O P JINDAL SCHOOL, SAVITRINAGAR

PRACTICE PAPER (SOLUTION)

CLASS XII PHYSICS **TOPIS : Electric potential and Capacitance**

Date : 09/04/20 **MM :40**

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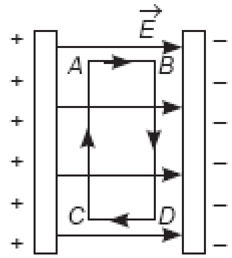
1 A uniform electric field E exists between two charged plates as shown in figure. What would be the work done in moving a charge q along 1



the closed rectangular path $ABCDA$?

ANS: Work done in moving a charge q along a closed rectangular path $ABCD$ is calculated as $W = W_{AB} + W_{BC} + W_{CD} + W_{DA}$ $W = qE + 0 - qE + 0 = 0$ [$\because$ $AB = CD$]

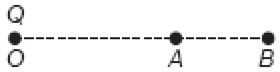
2 In the expression $W = pE$ (cos θ_0 – cos θ_1), why is θ_0 is taken as $\pi/2$ for obtaining expression for the potential energy of electric dipole? 1

ANS: When the dipole axis is perpendicular to the electric field, i.e. $\theta_0 = \pi/2$, the work done against the external electric field $\vec{E}$ in bringing the charges $+q$ and $-q$ is equal and opposite, and cancel out, i.e. $q[V(r_1) - V(r_2)] = 0$. Therefore, initial potential energy is zero.

3 For what position of an electric dipole in a uniform electric field its potential energy is (*i*) minimum and (*ii*) maximum? 1

ANS: (*i*) Potential energy of dipole in external field is minimum when $\vec{p}$ and $\vec{E}$ are parallel, i.e. $\theta = 0°$. $\therefore$ $U = -pE \Rightarrow$ U cos θ_{min} = $-pE$ (*ii*) The potential energy of dipole in the external field is maximum when $\vec{p}$ and $\vec{E}$ are anti-parallel, i.e. $\theta = 180°$ and $U_{max} = +pE$.

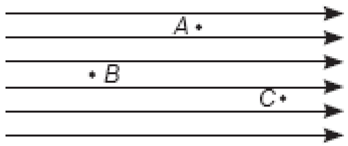
4 A point charge Q is placed at point O as shown in the figure. Is the potential difference $V_A - V_B$ positive, negative or zero, if Q is (i) positive



(ii) negative? 1

ANS: As $V \propto \frac{1}{r}$ (i) For Q having +ve value, $V_A > V_B$, i.e. $V_A - V_B$ is +ve. (ii) For Q having –ve value, $V_A < V_B$, i.e. $V_A - V_B$ is negative.

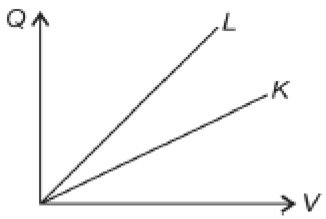
5 Figure given below shows three points A, B and C in a uniform electrostatic field. At which of the points will the electric potential be



maximum ? 1

ANS: At B, the electric potential will be maximum, because $E = -dV/dr$.

6 The following graph shows the variation of charge Q, with voltage V, for two capacitors K and L. In which capacitor is more electrostatic



energy stored? 1

ANS: In capacitor L, more electrostatic energy is stored.

7 A charge Q is given to three capacitors C_1, C_2 and C_3 connected in parallel. Determine the charge on each. 2

ANS: In parallel combination of capacitors, the total charge $Q = Q_1 + Q_2 + Q_3$. As potential difference across each capacitor is same,

$$\therefore \qquad P.D. = V = \frac{Q}{C_1+C_2+C_3} = \frac{Q_1}{C_1} = \frac{Q_2}{C_2} = \frac{Q_3}{C_3}$$

