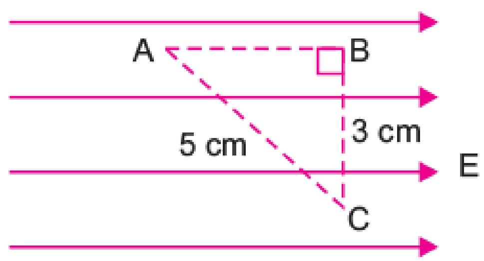
# Short Answer Questions – I (PYQ)

**Q. 1. Three points A, B and C lie in a uniform electric field (E) of $5 \times 10^3$ $NC^{-1}$ as shown in the figure. Find the potential difference between A and C. [CBSE (F) 2009]**




**Ans.** The line joining B to C is perpendicular to electric field, so potential of B = potential of C i.e., $V_B = V_C$

Distance AB =4 cm

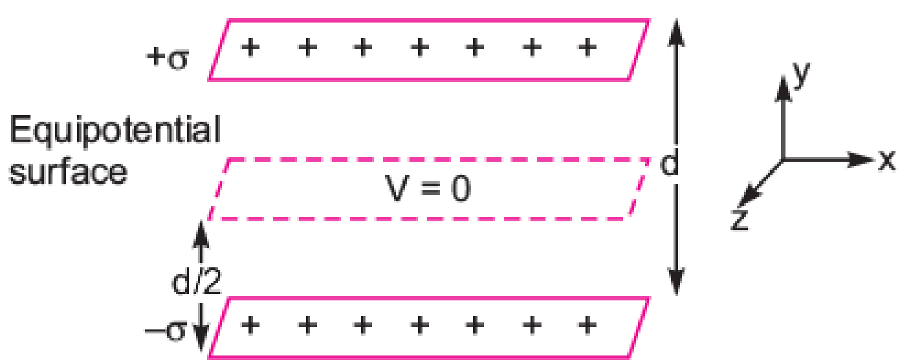
Potential difference between A and C = E × (AB)

$= 5 \times 10^3 \times (4 \times 10^{-2})$

**= 200 volt**

**Q. 2. Two uniformly large parallel thin plates having charge densities +σ and – σ are kept in the X-Z plane at a distance'd' apart. Sketch an equipotential surface due to electric field between the plates. If a particle of mass m and charge '–q' remains stationary between the plates, what is the magnitude and direction of this field?**
**[CBSE Delhi 2011]**

**Ans.** The equipotential surface is at a distance d/2 from either plate in X-Z plane. For a particle of charge (–q) at rest between the plates, then



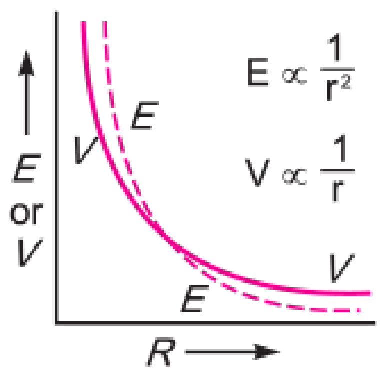
**(i)** Weight mg acts vertically downward
**(ii)** Electric force qE acts vertically upward.

so mg = qE

$E = \frac{mg}{q}$, Vertically downward, i.e., along (–)Y-axis.

**Q. 3. Plot a graph comparing the variation of potential 'V' and electric field 'E' due to a point charge 'Q' as a function of distance 'R' from the point charge. [CBSE Delhi 2012]**

**Ans.** The graph of variation of potential and electric field due to a point charge Q with distance R from the point charge is shown in figure.




**Q. 4. What is electrostatic shielding? How is this property used in actual practice? Is the potential in the cavity of a charged conductor zero? [CBSE South 2016]**

**Ans.** Whatever be the charge and field configuration outside, any cavity in a conductor remains shielded from outside electric influence. The field inside a conductor is zero. This is known as electrostatic shielding.

