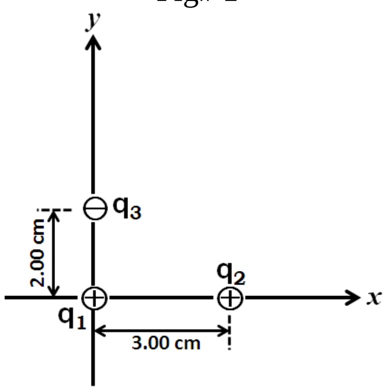
Q1.

In **FIGURE** 1, the three charges are: q_1 = +5.00 µC, q_2 = +4.00 µC, and q_3 = – 6.00 µC. What is the net electrostatic force on q_1 due to q_2 and q_3?

Fig# 1



A) $-200\,\hat{\mathbf{i}} + 675\,\hat{\mathbf{j}}$ (N)

B) $-540\,\hat{\mathbf{i}} + 1350\,\hat{\mathbf{j}}$ (N)

C) $-120\,\hat{\mathbf{i}} + 380\,\hat{\mathbf{j}}$ (N)

D) $-222\,\hat{\mathbf{i}} + 750\,\hat{\mathbf{j}}$ (N)

E) $-133\,\hat{\mathbf{i}} + 300\,\hat{\mathbf{j}}$ (N)

Ans:

$$\vec{F}_{12} = -\frac{kq_1q_2}{{r_{12}}^2}\,\hat{i}$$

$$= -\frac{9\times10^9\times5\times4\times10^{-12}}{9\times10^{-4}}\,\hat{i} = -200\,\hat{i} \quad \text{(N)}$$

$$\vec{F}_{13} = +\frac{kq_1q_3}{{r_{13}}^2}\,\hat{j}$$

$$= +\frac{9\times10^9\times5\times6\times10^{-12}}{4\times10^{-4}}\,\hat{j} = +675\,\hat{j} \quad \text{(N)}$$

$$\Rightarrow \vec{F}_{1,net} = \vec{F}_{12} + \vec{F}_{13}$$

$$= -200\,\hat{i} + 675\,\hat{j} \quad \text{(N)}$$

Q2.

Consider three distant spheres with charges Q_{1i} = 1C, Q_{2i} = 2C, and Q_{3i} = 3C. We allow these three charges to touch each other for a short time and then we separate them. The new charges of these spheres become Q_{1f} = q, Q_{2f} = 0.5q, and Q_{3f} = 1.5q. Find the value of q.

A) 2 C
B) 1 C
C) 3 C
D) 6 C
E) 4 C

Ans:

$$Q_i = Q_{1i} + Q_{2i} + Q_{3i} = 6C$$

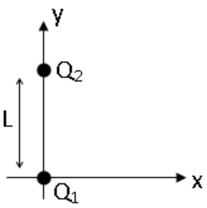
$$Q_f = Q_{1f} + Q_{2f} + Q_{3f} = 3q$$

$$Q_i = Q_f : 3q = 6C \Rightarrow q = 2C$$

Q3.

Particle 1 of charge Q_1 = 4Q and particle 2 of charge Q_2 = 9Q are fixed as shown in **FIGURE** 2. At what distance from Q_1 along the y-axis will the net electric field due to the two particles be zero?

Fig#2



A) 2L/5
B) 4L/9
C) 2L/3
D) 3L/2
E) 3L/5

Ans:

Since both particles are positive, $\vec{E}$ will be zero at a point between them.
Let $\vec{E}$ be zero at a point that is a distance d from Q_1:

$$E_1 = E_2 : \frac{kQ_1}{d^2} = \frac{kQ_2}{(L-d)^2} \Rightarrow \left(\frac{L-d}{d}\right)^2 = \frac{Q_2}{Q_1}$$

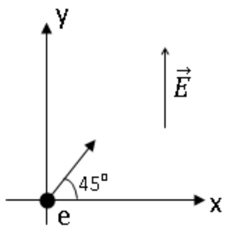
$$\frac{L-d}{d} = \sqrt{\frac{Q_2}{Q_1}} \Rightarrow \frac{L}{d} - 1 = \frac{3}{2} \Rightarrow \frac{L}{d} = \frac{5}{2}$$

$$\therefore \frac{d}{L} = \frac{2}{5} \Rightarrow d = \frac{2L}{5}$$

Q4.

An electron is shot (ejected) at an initial speed of 3.0×10^4 m/s at an angle of 45^o relative to the positive x-axis, as shown in **FIGURE** 3. At time t = 0, the electron enters a region of uniform electric field $\vec{\mathbf{E}} = 2.0\times10^{-6}\,\hat{\mathbf{j}}$(N/C). Find the velocity of the electron along y-axis at t = 1.0 s. Ignore gravity.