$$\therefore \text{ Charge on } C_1, \qquad Q_1 = \frac{C_1}{C_1+C_2+C_3}Q$$

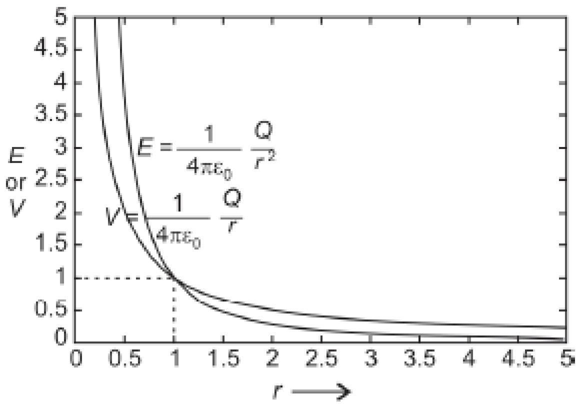
$$\text{Charge on } C_2, \qquad Q_2 = \frac{C_2}{C_1+C_2+C_3}Q$$

$$\text{Charge on } C_3, \qquad Q_3 = \frac{C_3}{C_1+C_2+C_3}Q$$

therefore ▪ $C_{eq} = C_1 + C_2 + C_3$

8 Draw a plot showing the variation of (*i*) electric field (*E* and (*ii*) electric potential (*V*) with distance *r* due to a point charge *Q*. 2

ANS:



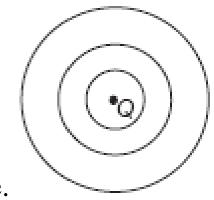
9 What is an electrostatic shielding? What is its practical importance? 2

ANS: Whatever be the charge and field configuration outside, any cavity in a conductor remains shielded from the outside electric influence. This is known as an electrostatic shielding. The effect can be made use of in protecting the sensitive instruments from the outside electrical influence.

10 (*a*) Draw equipotential surfaces due to a point $Q > 0$. (*b*) Are these surfaces equidistant from each other? If not, explain why. 2

ANS: The equipotential surfaces due to a charge *Q* are as shown below. (*a*) The equipotential surfaces are spherical concentric spheres.

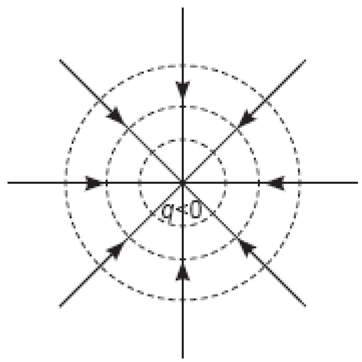
(*b*) The equipotential surfaces are not equidistant. $\because$ $E = -\frac{dV}{dr} \Rightarrow dr = -\frac{dV}{E}$ Clearly, as E decreases,

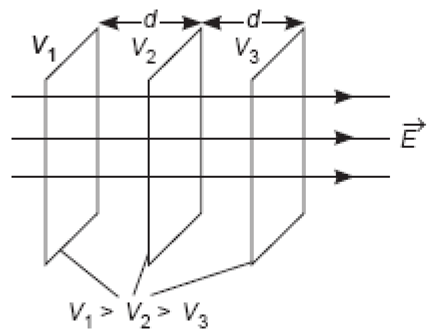


the distance between the equipotential surfaces goes on increasing as shown in the above figure.

11 Draw equipotential surfaces and corresponding electric field lines for the: (*i*) single point charge $q < 0$ and (*ii*) uniform electric field. 2

ANS: (*i*) Single point charge $q < 0$. (*ii*) Uniform electric field.

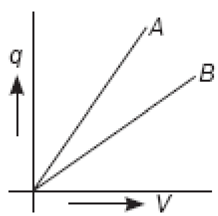




Equipotential

Surfaces Equipotential Surfaces

12 The given graph shows that 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 lines in the graph correspond to C_1 and C_2 and why?



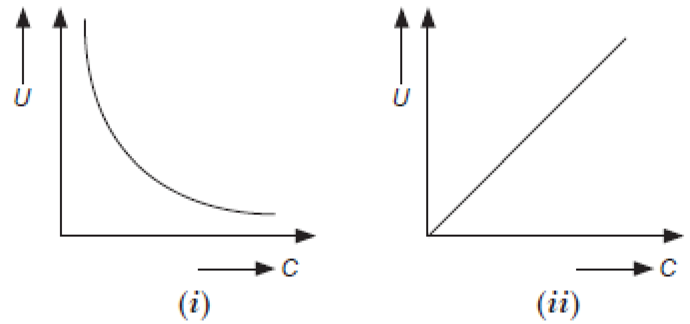
2

ANS: Since, $C \propto A$ [Area]

$\therefore C_2 = 2C_1$ ($\because A_2 = 2A_1$)

but $C = \frac{q}{V}$ So, more slope represents more capacitance.
Hence, A represents C_2 and B represents C_1.