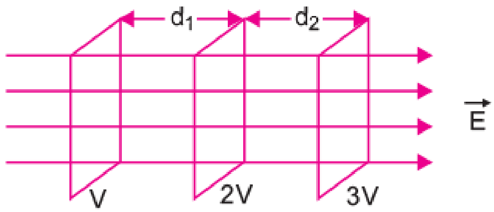
Sensitive instruments are shielded from outside electrical influences by enclosing them in a hollow conductor.

During lightning it is safest to sit inside a car, rather than near a tree. The metallic body of a car becomes an electrostatic shielding from lightening.

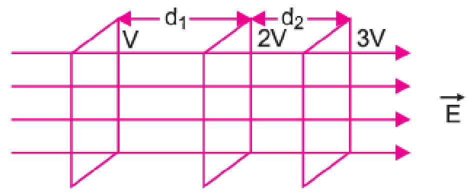
Potential inside the cavity is not zero. Potential is constant.

**Q. 5. Draw 3 equipotential surfaces corresponding to a field that uniformly increases in magnitude but remains constant along Z-direction. How are these surfaces different from that of a constant electric field along Z-direction? [CBSE (AI) 2009]**

**Ans.** For constant electric field $\vec{E}$ For increasing electric field



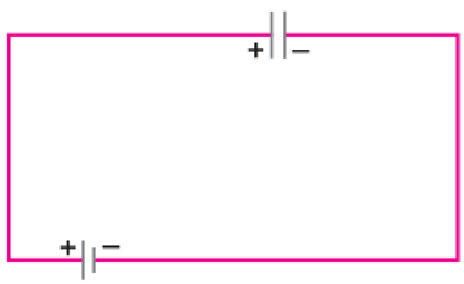

$d_1 = d_2$




$d_1 > d_2$

**Difference:** For constant electric field, the equipotential surfaces are equidistant for same potential difference between these surfaces; while for increasing electric field, the separation between these surfaces decreases, in the direction of increasing field, for the same potential difference between them.

**Q. 6. Why does current in a steady state not flow in a capacitor connected across a battery? However momentary current does flow during charging or discharging of the capacitor. Explain. [CBSE (AI) 2017]**

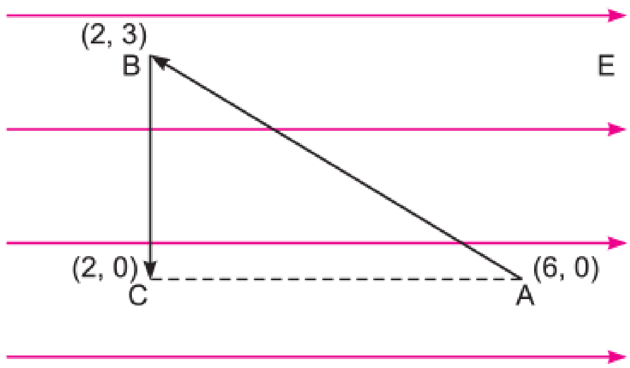



**Ans. (i)** In the steady state no current flows through capacitor because, we have two sources (battery and fully charged capacitor) of equal potential connected in opposition.

**(ii)** During charging or discharging there is a momentary flow of current as the potentials of the two sources are not equal to each other.

**Q. 7. A test charge 'q' is moved without acceleration from A to C along the path from A to B and then from B to C in electric field E as shown in the figure.**

**(i) Calculate the potential difference between A and C.**
**(ii) At which point (of the two) is the electric potential more and why?**
**[CBSE (AI) 2012]**




**Ans. (i)** Since electric field is conservative in nature, the amount of work done will depend upon initial and final positions only.

$$\therefore \qquad \text{Work done } W = \vec{F} \cdot \vec{d} = q\,\vec{E} \cdot \vec{d} = \text{qE}\,.4 \cos\ 180^\circ$$

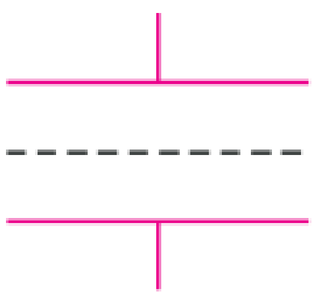
$$= -4\,qE$$

$$\text{Hence} \qquad V_c - V_A = \frac{W}{q} = -\,4E$$

**(ii)** $V_C > V_A$, because direction of electric field is in decreasing potential.

**Q. 8.Figure shows a sheet of aluminium foil of negligible thickness placed between the plates of a capacitor. How will its capacitance be affected if: [CBSE (F) 2009]**

