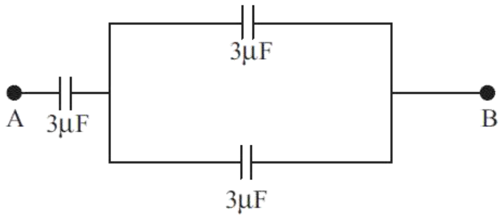
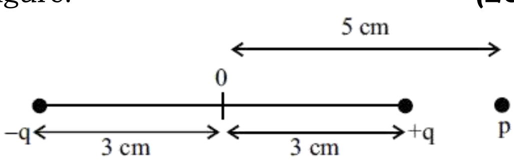
Electric Potential and Capacitance

1. The equivalent capacitance of the system shown in the following circuit is: **(2023)**



(a) 9 μF
(b) 2 μF
(c) 3 μF
(d) 6 μF

2. An electric dipole is placed as shown in the figure. **(2023)**



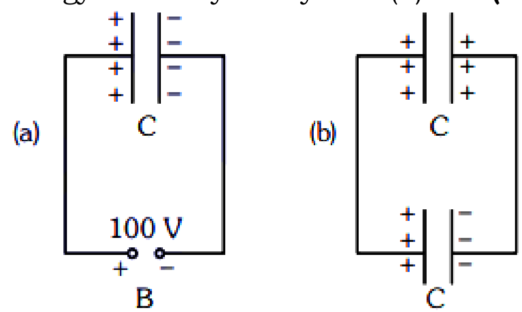
The electric potential (in 102 V) at point P due to the dipole is
(ϵ_0= permittivity of free space and $\frac{1}{4\pi} = K$:)

(a) $\left(\frac{8}{3}\right) qK$
(b) $\left(\frac{3}{8}\right) qK$
(c) $\left(\frac{5}{8}\right) qK$
(d) $\left(\frac{8}{5}\right) qK$

3. Two hollow conducting spheres of radii R_1 and R_2 ($R_1 \gg R_2$) have equal charges. The potential would be: **(2022)**
(a) More on smaller sphere
(b) Equal on both the spheres
(c) Dependent on the material property of the sphere
(d) More on bigger sphere

4. The angle between the electric lines of force and the equipotential surface is: **(2022)**
(a) 45°
(b) 90°
(c) 180°
(d) 0°

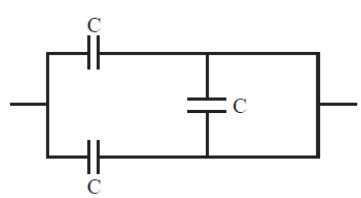
5. A capacitor of capacitance C = 900 pF is charged fully by 100 V battery B as shown in figure (a). Then it is disconnected from the battery and connected to another uncharged capacitor of capacitance C = 900 pF as shown in figure (b). The electrostatic energy stored by the system (b) is **(2022)**



(a) $3.25 \times 10^{-6} J$
(b) $2.25 \times 10^{-6} J$
(c) $1.5 \times 10^{-6} J$
(d) $4.5 \times 10^{-6} J$

6. Two charged spherical conductors of radius R_1 and R_2 are connected by a wire. Then the ratio of surface charge densities of the spheres (σ_1/σ_2) is: **(2021)**
(a) $\frac{R_2}{R_1}$
(b) $\sqrt{\left(\frac{R_1}{R_2}\right)}$
(c) $\frac{R_1^2}{R_2^2}$
(d) $\frac{R_1}{R_2}$

7. The equivalent capacitance of the combination shown in the figure is: **(2021)**



(a) 2C
(b) C/2
(c) 3C/2
(d) 3C

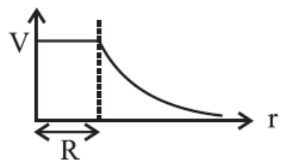
8. A parallel plate capacitor has a uniform electric field '$\vec{E}$' in the space between the plates. If the distance between the plates is 'd' and the area of each plate is 'A', the energy stored in the capacitor is: **(2021)**
(a) $\varepsilon_0 EAd$
(b) $\frac{1}{2}\varepsilon_0 E^2 Ad$

