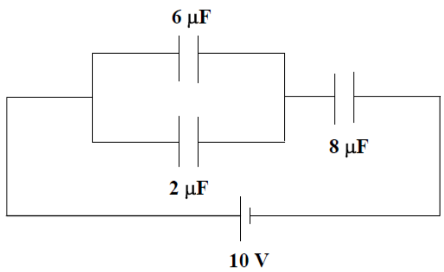
Ans:

$$C_{12} = C_1 + C_2 = 8\mu F$$

$$C_{eq} = \frac{C_{12}.C_3}{C_{12} + C_3} = \frac{8 \times 8}{8 + 8} = 4.0\ \mu F$$

Q19.

What is the charge on each plate on the 2-μF capacitor in **Figure 7**?



A) 10 μC
B) 20 μC
C) 30 μC
D) 60 μC
E) 80 μC

Ans:

$$q_{eq} = C_{eq}.V = 4 \times 10 = 40\ \mu C = q_3 = q_{12}$$

$$V_{12} = \frac{q_{12}}{c_{12}} = \frac{40}{8} = 5.0V = V_1 = V_2$$

$$\Rightarrow q_2 = C_2.V_2 = 2 \times 5 = 10\ \mu C$$

Q20.

A 10 pF parallel plate capacitor is charged with a 4.0 V battery. While the capacitor is still connected to the battery, a dielectric slab (κ = 5.0) is inserted between the plates to completely fill the gap. How much electric potential energy is stored in the capacitor after inserting the dielectric?

A) 4.0×10^{-10} J
B) 1.6×10^{-11} J
C) 2.0×10^{-11} J
D) 3.2×10^{-11} J
E) 5.6×10^{-10} J

Ans:

$$U = \frac{1}{2}CV^2 = \frac{1}{2}kC_0V^2$$

$$= \frac{1}{2} \times 5.0 \times 10 \times 10^{-12} \times 16 = 4.0 \times 10^{-10}\ J$$