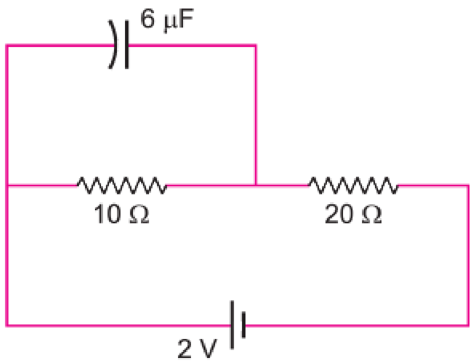
**(i) The foil is electrically insulated?**
**(ii) The foil is connected to the upper plate with a conducting wire?**



**Ans. (i)** No effect on capacitance if foil is electrically neutral.

**(ii)** If foil is connected to upper plate with a conducting wire, the effective separation between plates becomes half, so capacitance is doubled.

**Q. 9. Find the charge on the capacitor as shown in the circuit. [CBSE (F) 2014]**




**Ans.**

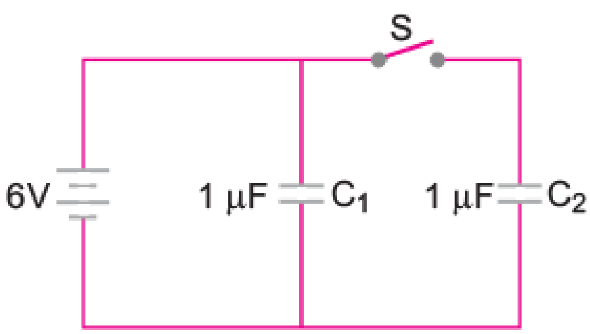
Total resistance, $R = 10\Omega + 20\Omega = 30\Omega$

$$\text{The current, } I = \frac{V}{R} = \frac{2V}{30\Omega} = \frac{1}{15}\ A$$

$$\text{Potential difference, } V = \text{IR} = \frac{1}{15} \times 10 = \frac{2}{3} V$$

$$\text{Charge, } q = \text{CV} = 6 \times \frac{2}{3} = 4\pi C$$

**Q. 10. Figure shows two identical capacitors, $C_1$ and $C_2$, each of 1 mF capacitance connected to a battery of 6 V. Initially switch 'S' is closed. After sometimes 'S' is left open and dielectric slabs of dielectric constant K = 3 are inserted to fill completely the space between the plates of the two capacitors. How will the (i) charge and (ii) potential difference between the plates of the capacitors be affected after the slabs are inserted? [CBSE Delhi 2011]**




**Ans.** When switch S is closed, p.d. across each capacitor is 6V

$V_1 = V_2 = 6$ V

$C_1 = C_2 = 1$ μC

∴ Charge on each capacitor

$q_1 = q_2$ (= CV) = (1 μF) × (6 V) = 6 μC

When switch S is opened, the p.d. across $C_1$ remains 6 V, while the charge on capacitor $C_2$ remains 6 μC. After insertion of dielectric between the plates of each capacitor, the new capacitance of each capacitor becomes

$C'1 = C'2 = 3 \times 1\ \mu F = 3\ \mu F$

Charge on capacitor $C_1$, $q'_1 = C'_1 V_1$ = (3 μF) × 6 V = 18 μC Charge on capacitor $C_2$ remains 6 μ

Potential difference across $C_1$ remains 6 V. Potential difference across $C_2$ becomes

$$V'_2 = \frac{q_2}{C'_2} = \frac{6\ \mu C}{3\ \mu F} = 2\ \text{V}$$

**Q. 11. Answer the following questions**

**(i) A parallel plate capacitor ($C_1$) having charge Q is connected, to an identical uncharged capacitor $C_2$ in series. What would be the charge accumulated on the capacitor $C_2$? [CBSE South 2016]**