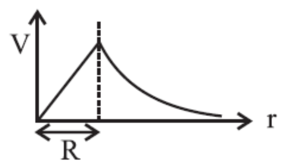
(c) $\frac{E^2 Ad}{\varepsilon_0}$

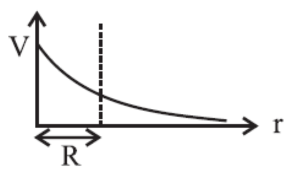
(d) $\frac{1}{2}\varepsilon_0 E^2$

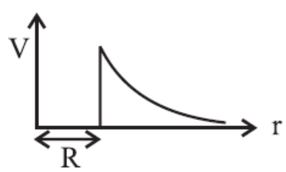
9. Twenty seven drops of same size are charged at 220 V each. They combine to form a bigger drop. Calculate the potential of the bigger drop. **(2021)**
(a) 1320 V
(b) 1520 V
(c) 1980 V
(d) 660 V

10. The variation of electrostatic potential with radial distance r from the centre of a positively charged metallic thin shell of radius R is given by the graph. **(2020 Covid Re-NEET)**

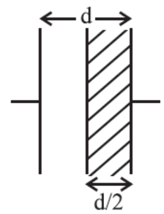
(a) 

(b) 

(c) 

(d) 

11. A parallel plate capacitor having cross-sectional area A and separation d has air in between the plates. Now an insulating slab of same area but thickness d/2 is inserted between the plates as shown in figure having dielectric constant K (= 4). The ratio of new capacitance to its original capacitance will be, **(2020 Covid Re-NEET)**



(a) 8 : 5
(b) 6 : 5
(c) 4 : 1
(d) 2 : 1

12. In a certain region of space with volume 0.2 m^3, the electric potential is found to be 5V throughout. The magnitude of electric field in this region is: **(2020)**
(a) 0.5 N/C
(b) 1 N/C
(c) 5 N/C
(d) Zero

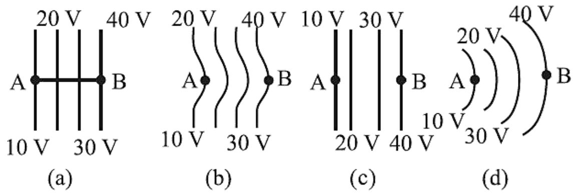
13. The capacitance of a parallel plate capacitor with air as medium is 6mF. With the introduction of a dielectric medium, the capacitance becomes 30 mF. The permittivity of the medium is : **(2020)**
($\varepsilon_0 = 8.85 \times 10^{-12} C^2N^{-1}m^{-2}$)
(a) $1.77 \times 10^{-12} C^2N^{-1}m^{-2}$
(b) $0.44 \times 10^{-10} C^2N^{-1}m^{-2}$
(c) $5.00 C^2N^{-1}m^{-2}$
(d) $0.44 \times 10^{-13} C^2N^{-1}m^{-2}$

14. A short electric dipole has a dipole moment of $16 \times 10^{-9} C\,m$. The electric potential due to the dipole at a point at a distance of 0.6 m from the centre of the dipole, situated on a line making an angle of 60° with the dipole axis is: **(2020)**
$\left(\frac{1}{4\pi\epsilon_0} = 9 \times 10^9 N\,m^2/C^2\right)$
(a) 200 V
(b) 400 V
(c) Zero
(d) 50 V

15. The electrostatic force between the metal plates of an isolated parallel plate capacitor C having a charge Q and area A, is **(2018)**
(a) Proportional to the square root of the distance between the plates.
(b) Linearly proportional to the distance between the plates.
(c) Independent of the distance between the plates.
(d) Inversely proportional to the distance between the plates.

16. A capacitor is charged by a battery. The battery is removed and another identical uncharged capacitor is connected in parallel. The total electrostatic energy of resulting system:
(a) Decreases by a factor of 2
(b) Remains the same
(c) Increases by a factor of 2
(d) Increases by a factor of 4

17. The diagrams below show regions of equipotentials **(2017-Delhi)**

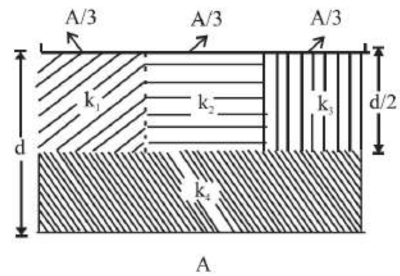


A positive charge is moved from A to B in each diagram.
(a) In all the four cases the work done is the same.
(b) Minimum work is required to move q in figure (a)
(c) Maximum work is required to move q in figure (b)
(d) Maximum work is required to move q in figure (c)