Fig# 3



A) $-3.2\times10^5\ \hat{\mathbf{j}}$ m/s

B) $+3.2\times10^5\ \hat{\mathbf{j}}$ m/s

C) $-2.5\times10^3\ \hat{\mathbf{j}}$ m/s

D) $+2.5\times10^3\ \hat{\mathbf{j}}$ m/s

E) $+3.2\times10^3\ \hat{\mathbf{j}}$ m/s

Ans:

$$F_e = ma \Rightarrow qE = ma \Rightarrow a = \frac{qE}{m}$$

$$\therefore a = \frac{1.6\times10^{-19}\times2.0\times10^{-6}}{9.11\times10^{-31}} = 3.5\times10^5\ \mathrm{m/s^2}$$

$$\Rightarrow \vec{a} = -3.5\times10^5\ \hat{j}\,(\mathrm{m/s^2})$$

$$V_y = V_{oy} - at$$

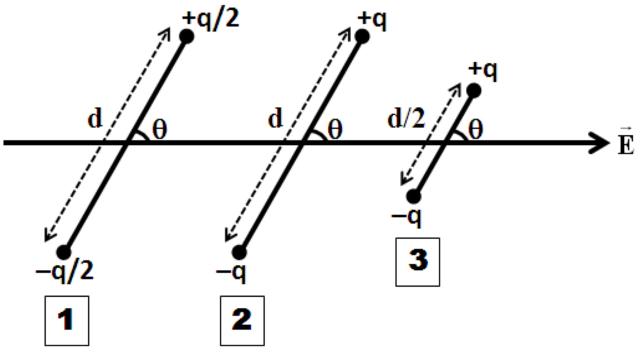
$$= (3.0\times10^4) - (3.5\times10^5\times1.0) = -3.2\times10^5\ \mathrm{m/s}$$

$$\Rightarrow \vec{V}_y = -3.2\times10^5\ \hat{j}\ \mathrm{m/s}$$

Q5.

Consider three **different** electric dipoles placed in the same uniform electric field **E**, as shown in **FIGURE** 4, where $\theta = 60^o$. Which of these dipoles has (or have) the **LOWEST** electric potential energy?

Fig # 4



A) 2
B) 1
C) 3
D) 1 and 3
E) 2 and 3

Ans:

$$U = -\vec{p}.\vec{E}$$

$$U_1 = -\frac{qd}{2}.E.\frac{1}{2} = -\frac{qdE}{4}$$

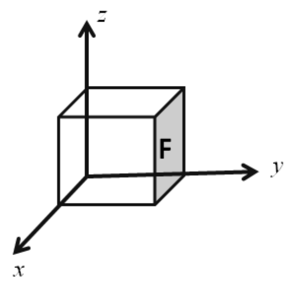
$$U_2 = -qd.E.\frac{1}{2} = -\frac{qdE}{2}$$

$$U_3 = -q.\frac{d}{2}.E.\frac{1}{2} = -\frac{qdE}{4}$$

Q6.

A cube of 2.0 m edge is placed in a uniform field given by $\vec{E} = 2.0\hat{i} + 1.0\hat{j}$ (N/C). The flux of the electric field through the face (**F**) perpendicular to the y- axis (see **FIGURE** 5) is

Fig# 5



A) 4.0 $N.m^2/C$
B) 8.0 $N.m^2/C$
C) 12 $N.m^2/C$
D) 48 $N.m^2/C$
E) zero

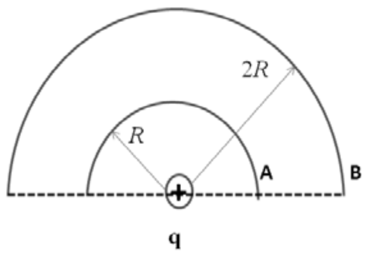
Ans:

$$\phi = \vec{E}.\vec{A} = \left(2.0\,\hat{i} + 1.0\,\hat{j}\right).(4.0\,\hat{j})$$
$$= 4.0\ N.m^2/C$$

Q7.