**(ii) Three identical capacitors each of capacitance 3 μF are connected, in turn, in series and in parallel combination to the common source of V volt. Find out the ratio of the energies stored in two configurations. [CBSE South 2016]**

**Ans. (i)** Zero

**(ii)**

We have $C$ series $= \frac{3\,\pi F}{3} = 1\pi F$

Also, $C_{parallel} = (3 + 3 + 3) = 9\ \mu\text{F}$

Energy stored $= \frac{1}{2}\text{CV}^2$

∴ Energy in series combination $= \frac{1}{2} \times 1 \times 10^{-6} \times V^2 \quad \Rightarrow \quad U_{\text{Series}} = \frac{10^{-6}}{2} V^2$

∴ Energy in parallel combination $= \frac{1}{2} \times 9 \times 10^{-6} \times V^2 \quad \Rightarrow \quad U_{\text{parallel}} = \frac{10^{-6} \times 9}{2} V^2$

∴ $U_{\text{series}} : U_{\text{parallel}} = 1 : 9$

**Q. 12. Net capacitance of three identical capacitors in series is 1 μF. What will be their net capacitance if connected in parallel?**

**Find the ratio of energy stored in the two configurations if they are both connected to the same source. [CBSE (AI) 2011]**

**Ans.** Let C be the capacitance of each capacitor, then in series

$$\frac{1}{C_S} = \frac{1}{C} + \frac{1}{C} + \frac{1}{C} = \frac{3}{C}$$

Or $C = 3C_s = 3 \times 1\ \mu F = 3\ \mu F$

When these capacitors are connected in parallel, net capacitance, $C_p = 3\ C = 3 \times 3 = 9\ \mu F$

When these two combinations are connected to same source the potential difference across each combination is same.

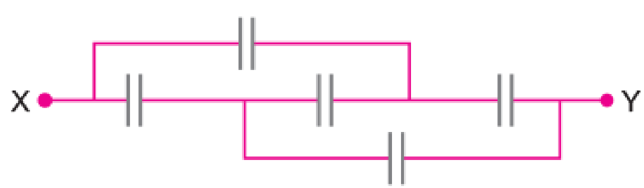
Ratio of energy stored,

$$\frac{U_s}{U_p} = \frac{\frac{1}{2}C_s V^2}{\frac{1}{2}C_p V^2} = \frac{C_s}{C_p} = \frac{1\ \mu F}{9\ \mu F} = \frac{1}{9}$$

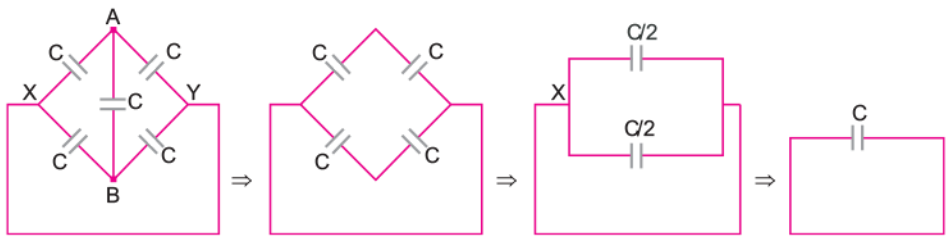
$$U_s : U_p = 1 : 9$$

**Q. 13. Find the equivalent capacitance of the network shown in the figure, when each capacitor is of 1 μF. When the ends X and Y are connected to a 6 V battery, find out**

**(i) The charge and**
**(ii) The energy stored in the network. [CBSE Patna 2015]**




**Ans.** The given circuit can be rearranged as




It is known as wheat stone bridge of the capacitor. Since $V_A = V_B$, so the bridge capacitor between points A and B can be removed.