13 The energy of a capacitor varying with its capacitance is shown by two graphs (i) and (ii). Find in which of the graphs: (a) charge is constant, and (b) potential difference is constant. 2



ANS: Energy stored by a capacitor, $U = \frac{1}{2}\frac{Q^2}{C} = \frac{1}{2}CV^2$

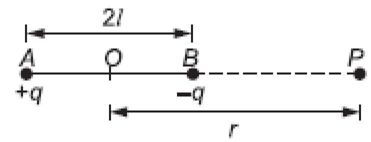
(a) In graph (i), the charge is constant as $U \propto \frac{1}{C}$.

(b) In graph (ii), the potential difference is constant as $U \propto V$.

14 Deduce an expression for the electric potential due to an electric dipole at any point on its axis. Mention one contrasting feature of electric potential of a dipole at a point as compared to that due to a single charge. 3

Potential at P due to charge at A is

$$V_{PA} = \frac{kq}{r+l}$$



Potential at P due to charge at B is

$$V_{PB} = -\frac{kq}{r-l}$$

Net potential at P is

$$V_P = V_{PA} + V_{PB} = kq\left[\frac{1}{r+l} - \frac{1}{r-l}\right] = kq\left[\frac{r-l-r-l}{r^2-l^2}\right] = -\frac{kq(2l)}{r^2-l^2}$$

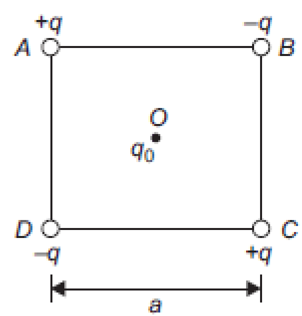
$$V_P = -\frac{kp}{r^2-l^2} \qquad [\because p = q(2l)]$$

ANS: In case $r >> l$, $V_P = -\frac{kp}{r^2}$, i.e. $V_P \propto \frac{1}{r^2}$, whereas due to a single charge potential at a point is $V \propto \frac{1}{r}$.

15 Four charges $+q$, $-q$, $+q$ and $-q$ are to be arranged respectively at the four corners of a square $ABCD$ of side a. (a) Find the work required to put together this arrangement. (b) A charge q_0 is bought to the centre of the square, the four charges being held fixed. How much extra work is needed to do this? 3

(a) $W = -\frac{4kq^2}{a} + \frac{kq^2}{a\sqrt{2}} + \frac{kq^2}{a\sqrt{2}} = +\frac{kq^2}{a}[\sqrt{2}-4]$

$$W = \frac{1}{4\pi\varepsilon_0}\frac{q^2}{a}[\sqrt{2}-4]$$



(b) Potential at the centre of the square, $V = 0$

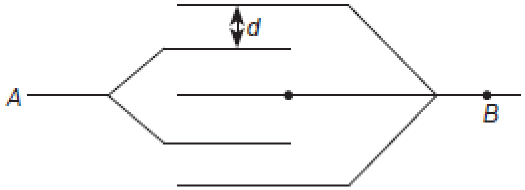
$$V_O = V_{OA} + V_{OB} + V_{OC} + V_{OD}$$

$$V_O = \frac{k\,q.q_0}{\left(\frac{a}{\sqrt{2}}\right)} + \frac{k(-q)q_0}{\left(\frac{a}{\sqrt{2}}\right)} + \frac{kq.q_0}{\frac{a}{\sqrt{2}}} + \frac{k(-q)q_0}{\left(\frac{a}{\sqrt{2}}\right)} = 0$$

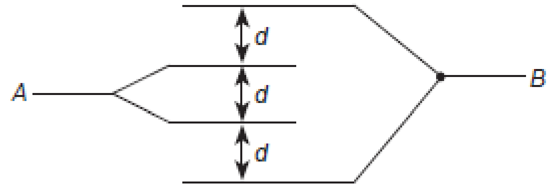
ANS: $\therefore$ Extra work done, $W = q_0 \times V = q_0 \times 0 = 0$

16 Five identical horizontal square metal plates each of area A are placed at a distance d apart in air and connected to the terminals A and B as 3

shown in the figures (a) and (b). Find the effective capacitance between the two terminals A and B.

