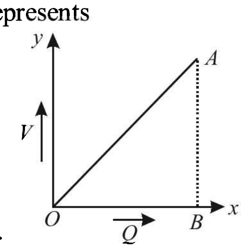
16 Electrostatic Potential and Capacitance

Conceptual MCQs

1. A dielectric slab is inserted between the plates of an isolated charged capacitor. Which of the following quantities remain unchanged ?
(a) The charge on the capacitor
(b) The stored energy in the Capacitor
(c) The potential difference between the plates
(d) The electric field in the capacitor

2. Charge Q on a capacitor varies with voltage V as shown in the figure, where Q is taken along the X-axis and V along the Y-axis. The area of triangle OAB represents



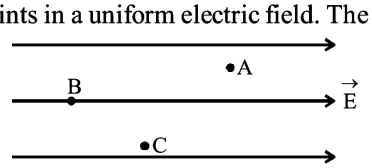
(a) capacitance
(b) electric field
(c) electrostatic force
(d) energy stored in the capacitor

3. Potential at any point inside a charged hollow sphere
(a) increases with distance from surface
(b) is a constant
(c) decreases with distance from centre
(d) is zero

4. The electric potential at a point (x, y) in the x-y plane is given by V = – kxy. The magnitude of field intensity at a distance r from the origin varies as (directly proportional)

(a) r^2 (b) r (c) $\frac{1}{r}$ (d) $\frac{1}{r^2}$

5. A, B and C are three points in a uniform electric field. The electric potential is



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

6. The electrostatic force between the metal plates of an isolated parallel plate capacitor C having a charge Q and area A, is
(a) independent of the distance between the plates
(b) linearly proportional to the distance between the plates
(c) inversely proportional to the distance between the plates
(d) proportional to the square root of the distance between the plates

7. A hollow conducting sphere of radius R has a charge (+Q) on its surface. What is the electric potential within the sphere at a distance r = R/3 from its centre

(a) Zero (b) $\frac{3}{4\pi\varepsilon_0}\frac{Q}{R}$

(c) $\frac{1}{4\pi\varepsilon_0}\frac{Q}{R}$ (d) $\frac{1}{4\pi\varepsilon_0}\frac{Q}{R^2}$

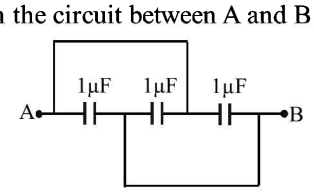
8. A parallel plate capacitor is charged by a battery to a potential. The battery is disconnected and a dielectric slab (K) is inserted to completely fill the space between the plates. How will its potential difference between the plates and energy stored in the capacitor be affected?

(a) reduced to $\frac{1}{K}$ times (b) increased to $\frac{1}{K}$ times
(c) reduced to K times (d) increased to K times

9. An electron of mass m and charge e is accelerated from rest through a potential difference V in vacuum. The final speed of the electron will be

(a) $V\sqrt{e/m}$ (b) $\sqrt{eV/m}$
(c) $\sqrt{2eV/m}$ (d) $2eV/m$

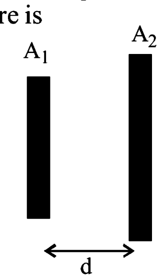
10. The equivalent capacitance in the circuit between A and B will be



(a) 1 μF
(b) 2 μF
(c) 3 μF
(d) 1/3 μF

11. Equal charges are given to two spheres of different radii. The potential will be
(a) more on smaller sphere (b) more on bigger sphere
(c) equal on both sphere (d) None of these

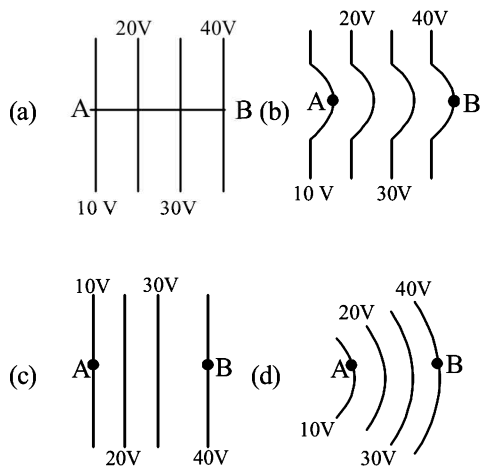
12. The capacitance of the capacitor of plate areas A_1 and A_2 ($A_1 < A_2$) at a distance d, as shown in figure is