18. A molecule of a substance has permanent dipole moment P. A mole of this substance is polarised by applying a strong electrostatic field E. The direction of the field is suddenly changed by an angle of 60°. If N is the Avogadro's number the amount of work done by the field is: **(2017-Gujrat)**
(a) 2NPE
(b) $\frac{1}{2}$NPE
(c) NPE
(d) $\frac{3}{2}$NPE

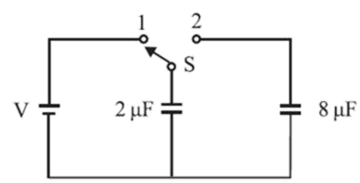
19. A parallel-plate capacitor is to be designed, using a dielectric of dielectric constant 3, so as to have a dielectric strength of $10^9 Vm^{-1}$. If the voltage rating of the capacitor is 12 kV, the minimum area of each plate required to have a capacitance of 80 pF is: **(2017-Gujarat)**
(a) $3.6 \times 10^{-5} m^2$
(b) $21.7 \times 10^{-6} m^2$
(c) $25.0 \times 10^{-5} m^2$
(d) $12.5 \times 10^{-5} m^2$

20. A parallel-plate capacitor of area A, plate separation d and capacitance C is filled with four dielectric materials having dielectric constants k_1, k_2, k_3 and k_4 as shown in the figure below. If a single dielectric material is to be used to have the same capacitance C in this capacitor, then its dielectric constant k is given by: **(2016-II)**



(a) $\frac{2}{k} = \frac{3}{k_1+k_2+k_3} + \frac{1}{k_4}$
(b) $\frac{1}{k} = \frac{1}{k_1} + \frac{1}{k_2} + \frac{1}{k_3} + \frac{3}{2k_4}$
(c) $k = k_1 + k_2 + k_3 + 3k_4$
(d) $k = \frac{2}{3}(k_1 + k_2 + k_3) + 2k_4$

21. A capacitor of 2 μF is charged as shown in the diagram. When the switch S is turned to position 2, the percentage of its stored energy dissipated is: **(2016-I)**



(a) 0%
(b) 20%
(c) 75%
(d) 80%

22. A parallel plate air capacitor of capacitance C is connected to a cell of emf V and then disconnected from it. A dielectric slab of dielectric constant K, which can just fill the air gap of the capacitor, is now inserted in it. Which of the following is incorrect? **(2015)**
(a) The energy stored in the capacitor decreases K times
(b) The change in energy stored is $\frac{1}{2}CV^2\left(\frac{1}{K} - 1\right)$
(c) The charge on the capacitor is not conserved
(d) The potential difference between the plates decreases K times

23. If potential (in volts) in a region is expressed as $V(x, y, z) = 6xy - y + 2yz$, the electric field (in N/C) at point (1, 1, 0) is: **(2015 Re)**

(a) $-(6\hat{i} + 9\hat{j} + \hat{k})$
(b) $-(3\hat{i} + 5\hat{j} + 3\hat{k})$
(c) $-(6\hat{i} + 5\hat{j} + 2\hat{k})$
(d) $-(2\hat{i} + 3\hat{j} + \hat{k})$

24. A parallel plate air capacitor has capacity 'C' distance of separation between plates is 'd' and potential difference 'V' is applied between the plates force of attraction between the plates of the parallel plate air capacitor is: **(2015 Pre)**

(a) $\frac{V^2V^2}{2d^2}$
(b) $\frac{C^2V^2}{2d}$
(c) $\frac{CV^2}{2d}$
(d) $\frac{CV^2}{d}$

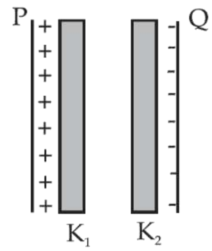
25. In a region, the potential is represented by V(x, y, z) = 6x – 8xy – 8y + 6yz, where V is in volts and x, y, z are in meters. The electric force experienced by a charge of 2 coulomb situated at point (1, 1, 1) is: **(2014)**