In **FIGURE** 6, a charge **q** is placed at the common center of two hemispheres **A** and **B**. The flux of the electric field through hemisphere **B** is

Fig# 6



A) equal to the flux through hemisphere **A**
B) double the flux through hemisphere **A**
C) four times the flux through hemisphere **A**
D) zero
E) half the flux through hemisphere **A**

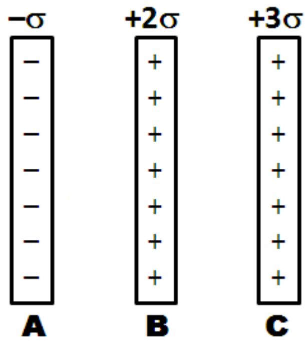
Ans:

In both surfaces: $q_{enc} = q$

Q8.

Consider three infinite non-conducting sheets with uniform charge densities (–σ, +2σ, +3σ), as shown in cross section in **FIGURE** 7. The electric field between plates A and B is given by

Fig# 7



A) $\dfrac{3\sigma}{\varepsilon_o}$ to the left

B) $\dfrac{6\sigma}{\varepsilon_o}$ to the left

C) $\dfrac{3\sigma}{\varepsilon_o}$ to the right

D) $\dfrac{6\sigma}{\varepsilon_o}$ to the right

E) $\dfrac{\sigma}{\varepsilon_o}$ to the right

Ans:

$$E_A = \frac{\sigma}{2\varepsilon_0} \longrightarrow \text{to the left}$$

$$E_B = \frac{2\sigma}{2\varepsilon_0} \longrightarrow \text{to the left}$$

$$E_C = \frac{3\sigma}{2\varepsilon_0} \longrightarrow \text{to the left}$$

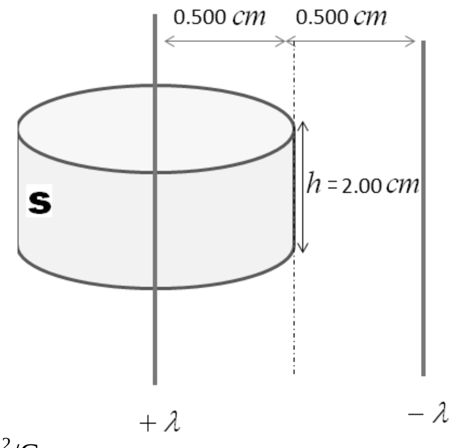
$$\therefore E_{net} = E_A + E_B + E_C$$

$$= \frac{\sigma + 2\sigma + 3\sigma}{2E_0} = \frac{3\sigma}{\varepsilon_0} \longrightarrow \text{to the left}$$

Q9.

Two infinite wires are charged with uniform and opposite linear charge densities +λ and –λ, where λ = 1.00 nC/m, as shown in **FIGURE** 8. The flux of the electric field through the Gaussian cylindrical surface (S) is

Fig# 8



A) +2.26 N.m²/C
B) –2.26 N.m²/C
C) +113 N.m²/C
D) –113 N.m²/C
E) zero

Ans:

Only + λ contributes to the flux

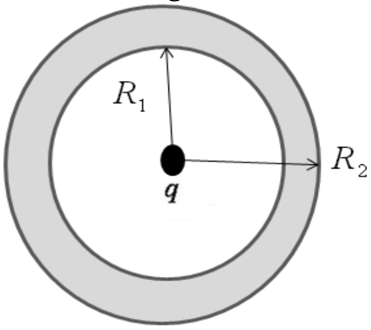
$$q_{enc} = \lambda h = 1.00 \times 10^{-9} \times 2.00 \times 10^{-2} = 2.00 \times 10^{-11} \mathrm{C}$$

$$\phi = \frac{q_{enc}}{\epsilon_0} = \frac{2.00 \times 10^{-11}}{8.85 \times 10^{-12}} = +2.26 \ \mathrm{N.m^2/C}$$

Q10.

A point charge $q = -1.0\times10^{-10}$ C is placed at the center of a spherical conducting shell that has a total charge $Q = 5.0\times10^{-10}$ C, as shown in **FIGURE** 9. The outer surface has radius $R_2 = 10$ cm. The charge density on the external surface is equal to:

Fig# 10



A) $+3.2$ nC/m^2
B) -3.2 nC/m^2
C) $+4.0$ nC/m^2
D) $+0.80$ nC/m^2
E) -0.80 nC/m^2

Ans:

$$q_{in} = -q = +1.0\times10^{-10}\ \text{C}$$

$$Q = q_{in} + q_{out}$$

$$\therefore q_{out} = Q - q_{in} = 5.0\times10^{-10} - 1.0\times10^{-10}$$

$$= +4.0\times10^{-10}\ \text{C}$$

$$\sigma_{out} = \frac{q_{out}}{4\pi {R_2}^2} = +\frac{4.0\times10^{-10}}{4\pi\times0.01} = +3.2\times10^{-9}\ \text{C/m}^2 = +3.2\ \text{nC/m}^2$$

Q11.