(a) $\frac{\epsilon_0 (A_1 + A_2)}{2d}$ (b) $\frac{\epsilon_0 A_2}{d}$

(c) $\frac{\epsilon_0 \sqrt{A_1 A_2}}{d}$ (d) $\frac{\epsilon_0 A_1}{d}$

13. The diagrams below show regions of equipotentials.



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)

14. 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

15. A particle A has a charge q and particle B has charge + 4q with each of them having the mass m, when allowed to fall from rest through same potential difference. The ratio of their speeds $v_A : v_B$ will be

(a) 4 : 1 (b) 1 : 4 (c) 1 : 2 (d) 2 : 1

Application Based MCQs

16. The electrostatic potential inside a charged spherical ball is given by $\phi = ar^2 + b$ where r is the distance from the centre a, b are constants. Then the charge density inside the ball is

(a) $-6a\varepsilon_0 r$ (b) $-24\pi a\varepsilon_0$

(c) $-6a\varepsilon_0$ (d) $-24\pi a\varepsilon_0 r$

17. 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 metres. The electric force experienced by a charge of 2 coulomb situated at point (1, 1, 1) is :

(a) $6\sqrt{5}$ N (b) 30 N

(c) 24 N (d) $4\sqrt{35}$ N

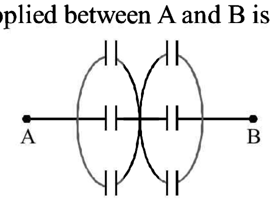
18. All six capacitors shown are identical. Each can withstand maximum 200 volts between its terminal. The maximum voltage that can be safely applied between A and B is

(a) 1200 V

(b) 400 V

(c) 800 V

(d) 200 V

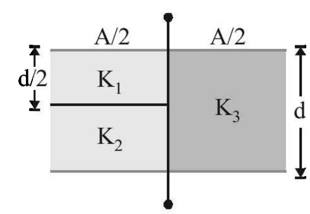


19. A ball of mass 1 g and charge 10^{-8} C moves from a point A where potential is 600 V to the point B where potential is zero. Velocity of the ball at the point B is 20 cm/s. The velocity of the ball at the point A will be

(a) 22.8 cm/s (b) 228 cm/s

(c) 16.8 m/s (d) 168 m/s

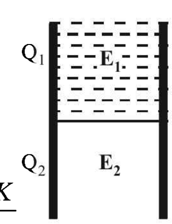
20. In the figure a capacitor is filled with dielectrics. The resultant capacitance is



(a) $\frac{2\varepsilon_0 A}{d}\left[\frac{1}{k_1}+\frac{1}{k_2}+\frac{1}{k_3}\right]$ (b) $\frac{\varepsilon_0 A}{d}\left[\frac{1}{k_1}+\frac{1}{k_2}+\frac{1}{k_3}\right]$

(c) $\frac{2\varepsilon_0 A}{d}[k_1 + k_2 + k_3]$ (d) None of these

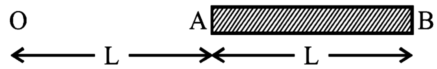
21. A parallel plate capacitor has a dielectric slab of dielectric constant K between its plates that covers 1/3 of the area of its plates, as shown in the figure. The total capacitance of the capacitor is C while that of the portion with dielectric in between is C_1. When the capacitor is charged, the plate area covered by the dielectric gets charge Q_1 and the rest of the area gets charge Q_2. Choose the correct option, ignoring edge effects.



(a) $\frac{E_1}{E_2} = 2$ (b) $\frac{E_1}{E_2} = \frac{1}{K}$

(c) $\frac{Q_1}{Q_2} = \frac{3}{K}$ (d) $\frac{C}{C_1} = \frac{2+K}{K}$

22. A charge Q is uniformly distributed over a long rod AB of length L as shown in the figure. The electric potential at the point O lying at distance L from the end A is



(a) $\frac{Q}{8\pi\varepsilon_0 L}$ (b) $\frac{3Q}{4\pi\varepsilon_0 L}$

(c) $\frac{Q}{4\pi\varepsilon_0 L \ln 2}$ (d) $\frac{Q \ln 2}{4\pi\varepsilon_0 L}$

23. Assume that an electric field $\vec{E} = 30x^2\hat{i}$ exists in space. Then the potential difference $V_A - V_O$, where V_O is the potential at the origin and V_A the potential at x = 2 m is:

(a) 120 J/C (b) –120 J/C

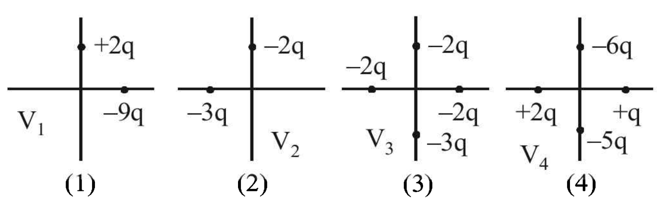
(c) –80 J/C (d) 80 J/C

24. Each corner of a cube of side l has a negative charge, –q. The electrostatic potential energy of a charge q at the centre of the cube is

(a) $-\frac{4q^2}{\sqrt{2}\pi\varepsilon_0 l}$ (b) $\frac{\sqrt{3}q^2}{4\pi\varepsilon_0 l}$

(c) $\frac{4q^2}{\sqrt{2}\pi\varepsilon_0 l}$ (d) $-\frac{4q^2}{\sqrt{3}\pi\varepsilon_0 l}$

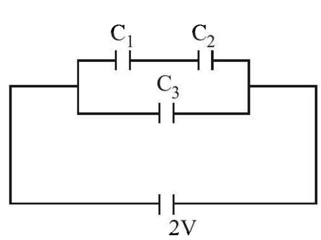
25. The figure given below shows four arrangements of charged particles, all at the same distance from the origin. Rank the situation according to the net electric potential (V_1, V_2, V_3, V_4) at the origin, most positive first :



(a) $V_1 > V_2 > V_3 > V_4$ (b) $V_2 > V_1 > V_3 > V_4$

(c) $V_2 > V_1 > V_4 > V_3$ (d) $V_4 > V_1 > V_3 > V_2$

26. Two capacitors $C_1 = 2\mu F$ and $C_2 = 6\mu F$ are connected in series, then connected in parallel to a third capacitor $C_3 = 4\mu F$. This arrangement is then connected to a battery of emf 2V as shown in figure. How much energy is lost by the battery in charging the capacitor ?



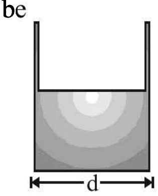
(a) $\frac{16}{3} \times 10^{-6}$ J (b) $\frac{32}{3} \times 10^{-6}$ J

(c) 11×10^{-6} J (d) 22×10^{-6} J

27. There exists a uniform electric field $E = 4 \times 10^5\ Vm^{-1}$ directed along negative x-axis such that electric potential at origin is zero. A charge of – 200 μC is placed at origin, and a charge of + 200 μC is placed at (3m, 0). The electrostatic potential energy of the system is

(a) 120 J (b) – 120 J (c) – 240 J (d) Zero

28. A parallel plate air capacitor has a capacitance C. When it is half filled with a dielectric of dielectric constant 5, the percentage increase in the capacitance will be



(a) 400%

(b) 66.6%

(c) 33.3%

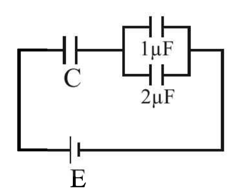
(d) 200%

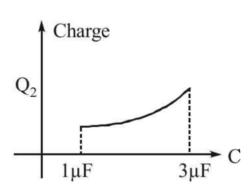
29. A parallel plate capacitor has a plate area of 50 cm^2 and plate separation of 1.0 cm. A potential difference of 200 volt is applied across the plates with air as the dielectric between plates. The battery is then disconnected and a piece of bakelite of dielectric constant 4.8 inserted which fills the complete volume between the plates. The capacitance before and after inserting bakelite are respectively

(a) 44pF, 211.2pF (b) 4.4pF, 211.2pF

(c) 4.4pF, 21.12pF (d) 21.12pF, 44pF

30. In the given circuit, charge Q_2 on the 2μF capacitor changes as C is varied from 1μF to 3μF. Q_2 as a function of 'C' is given properly by: (*figures are drawn schematically and are not to scale*)



(a)


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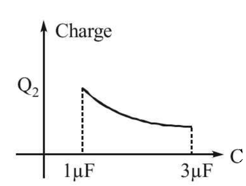

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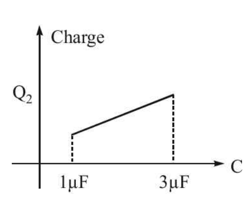
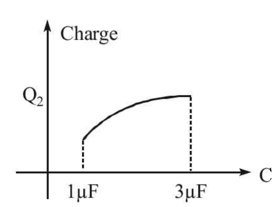