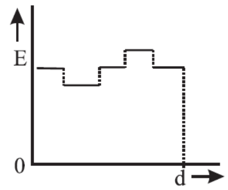
(a) $6\sqrt{5}N$
(b) $30\ N$
(c) $24\ N$
(d) $4\sqrt{35}N$

26. A conducting sphere of radius R is given a charge Q. The electric potential and the electric field at the center of the sphere respectively are: **(2014)**

(a) Zero and $\frac{Q}{4\pi\varepsilon_0 R^2}$
(b) $\frac{Q}{4\pi\varepsilon_0 R^2}$ and Zero
(c) $\frac{Q}{4\pi\varepsilon_0 R^2}$ and $\frac{Q}{4\pi\varepsilon_0 R^2}$
(d) Both are zero

27. Two thin dielectric slabs of dielectric constants K_1 and K_2 ($K_1 < K_2$) are inserted between plates of a parallel plate capacitor, as shown in the figure. The variation of electric field E between the plates with distance d as measured from plate P is correctly shown by: **(2014)**



(a)


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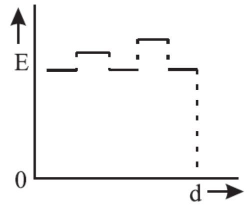

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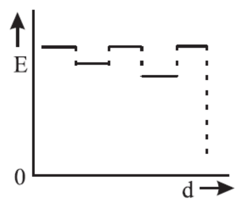
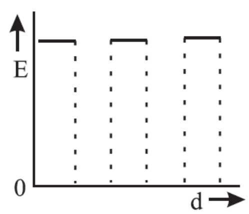
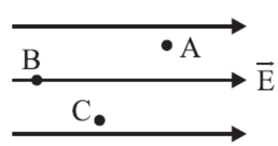


(d)


28. A, B and C are three points in a uniform electric field. The electric potential is: **(2013)**



(a) Same at all the three points A, B and C
(b) Maximum at A
(c) Maximum at B
(d) Maximum at C

Answer Key

S1. Ans. (b)

S2. Ans. (c)

S3. Ans. (a)

S4. Ans. (b)

S5. Ans. (b)

S6. Ans. (a)

S7. Ans. (a)

S8. Ans. (b)

S9. Ans. (c)

S10. Ans. (a)

S11. Ans. (d)

S12. Ans. (b)

S13. Ans. (a)

S14. Ans. (c)

S15. Ans. (c)

S16. Ans. (a)

S17. Ans. (a)

S18. Ans. (b)

S19. Ans. (a)

S20. Ans. (a)

S21. Ans. (d)

S22. Ans. (c)

S23. Ans. (c)

S24. Ans. (c)

S25. Ans. (d)

S26. Ans. (b)

S27. Ans. (c)

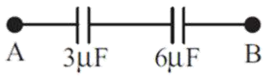
S28. Ans. (c)

Solutions

S1. Ans.(b)

$3\mu F$ and $3\mu F$ in parallel

$\Rightarrow C_{eqv} = 3 + 3 = 6\mu F$



$C'_{eqv} = \frac{3\times6}{9} = 2\mu F$

S2. Ans.(c)

$V_P = V_q + V_{-q}$

$= \left(\frac{Kq}{5-3} + \frac{K(-q)}{5+3}\right) \times 10^2$

$= \left(\frac{Kq}{2} - \frac{Kq}{8}\right) \times 10^2$

$= \left(\frac{3Kq}{8}\right) \times 10^2$

S3. Ans.(a)

$V = \frac{1}{4\pi\epsilon_0} = \text{constant}$

$Q = \text{Same (Given)}$

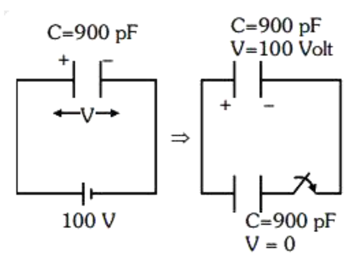
$\therefore V \propto \frac{1}{R}$

$\therefore$ Potential is more on smaller sphere.

S4. Ans.(b)

Electric field is always perpendicular to EPS.