A uniform electric field of magnitude 325 V/m is directed in the negative y direction. The coordinates of point A are (–0.200, –0.300) m, and those of point B are (0.400, 0.500) m. Calculate the electric potential difference $V_B - V_A$.

A) +260 V
B) –260 V
C) –195 V
D) +195 V
E) +325 V

Ans:

$$\Delta V = -\vec{E}.\Delta\vec{r}$$

$$V_B - V_A = -\vec{E}.(\vec{r}_B - \vec{r}_A)$$

$$= 325\hat{j}.(0.6\hat{\imath} + 0.8\hat{j}) = +260\ \text{V}$$

Q12.

An electron is released from rest at the origin in a uniform electric field that points in the positive *x* direction and has a magnitude of 850 N/C. What is the change in the electric potential energy of the electron-field system when the electron moves a distance of 2.5 m?

A) -3.4×10^{-16} J
B) $+3.4 \times 10^{-16}$ J
C) -1.4×10^{-16} J
D) $+1.4 \times 10^{-16}$ J
E) -5.4×10^{-16} J

Ans:

The electron will move opposite to the field

$\Rightarrow \Delta\vec{r} = -2.5\,\vec{\imath}$ (m)

$\Delta u = q.\Delta V = q\left(-\vec{E}.\Delta\vec{r}\right) = -q\vec{E}.\Delta\vec{r}$

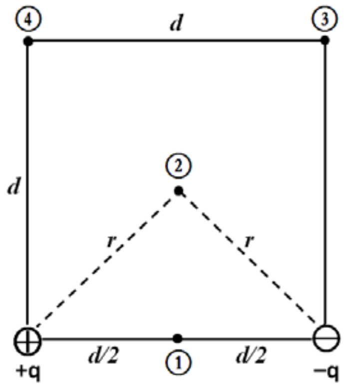
$= -(-1.6 \times 10^{-19}).(\,850\vec{\imath}\,).(-2.5\vec{\imath}\,)$

$= -3.4 \times\ 10^{-16}$ J

Q13.

Two point charges (**+q** and **– q**) are placed as shown in **FIGURE** 10. Consider the points 1, 2, 3, and 4 that are shown on the figure. At which point is the net electric potential **HIGHEST**? Take $V = 0$ at infinity.

Fig#10



A) 4
B) 3
C) 2
D) 1
E) All points have the same potential

Ans:

$V_1 = V_2 = 0$

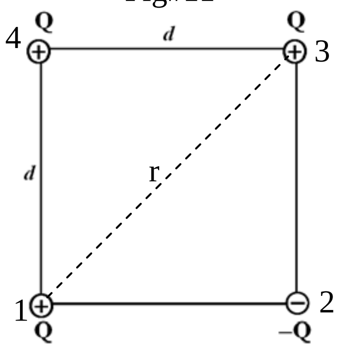
Point 4 is closer to the positive charge.

$\Rightarrow V_4 > V_3$

Q14.

Four point charges are placed at the corners of a square, as shown in **FIGURE** 11. The magnitudes of the charges are equal. What is the electric potential energy of the system?

Fig#11



A) zero
B) $+5.4\ kQ^2/d$
C) $+2.6\ kQ^2/d$
D) $-2.6\ kQ^2/d$
E) $+0.71\ kQ^2/d$

Ans:

$$U = k\left[-\frac{Q^2}{d}+\frac{Q^2}{r}+\frac{Q^2}{d}-\frac{Q^2}{d}-\frac{Q^2}{r}+\frac{Q^2}{d}\right]$$
$$= zero$$

Q15.

In a certain region of space, the electric potential is given by: $V = 2.0\ xyz^2$, where V is in volts, and x, y, and z are in meters. What is the magnitude of the electric field at the point with position vector ($2.0\hat{\mathbf{i}} - 2.0\hat{\mathbf{j}} + 4.0\hat{\mathbf{k}}$)?

A) 111 V/m
B) 90.8 V/m
C) 16.1 V/m
D) 743 V/m
E) 571 V/m

Ans:

$$E_x = -\frac{\partial V}{\partial x} = -2yz^2 \rightarrow E_{xp} = (-2)(-2)(16) = +64\frac{V}{m}$$

$$E_y = -\frac{\partial V}{\partial y} = -2xz^2 \rightarrow E_{yp} = (-2)(2)(16) = -64\ V/m$$

$$E_z = -\frac{\partial V}{\partial z} = -4xyz \rightarrow E_{zp} = (-4)(2)(2)(4) = -64\ V/m$$

$$E = (Ex^2 + Ey^2 + Ez^2)^{1/2} = 111\ V/m$$

Q16.