**(i)** The equivalent capacitor of the network

$$C_{eq} = \frac{C \times C}{C+C} + \frac{C \times C}{C+C}$$

$$= \frac{C}{2} + \frac{C}{2}$$

$$= C = 1\mu F$$

Charge in the network, $Q = C_{eq} V$

$$= C \times V = 1\ \mu F \times 6\ V = 6\ \mu C$$

**(ii)** Energy stored in the capacitor,

$$U = \frac{1}{2}\ C_{eq}\ V^2$$

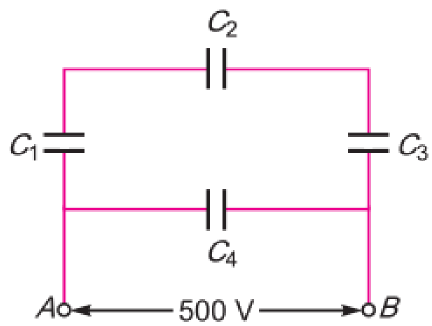
$$= \frac{1}{2} \times 1\ \mu F \times (6)^2$$

$$= 18\ \mu J$$

**Q. 14. A network of four capacitors each of 15 µF capacitance is connected to a 500 V supply as shown in the figure. Determine**

**(a) Equivalent capacitance of the network and**
**(b) Charge on each capacitor. [CBSE (AI) 2010]**

**Ans. (a)** $C_1$, $C_2$ and $C_3$ are in series, their equivalent capacitance C′ is given by




$$\frac{1}{C'} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} = \frac{1}{15} + \frac{1}{15} + \frac{1}{15}$$

$\Rightarrow \quad C' = 5\ \mu F$

$C_4$ is in parallel with $C$, so equivalent capacitance of network

$C_{eq} = C + C_4 = 5 + 15 = 20\ \mu F$

b. Charge on capacitor $C_4$ is

$$q_4 = C_4 V = (15\ \mu F) \times 500\ V = 7500\ \mu C = 7.5\ mC$$

Charge on $C_1$, $C_2$ and $C_3$ is

$$q_1 = q_2 = q_3 = C\ V$$

$$= 5\ \mu F \times 500\ V = 2500\ \mu C = 2.5\ mC$$

**Q. 15. Four charges +q, – q, + q and – q are to be arranged respectively at the four corners of a square ABCD of side ‘a’.**

**(i) Find the work required to put together this arrangement. [Hots][CBSE (F) 2015]**

**(ii) A charge q0 is brought to the centre of the square, the four charges being held fixed. How much extra work is needed to do this? [Hots][CBSE (F) 2015]**

**Ans. (i)** Work done in bringing charge +q at point A

$W_A = 0$

Work done in bringing charge –q to the point B

$$W_B = W_{AB} = -q \times \frac{1}{4\pi\varepsilon_0}\frac{q}{a} = -\frac{1}{4\pi\varepsilon_o}\frac{q^2}{a}$$

Work done in bring the charge +q to the point C

$W_C = W_{AC} + W_{BC}$

$$= q \times \frac{1}{4\pi\varepsilon_0}\cdot\frac{q}{a\sqrt{2}} + q \times \left(-\frac{1}{4\pi\varepsilon_0}\frac{q}{a}\right) = \frac{1}{4\pi\varepsilon_0}\cdot\frac{q^2}{a\sqrt{2}} - \frac{1}{4\pi\varepsilon_0}\cdot\frac{q^2}{a}$$

Work done in bringing a charge – q to the point D

$W_D = W_{AD} + W_{BD} + W_{CD}$

$$= -q \times \frac{1}{4\pi\varepsilon_0}\frac{q}{a} + (-q)\left(\frac{1}{4\pi\varepsilon_o}\frac{-q}{a\sqrt{2}}\right) + (-q) \times \frac{1}{4\pi\varepsilon_o}\cdot\frac{q}{a}$$

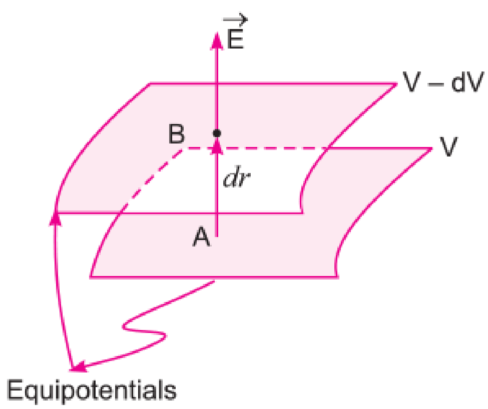
Total work done $W = W_A + W_B + W_C + W_D$

$$= 2 \times \frac{1}{4\pi\varepsilon_0}\frac{q^2}{a\sqrt{2}} - 4 \times \frac{1}{4\pi\varepsilon_o}\frac{q^2}{a} = \frac{1}{4\pi\varepsilon_o}\frac{q^2}{a}(\sqrt{2} - 4)$$