S5. Ans.(b)



Common potential

$V_C = \frac{C_1V_1+C_2V_2}{C_1+C_2}$

$= \frac{C\times100+C\times0}{C+C}$

$= 50$ Volt

Electrostatic energy stored

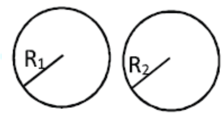
$= 2 \times \frac{1}{2}CV^2 = CV^2$

$= 900 \times 10^{-12} \times 50 \times 50$

$= 225 \times 10^{-8} J$

$= 2.25 \times 10^{-6} J$

S6. Ans.(a)



$Q_1 = \frac{1}{2}\varepsilon_0 E^2 Ad$

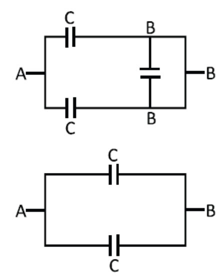
$Q_2 = \frac{\Sigma Q}{R_1+R_2} \times R_1$

$\sigma_1 = \frac{\Sigma Q}{R_1+R_2} \times R_2$

$\sigma_2 = \frac{Q_1}{4\pi R_1^2} = \frac{\Sigma Q}{R_1+R_2} \times \frac{R_1}{4\pi R_1^2} \propto \frac{1}{R_1}$

$\frac{\sigma_1}{\sigma_2} = \frac{R_2}{R_1}$

S7. Ans.(a)



$C_{AB} = 2C$

S8. Ans.(b)

Energy = Energy density × volume

$\frac{1}{2}\varepsilon_0 E^2 Ad$

S9. Ans.(c)

The radius of the bigger drop will be

$\frac{4}{3}\pi R^3 = 27 \times \frac{4}{3}\pi r^3$

R = 3r the potential of the small drop

$= \frac{KQ}{r} = \text{v}$

The potential of the big drop

$Q = ng = 27q$

$V' = \frac{KQ}{R} = \frac{K\times27q}{3r} = 9\text{v}$

$9 \times 220 = 1980\, V$

S10. Ans.(a)

$V_{in} = V_s = \frac{KQ}{R}$ and $V_{out} = \frac{KQ}{r} (r > R)$

S11. Ans.(a)

$C_K = \frac{\varepsilon_0 A}{d-t+\frac{t}{K}} = \frac{\varepsilon_0 A}{d-\frac{d}{2}+\frac{d}{8}} = \frac{8}{5}\frac{\varepsilon_0 A}{d}$

$C_a = \frac{\varepsilon_0 A}{d}$

$\therefore C_k = \frac{8}{5} C_a \Rightarrow \frac{C_k}{C_a} = \frac{8}{5}$

S12. Ans.(d)

Since, electric potential is found to be constant throughout, hence electric field, $E = \frac{-dv}{dr} = 0$.

S13. Ans.(b)

$C_m = \varepsilon_r C_0$

$\varepsilon_r = \frac{30}{6} = 5$

$\varepsilon = \varepsilon_0, \varepsilon_r = 8.85 \times 10^{-12} \times 5$

$\varepsilon = 0.44 \times 10^{-10}$

S14. Ans.(a)

The electric potential due to the dipole at a point at a distance of 0.6 m from the centre of the dipole is

$V = \frac{K_p \cos\theta}{r^2}$

$V = \frac{9\times10^9\times16\times10^{-9}\times\cos 60}{0.36}$

$V = 200\,V$

S15. Ans.(c)

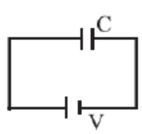
Force $= \frac{Q^2}{2A\varepsilon_0}$

Force is independent of separation d.

S16. Ans.(a)

Energy stored in capacitor by charging

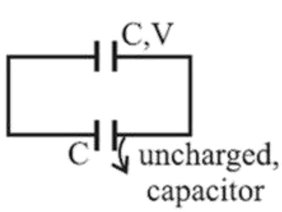
$U_1 = \frac{1}{2} CV^2$



When it is connected parallel to uncharged capacitor

$V_1 = \frac{V}{2}$ [potential equal]

$C_{eff} = C + C = 2C$



$U_2 = \frac{1}{2} \times (2C) \left(\frac{V}{2}\right)^2 = \frac{U}{2}$

S17. Ans.(a)

$W = q\Delta V$

For all cases potential difference remains same hence work done is same for all cases.