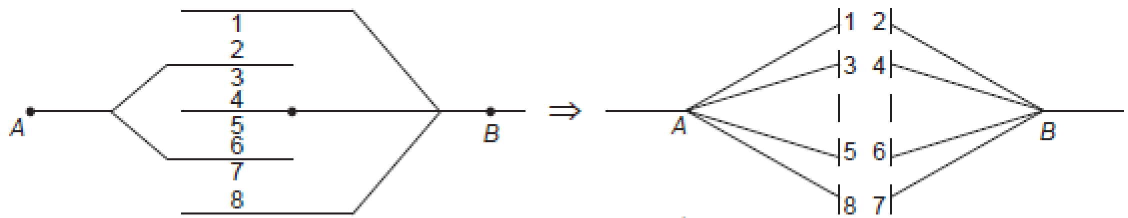


(*a*)



(*b*)

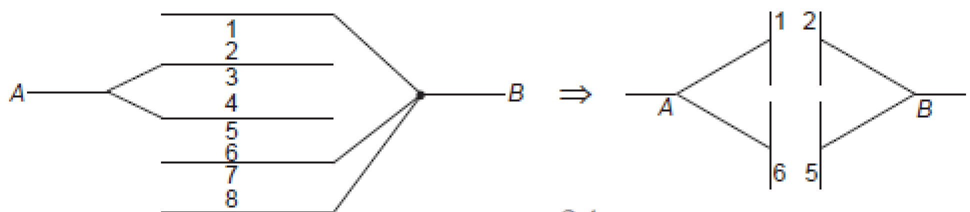
(*a*)



If the capacitance of a capacitor $= C_o = \dfrac{A\varepsilon_0}{d}$

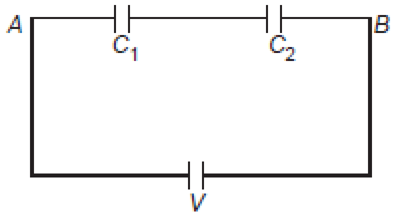
Then, $\quad C_{AB} = C_o + C_o + C_o + C_o = 4C_o = \dfrac{4A\varepsilon_0}{d}$

(*b*)

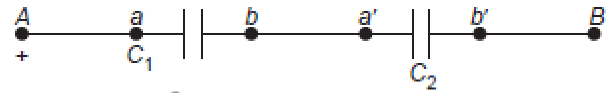


ANS: Then, $\quad C_{AB} = C_o + C_o = 2C_o = \dfrac{2A\varepsilon_0}{d}$

17 Two air-filled capacitors C_1 and C_2 of capacitances $2C$ and C are connected in series to a battery as shown below. (a) Find across which capacitor, the potential difference is high. (b) Draw the graph for variation of potential with distance from A to B. (c) If a dielectric of constant 2 is filled completely in the air gap of second capacitor, then what will be the final ratio of charge, potential difference and energy 3

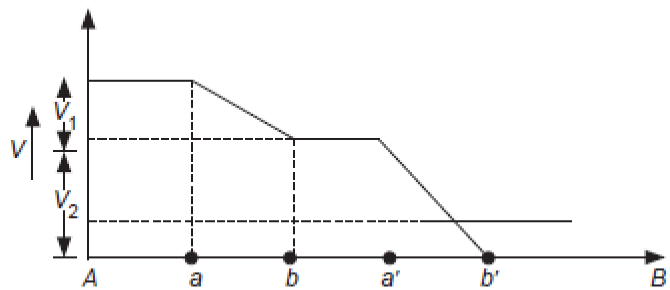


stored by each capacitor.