## Short Answer Questions – I (OIQ)

**Q. 1. Establish the relation between electric field and potential gradient.**

**Ans.** Let us consider two closely spaced equipotential surfaces A and B as shown in figure.




Let the potential of A be $V_A = V$ and potential of B be $V_B = V - dV$ where dV is decrease in potential in the direction of electric field $\vec{E}$ normal to A and B.

Let dr be the perpendicular distance between the two equipotential surfaces. When a unit positive charge is moved along this perpendicular from the surface B to surface A against the electric field, the work done in this process is

$$W_{BA} = -\vec{E}\,(\mathrm{dr})$$

This work done equals the potential difference $V_A - V_B$.

$$\therefore \quad W_{BA} = V_A - V_B = V - (V - \mathrm{dV}) = \mathrm{dV}$$

$$\therefore \quad -\vec{E}\,\mathrm{dr} = \mathrm{dV}$$

$$\text{or}, \quad \vec{E} = -\frac{\mathrm{dV}}{\mathrm{dr}} = \text{negative of potential gradiant}$$

**Q. 2. How does the energy stored in a capacitor change if after disconnecting the battery, the plates of a charged capacitor are moved farther?**

**Ans.** Capacitance $C \propto \frac{1}{d}$, when plates of a capacitor are moved farther, the capacitance decreases. After disconnecting the battery, the charge on capacitor remains constant, therefore the energy stored by capacitor $U\left(= \frac{q^2}{2C}\right)$, increases.

**Q. 3. How does the energy stored in a capacitor change if the plates of a charged capacitor are moved farther, the battery remaining connected?**

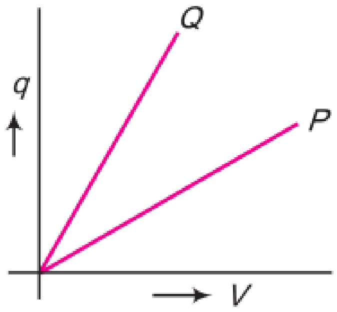
**Ans.** The capacitance of capacitor decreases on moving its plates farther. As the battery remains connected, the potential difference remains constant. Hence, energy stored $U = \frac{1}{2}\mathrm{CV}^2$, decreases.

**Q. 4. When a capacitor is charged by a battery; is the energy stored in the capacitor same as energy supplied by the battery?**

**Ans.** No, Energy stored in the capacitor = $\frac{1}{2}\mathrm{CV}^2 = \frac{1}{2}\mathrm{qV}$ while energy supplied by battery =qV.

The balance of energy is dissipated as heat during charging.

**Q. 5. The given graph shows the variation of charge q versus potential difference V for two capacitors $C_1$ and $C_2$. The two capacitors have same plate separation but the plate area of $C_2$ is double than that of $C_1$. Which of the two graphs P and Q correspond to capacitors $C_1$ and $C_2$ and why?**

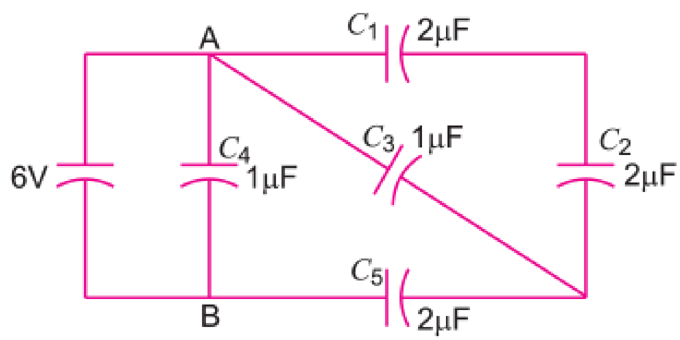



**Ans.** Q represents $C_2$ and P represents $C_1$

**Reason:** From the graph the slope q/v = Capacitance is greater for Q.

Also according to given conditions the capacitance $\frac{\varepsilon A}{d}$ is larger for the C2 because the area of its plates is large and d for the two capacitors is same. Hence, Q represents $C_2$.

