Electrostatic Potential and Capacitance

CHAPTER 2

TRY YOURSELF ANSWERS

1. Electric potential $= \frac{\text{Work done}}{\text{Charge}} = \frac{[ML^2T^{-2}]}{[AT]} = ML^2T^{-3}A^{-1}$

$= \text{kg m}^2\text{s}^{-3}\text{ A}^{-1}$.

2. The electric potential at infinity is considered as zero.

3. Given : $q = 500\ \mu C$, $V_B = 20$ V, $V_A = ?$, $W_{BA} = 10$ J

$W_{AB} = q(V_A - V_B)$

$\frac{10}{500 \times 10^{-6}} = V_A - 20 \Rightarrow V_A = 20020$ V

4. Yes, the potential of a conductor depends not only on the net charge but also its geometrical shape and size. So, two different conductors of different shape and size will have different potentials even if they carry equal charges.

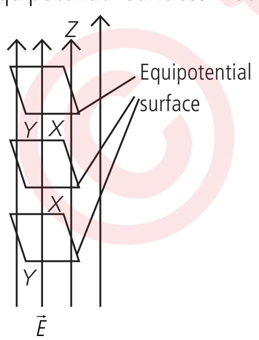
5. From figure, $V_A - V_B = \frac{kQ}{OA} - \frac{kQ}{OB}$

As $OA < OB$,

When Q is '+ve', $V_A - V_B$ is positive and when Q is negative $V_A - V_B$ is negative.

6. $V = V_A + V_B + V_C + V_D = \frac{1}{4\pi\epsilon_0 r}[-Q-Q+Q+Q] = 0$

7. As the magnitude of field increases along positive z-direction, distance between successive equipotential surfaces decreases as shown. If the electric field were constant, distance between successive equipotential surfaces would stay constant.



8. No work is done in moving a charge from one point to another on an equipotential surface. So, the component of electric field intensity along the equipotential surface is zero, it means the electric field intensity is perpendicular to the equipotential surface. Hence the surface is perpendicular to field lines.

9. According to the diagram, B and C are in same vertical line, so $V_B = V_C$

Now potential difference between A and C = potential difference between A and B

$V_{AC} = V_{AB} = -E\,.\Delta x$, $\Delta x = AB = \sqrt{5^2 - 3^2} = 4$ cm

$V_{AC} = -5 \times 10^3 \times 4 \times 10^{-2} = -200$ V

10. $E = -dV/dr$, as V is constant, so $E = 0$

11. Using the relation, $E = -\frac{dV}{dr}$, we find that the electric field intensity is maximum at P and minimum at R.

12. Let A be the area of each plate. When the two plates are placed d distance apart, capacitance of parallel plate capacitor formed is $C = \frac{\epsilon_0 A}{d}$

If E_1 and E_2 are electric fields due to the two plates, then the net field between the plates

$E = E_1 - E_2$

$\frac{\sigma_1}{2\epsilon_0} - \frac{\sigma_2}{2\epsilon_0} = \frac{1}{2A\epsilon_0}(q_1 - q_2)$

potential difference between the plates

$V = Ed = \frac{1}{2A\epsilon_0}(q_1 - q_2)d$

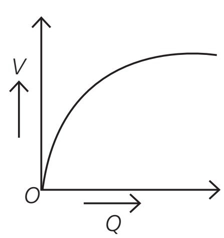
$V = \frac{1}{\frac{2\epsilon_0 A}{d}}(q_1 - q_2) = \frac{q_1 - q_2}{2C}$

13. $V = \frac{4\pi R^3}{3} \Rightarrow V \propto R^3 \Rightarrow R \propto V^{1/3}$

$\frac{C_2}{C_1} = \frac{R_2}{R_1} = \left(\frac{V_2}{V_1}\right)^{1/3} = \left(\frac{8V}{V}\right)^{1/3} = 2$

$C_2 = 2C_1$

14. Initially, the graph between V and Q is a straight line. But beyond a certain stage some leakage of charge starts and V does not increase with increasing Q. So, the graph is as shown in the figure.



15. No, the maximum charge that can be given to a capacitor is determined by the capacity of the condenser.

16. Dielectrics are non-conductors and do not have free electrons at all. While conductors has free electrons which makes it able to pass the electricity through it.

17. In series grouping, the resultant capacitance is minimum,

i.e., $C_s = \frac{C_1C_2}{C_1+C_2} = 4\ \mu F$

In parallel grouping, the resultant capacitance is maximum,

$C_P = C_1 + C_2 = 25\ \mu F$

It implies that the remaining values of 5 μF and 20 μF represent the individual capacitance values of two capacitors.

18. The new arrangement is equivalent to two capacitors connected in parallel.

$$C_1 = \frac{\epsilon_0 A/2}{d}, C_2 = \frac{k\epsilon_0 A/2}{d}$$

$$C_P = C_1 + C_2 = \frac{\epsilon_0 A}{2d} + \frac{k\epsilon_0 A}{2d} = \frac{\epsilon_0 A}{2d}(k+1) = \frac{C}{2}(k+1)$$

19. On introducing a thin metal foil, d is halved.

Arrangement is equivalent to two condensers each of capacity $2C$ in series

$$\frac{1}{C_S} = \frac{1}{2C} + \frac{1}{2C} = \frac{1}{C} \Rightarrow C_S = C$$

Capacity is unchanged.

20. In series, charge on C_1 = charge on C_2

$6 \times 2 = 12 \times V_2$

$V_2 = \frac{12}{12} = 1$ volt

Total voltage, $V = V_1 + V_2 = 2 + 1 = 3V$

21. Total charge, $q = CV$ and total energy, $U = \frac{1}{2}CV^2$

Now, V is constant and $C_P > C_S$.

Therefore parallel combination is required for storing greater charge and greater energy.

22. (a) As $Q = CV$, if V is doubled, charge also doubled.

(b) As $U = \frac{1}{2}CV^2$, if V is doubled, U becomes four times.

23. Let the capacitance is C

Emf of battery = V

Charge, $q = CV$

Energy supplied by battery = Work done by battery = qV

Energy stored in capacitor = $\frac{1}{2}CV^2 = \frac{1}{2}qV$

Energy lost as heat = $qV - \frac{1}{2}qV = \frac{1}{2}qV$

So, half energy is lost as heat while charging the capacitor.

24. A capacitor supplies electric energy stored in it. A cell supplies electrical energy by converting chemical energy into electrical energy at constant potential difference.

25. With increase in separation between the two plates, capacity C decreases.

When battery is removed, charge Q and electric field $E = \frac{\sigma}{\epsilon_0} = \frac{Q}{A\epsilon_0}$ would remain constant. But when battery remains connected, V is constant, Q (=CV) decreases and hence E decreases. Clearly more work is required to be done in the first case.