ANS: (a) In series, the charge remains same on each capacitor $\therefore$ P.D. $= V = \dfrac{Q}{C} \propto \dfrac{1}{C}$ Hence, the potential difference is high across C_2.

(*b*)



(*c*) Given: $C_1 = 2C$, $C_2 = C$

When the dielectric of $K = 2$ is filled completely in C_2, then $C_2' = 2C$ [$\because C = KC_0$]

$C_1 = C_2'$, if Q' is the charge on each capacitor

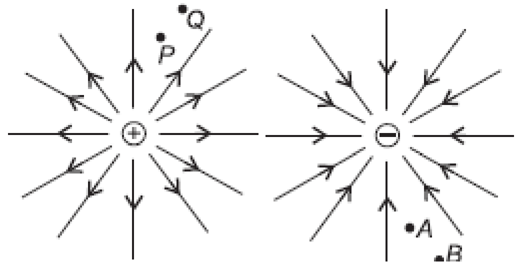
$\because \quad V_1 = \dfrac{Q'}{2C}; \quad V_2 = \dfrac{Q'}{2C}$

$\therefore \quad V_1 : V_2 :: 1 : 1$

Energy stored, $U_1 = \dfrac{1}{2} \times \dfrac{(Q')^2}{2C}$ and $U_2 = \dfrac{1}{2}\dfrac{(Q')^2}{2C}$

$\therefore \quad \dfrac{U_1}{U_2} = \dfrac{1}{1} = 1:1$

18 Figures (i) and (ii) show the field lines of the positive and negative point charges respectively. (a) Give the signs of the potential difference $V_p - V_Q$, $V_B - V_A$. (b) Give the sign of the potential energy difference of a small negative charge between the points Q and P, A and B. (c) Give the sign of the work done by the field in moving a small positive charge from Q to P. (d) Give the sign of the work done by the external agency in moving a small negative charge from B to A. (e) Does the kinetic energy of a small negative charge increase or decrease in going from B to A? 3



(i) (ii)

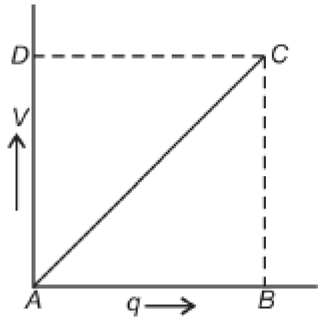
ANS: (a) As $V \propto \frac{1}{r}$, $V_P > V_Q$ and $V_B > V_A$

Thus, $V_P - V_Q$ is +ve and $V_B - V_A$ is +ve.

(b) Negative charge moves from Q to P, i.e. from higher potential energy to lower potential energy side. Therefore, lower potential energy side. Therefore, $(P.E.)_Q - (P.E.)_P > 0$ Similarly, $(P.E.)_A > (P.E.)_B$ i.e. $(P.E.)_A - (P.E.)_B > 0$ (c) In order to move a small positive charge from Q to P, work has to be done by an external agency against the electric field. So, the work done by the field is negative. (d) Work is done by an external agency in moving a small negative charge from B to A. Therefore, it is positive. (e) Due to force of repulsion, the velocity of the negative charge decreases. Hence, K.E. decreases in going from B to A.

19 Show by graph how q given to a capacitor varies with its potential difference.
Using the graph or otherwise, prove that the energy of a capacitor is 1/2 CV^2. Calculate the energy density of the electrostatic field in a parallel plate capacitor. 5

ANS: As $q = CV$, V versus q will be a straight line. During the process of giving charge q to the capacitor, the potential difference across the capacitor rises linearly from 0 to V. So, the charge q is given to the capacitor at on average potential difference $V/2$.



From the graph, areaof $ABC = \frac{1}{2}qV$

$[\because q = CV]$ $\therefore$ Energy stored $= q\left(\frac{V}{2}\right) = \frac{1}{2}CV^2$

$$\text{Energy density, } u = \frac{\text{Energy}}{\text{Volume}} = \frac{\frac{1}{2}CV^2}{Ad} = \frac{1}{2}\frac{\varepsilon_0 A}{d}\frac{(Ed)^2}{Ad} = \frac{1}{2}\varepsilon_0 E^2$$

N.B.-This sheet is prepared from home