**Q. 6. Find the total energy stored in the capacitors in the given network.**




**Ans.** The equivalent capacitance of $C_1$ and $C_2$ in series

$$C' = \frac{C_1 C_2}{C_1 + C_2} = \frac{2\times2}{2+2} = 1\,\mu F$$

C′ is in parallel with C3, so equivalent capacitance of $C_1$, $C_2$ and $C_3$ is

$$C'' = 1 + 1 = 2\,\mu F$$

C″ is in series with $C_4$; their equivalent capacitance

$$C''' = \frac{C_4 C''}{C_4 + C''} = \frac{2\times2}{2+2} = 1\,\mu F$$

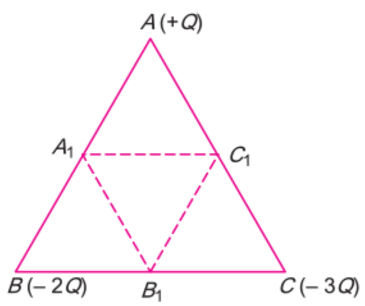
This is in parallel with $C_5$; So equivalent capacitance across AB is $C_{AB}$ = 1 +1 = 2 μF

Energy stored $V = \frac{1}{2} C_{AB} V^2 = \frac{1}{2} \times 2 \times 10^{-6} \times (6)^2 = 36 \times 10^{-6} J$

**Q. 7. Three point charges +Q, –2Q and –3Q are placed at the vertices of an equilateral triangle ABC of side l**

**If these charges are displaced to the mid points $A_1$, $B_1$ and $C_1$ respectively, calculate the amount of work done in shifting the charges to the new locations. [HOTS]**

**Ans.** Work done to put the three charges at A, B and C




$$U_{\text{initial}} = \frac{1}{4\pi\varepsilon_0} \left[ \frac{Q(-2Q)}{l} + \frac{Q(-3Q)}{l} + \frac{2Q(3Q)}{l} \right]$$

$$= \frac{1}{4\pi\varepsilon_0} \frac{1Q^2}{l}.$$

Work done to take the three charges to position $A_1$, $B_1$ and $C_1$

$$U_{\text{initial}} = \frac{1}{4\pi\varepsilon_0} \left[ \frac{Q(-2Q)}{l/2} + \frac{Q(-3Q)}{l/2} + \frac{2Q(3Q)}{l/2} \right]$$

$$= \frac{1}{4\pi\varepsilon_0} \frac{2Q^2}{l}.$$

Work done to shift the charges to the new locations is

$$W = U_{\text{final}} - U_{\text{initial}} = - \frac{1}{4\pi\varepsilon_0} \frac{2Q^2}{l}$$

**Q. 8. Consider two conducting spheres of radii R1 and R2 with R1 > R2. If the two are at the same potential, the larger sphere has more charge than the smaller sphere. State whether the charge density of the smaller sphere is more or less than that of the larger one. [HOTS][NCERT Exemplar]**

**Ans.** Since two spheres are at the same potential, therefore

$V_1 = V_2$

$$\frac{Q_1}{4\pi\varepsilon_0 R_1} = \frac{Q_2}{4\pi\varepsilon_0 R_2}$$

$$\Rightarrow \qquad \frac{Q_1}{Q_2} = \frac{R_1}{R_2}$$

Given, $R_1 > R_2$, $\quad \therefore \quad Q_1 > Q_2$

$\Rightarrow$ Larger sphere has more charge

Now, $\quad \sigma_1 = \frac{Q_1}{4\pi R^2{}_1}$ and $\sigma_2 = \frac{Q_2}{4\pi R^2{}_2}$