S18. Ans.(b)

Work done by the field for a dipole

$W = PE[\cos\theta_1 - \cos\theta_2]$

$\theta_1 = 0 \qquad \theta_2 = 60$

$W = PE[\cos 0 - \cos 60]$

$W = \frac{PE}{2}$

For "N" molecule

$W = \frac{NPE}{2}$

S19. Ans.(a)

$C = \frac{kA\varepsilon_0}{d}$

$E = \frac{V}{d}$

$C = \frac{kA\varepsilon_0 E}{V}$

$A = \frac{CV}{k\varepsilon_0 E} = \frac{80\times10^{-12}\times12\times10^3}{3\times8.85\times10^{-12}\times10^9}$

$A = 3.6 \times 10^{-5}$

S20. Ans.(a)

$C_1 = \frac{2k_1\varepsilon_0 A}{3d} \qquad C_2 = \frac{2k_2\varepsilon_0 A}{3d}$

$C_3 = \frac{2k_3\varepsilon_0 A}{3d} \qquad C_4 = \frac{k_4 2\varepsilon_0 A}{d}$

$\frac{1}{C} = \frac{1}{C_1+C_2+C_3} + \frac{1}{C_4}$

Solving, we get

$C = \frac{k\varepsilon_0 A}{d}$

$\therefore \frac{d}{k\varepsilon_0 A} = \frac{d}{2\varepsilon_0 A}\left[\frac{3}{k_1+k_2+k_3} + \frac{1}{k_4}\right]$

$\Rightarrow \frac{2}{K} = \left[\frac{3}{k_1+k_2+k_3} + \frac{1}{k_4}\right]$

S21. Ans.(d)

Initial energy stored in capacitor 2 μF

$U_i = \frac{1}{2} 2(V)^2 = V^2$

$= \frac{1}{2} \times 2 \times 10^{-6} \times V^2$

$= V^2 \times 10^{-6}$

Final voltage after switch 2 in ON

$V_f = \frac{C_1 V_1}{C_1+C_2} = \frac{2V}{10} = 0.2V$

Final energy in both capacitors

$U_f = \frac{1}{2}(C_1 + C_2)V_f^2 = \frac{1}{2} \times 10 \times 10^{-6} \times \left(\frac{2V}{10}\right)^2$

$= 0.2V^2$

So energy dissipated

$= \frac{V^2 - 0.2V^2}{V^2} \times 100 = 80\%$

S22. Ans.(c)

Once the capacitor is charged, its charge will be constant Q = CV

When dielectric slab is inserted

$C_{New} = KC$

$E = \frac{Q^2}{2C} \Rightarrow E_{New} = \frac{1}{K} E_{initial}$

$V = \frac{Q}{C}$ so $V_{New} = \frac{1}{K} V$

S23. Ans.(c)

$\vec{E} = -\frac{\partial V}{\partial x}\hat{\imath} - \frac{\partial V}{\partial y}\hat{\jmath} - \frac{\partial V}{\partial z}\hat{k}$

At point (1,1,0)

$\vec{E} = -6\hat{\imath} - 5\hat{\jmath} - 2\hat{k} = -(6\hat{\imath} + 5\hat{\jmath} + 2\hat{k})$

S24. Ans.(c)

$F = \frac{Q^2}{2\varepsilon_0 A}$

$\because Q = CV$ and $C = \frac{\varepsilon_0 A}{d} \Rightarrow \varepsilon_0 A = Cd$

So $F = \frac{C^2V^2}{2Cd} = \frac{CV^2}{2d}$

S25. Ans.(d)

$\vec{E} = -\frac{\partial V}{\partial x}\hat{\imath} - \frac{\partial V}{\partial y}\hat{\jmath} - \frac{\partial V}{\partial z}\hat{k}$

$= -[(6 - 8y)\hat{\imath} + (-8x - 8 + 6z)\hat{\jmath} + (6y)\hat{k}]$

At (1,1,1), $\vec{E} = 2\hat{\imath} + 10\hat{\jmath} - 6\hat{k}$

$\Rightarrow (\vec{E}) = \sqrt{2^2 + 10^2 + 6^2} = \sqrt{140} = 2\sqrt{35}$

Force $= qE = 2 \times 2\sqrt{35} = 4\sqrt{35}N$

S26. Ans.(b)

At center, E = 0 and $V = \frac{Q}{4\pi\varepsilon_0 R}$

S27. Ans.(c)

As $K_1 < K_2$ so $E_1 > E_2$

S28. Ans.(c)

Electric potential decreases in the direction of electric field. Therefore, potential is maximum at B.