The electric potential immediately outside a charged conducting sphere is 200 V, and 10 cm farther from the surface of the sphere the potential is 150 V. What is the charge on the sphere?

A) 6.7 nC
B) 0.95 nC
C) 1.3 nC
D) 8.9 nC
E) 5.4 nC

Ans:

$$\left.\begin{aligned} V_1 &= \frac{kQ}{R} \\ V_2 &= \frac{kQ}{R+0.1} \end{aligned}\right\} \begin{aligned} \frac{V_2}{V_1} &= \frac{kQ}{R+0.1}.\frac{R}{kQ} = \frac{R}{R+0.1} \\ \frac{150}{200} &= \frac{R}{R+0.1} \rightarrow \frac{3}{4} = \frac{R}{R+0.1} \end{aligned}$$

$$3R + 0.3 = 4R \rightarrow R = 0.3 \text{ m}$$

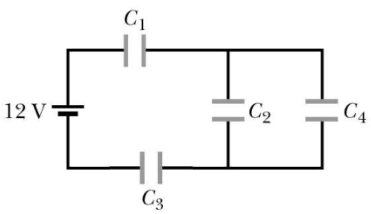
$$\Rightarrow Q = \frac{V_1.R}{k} = \frac{200 \times 0.3}{9 \times 10^9} = 6.7 \text{ nC}$$

Q17.

FIGURE 12 shows a combination of four capacitors $C_1 = C_3 = 8.0$ µF and $C_2 = C_4 =$ 6.0 µF connected to a 12-V battery. Calculate the charge on capacitor C_1.

Fig# 12

A) 36 µC
B) 18 µC
C) 12 µC
D) 24 µC
E) 30 µC



Ans:

$$C_{24} = C_2 + C_4 = 12\mu F$$

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_3} + \frac{1}{C_{24}} = \frac{1}{8} + \frac{1}{8} + \frac{1}{12}$$

$$= \frac{3}{24} + \frac{3}{24} + \frac{2}{24} = \frac{8}{24}$$

$$\Rightarrow C_{eq} = 3.0 \text{ µF}$$

$$Q_{eq} = C_{eq}.V = 3.0 \times 12 = 36 \text{ V}$$

$$= Q_1 = Q_3 = Q_{24}$$

Q18.

A 20-V battery is connected to a series of **N** capacitors, each of capacitance 4.0 µF. If the total energy stored in the capacitors is 50 µJ, what is **N**?

A) 16
B) 12
C) 4
D) 10
E) 8

Ans:

Series identical capacitance: $= \frac{1}{C_{eq}} = \frac{1}{C} + \frac{1}{C} + \frac{1}{C} + \ldots = \frac{N}{C}$

$\Rightarrow C_{eq} = \frac{C}{N}$

$U = \frac{1}{2} C_{eq} V^2 = \frac{CV^2}{2N} \rightarrow N = \frac{CV^2}{2U} = \frac{4.0 \times 10^{-6} \times 400}{2 \times 50 \times 10^{-6}} = 16$

Q19.

A 2-µF and a 1-µF capacitor are connected in series and charged by a battery. They store charges P and Q, respectively. When disconnected and charged separately using the same battery, they have charges R and S, respectively. Then:

A) R > S > P = Q
B) P > Q > R = S
C) R > P > S = Q
D) R > Q > S = P
E) S > R > P = Q

Ans:

Series: $P = Q$

Charge on R is more because $C_R > C_s$

Q20.

A 2.0-nF parallel plate capacitor is charged using a 12-V battery. The battery is removed and a dielectric of dielectric constant κ = 3.5 is inserted, filling completely the space between the plates of the capacitor. What is the energy stored in the capacitor after inserting the dielectric?

A) 4.1×10^{-8} J
B) 5.0×10^{-5} J
C) 1.4×10^{-7} J
D) 2.4×10^{-8} J
E) 1.0×10^{-6} J

Ans:

$$Q_i = C_i . V_i = Q_f$$

$$U_f = \frac{Q_f^{\ 2}}{2C_f} = \frac{1}{2} C_i^{\ 2} V_i^{\ 2} . \frac{1}{kC_i} = \frac{C_i V_i^{\ 2}}{2k}$$

$$= \frac{2.0 \times 10^{-9} \times 144}{2 \times 3.5} = 4.1 \times 10^{-8} \ \ \text{J}$$