$$\frac{\sigma_2}{\sigma_1} = \frac{Q_2}{Q_1} \cdot \frac{R_1^2}{R_2^2}$$

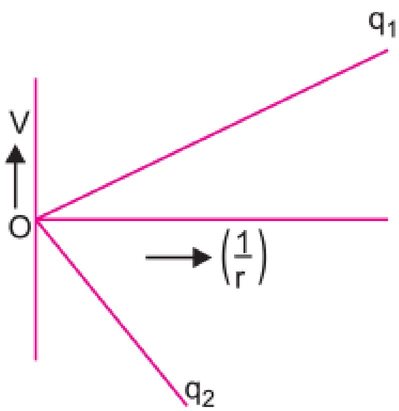
$$\Rightarrow \qquad \frac{\sigma_2}{\sigma_1} = \frac{R_2}{R_1} \cdot \frac{R_1^2}{R_2^2} \qquad \text{[From equation } (i)\text{]}$$

Since $R_1 > R_2$, therefore $\sigma_2 > \sigma_1$.

Charge density of smaller sphere is more than that of larger one.

**Q. 9. The two graphs are drawn below, show the variations of electrostatic potential (V) 1/r (r being the distance of field point from the point charge) for two point charges $q_1$ and $q_2$.**

**(i) What are the signs of the two charges?**
**(ii) Which of the two charges has the larger magnitude and why? [HOTS]**




**Ans. (i)** The potential due to positive charge is positive and due to negative charge, it is negative, so, is $q_1$ positive and $q_2$ is negative.

**(ii)** $V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$

The graph between V and 1/r is a straight line passing through the origin with slope $\frac{q}{4\pi\varepsilon_0}$

As the magnitude of slope of the line due to charge $q_2$ is greater than that due to $q_1$, $q_2$ has larger magnitude.

**Q. 10. The potential V due to a charge distribution at a point (x, y) is given by V = - x2 + 3y**

**Calculate the electric field, in magnitude and direction, due to this charge configuration at the point (1, 1).[HOTS]**

**Ans.**

$V = -4x^2+3y$

$$\therefore \quad E_x = -\frac{\partial V}{\partial x} = +8x \quad \text{and } E_y = -\frac{\partial V}{\partial y} = -3$$

$$\therefore \quad \text{Total } \vec{E} = 8x\hat{i} - 3\hat{j}$$

$$\text{At point } (1, 1), \vec{E} = 8x\hat{i} - 3\hat{j}$$

$$\therefore \quad |\vec{E}| = \sqrt{(8)^2 + (3)^2} = \sqrt{73}\, N/C$$

Also angle θ, which $\vec{E}$ makes with x-axis, is given by

$$\tan\theta = \frac{E_y}{E_x} = -\frac{3}{8} = -0.375$$

$$\theta = \tan^{-1}(-0.375)$$

**Q. 11. Two charges 5 nC and –2 nC are placed at points (5 cm, 0, 0) and (23 cm, 0, 0) in a region of space where there is no other external field. Calculate the electrostatic potential energy of this charge system. [HOTS]**

**Ans.** Given $q_1$ = 5 nC = $5\times10^{-9}$ C, $q_2$ = – 2 nC =$-2\times10^{-9}$ C

The charges are placed on X-axis. The distance between the charges

x = x2 –x1 = (23–5) cm = 18 cm = 0.18 m

∴ Electrostatic potential energy of charges

$$U = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{x}$$

$$\frac{9\times10^9(5\times10^{-9})(-2\times10^{-9})}{0.18} = 5 \times 10-7\text{J}$$

**Q. 12. A very thin plate of metal is placed exactly in the middle of the two plates of a parallel plate capacitor. What will be the effect on the capacitance of the system?**

**[HOTS]**

**Ans.** For a metal K=∞ and so when t << d, the capacitance

$$C=\frac{\varepsilon_0 A}{d-t\left(1-\frac{1}{K}\right)}=\frac{\varepsilon_\circ A}{d-t\left(1-\frac{1}{\infty}\right)}=\frac{\varepsilon_\circ A}{d-t}$$

$\text{As } t << \text{dC} = \frac{\varepsilon_0 A}{d},$ i.e., capacitance will remain unchanged.