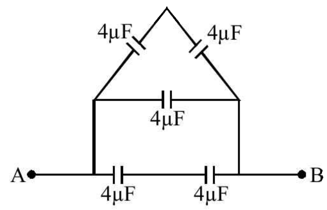
(d)


31. Two points P and Q are maintained at the potentials of 10 V and – 4 V, respectively. The work done in moving 100 electrons from P to Q is:

(a) 9.60×10^{-17}J (b) -2.24×10^{-16} J
(c) 2.24×10^{-16} J (d) -9.60×10^{-17} J

32. Equivalent capacitance between A and B is

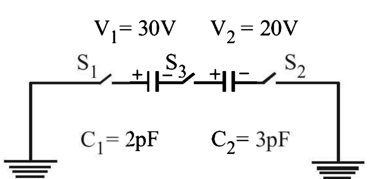
(a) 8μF
(b) 6μF
(c) 26μF
(d) 10/3μF



33. A capacitor has two circular plates whose radius are 8cm and distance between them is 1mm. When mica (dielectric constant = 6) is placed between the plates, the capacitance of this capacitor and the energy stored when it is given potential of 150 volt respectively are

(a) 1.06×10^{-5} F, 1.2×10^{-9} J
(b) 1.068×10^{-9} F, 1.2×10^{-5} J
(c) 1.2×10^{-9} F, 1.068×10^{-5} J
(d) 1.6×10^{-9} F, 1.208×10^{-5} J

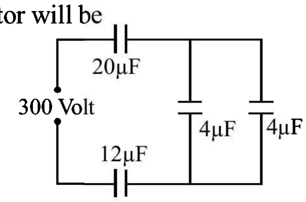
34. For the circuit shown in figure, which of the following statements is true ?



(a) With S_1 closed $V_1 = 15$V, $V_2 = 20$V
(b) With S_3 closed $V_1 = V_2 = 25$ V
(c) With S_1 and S_2 closed $V_1 = V_2 = 0$
(d) With S_1 and S_3 closed, $V_1 = 30$ V, $V_2 = 20$ V

35. In the adjoining figure, four capacitors are shown with their respective capacities and the P.D. applied. The charge and the P.D. across the 4μF capacitor will be

(a) 600μC; 150 volts
(b) 300μC; 75 volts
(c) 800μC; 200 volts
(d) 580μC; 145 volts



36. Electric potential in a region is given by $V = (3x^2 + 4y^2)$ J/C. Find the acceleration of an electron at A (1m, 1m).

(a) 1.77×10^{12} m/s^2 (b) 3.33×10^{12} m/s^2
(c) 1.77×10^{10} m/s^2 (d) 1.77×10^{6} m/s^2

37. A parallel plate capacitor with air between the plates has a capacitance of 9 pF. The separation between its plates is 'd'. The space between the plates is now filled with two dielectrics. One of the dielectrics has dielectric constant $k_1 = 3$ and thickness d/3 while the other one has dielectric constant $k_2 = 6$ and thickness 2d/3. Capacitance of the capacitor is now

(a) 45 pF (b) 40.5 pF
(c) 20.25 pF (d) 1.8 pF

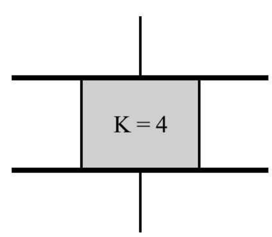
38. A 10 μF capacitor is charged to a potential difference of 1000 V. The terminals of the charged capacitor are disconnected from the power supply and connected to the terminals of an uncharged 6μF capacitor. What is the final potential difference across each capacitor?

(a) 167 V (b) 100 V
(c) 625 V (d) 250 V

39. Four charges $q_1 = 2 \times 10^{-8}$ C, $q_2 = -2 \times 10^{-8}$ C, $q_3 = -3 \times 10^{-8}$ C, and $q_4 = 6 \times 10^{-8}$ C are placed at four corners of a square of side $\sqrt{2}$ m. What is the potential at the centre of the square?

(a) 270 V (b) 300 V (c) Zero (d) 100 V

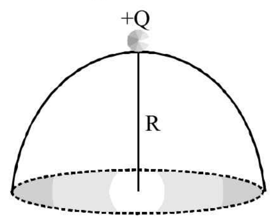
40. Consider a parallel plate capacitor of 10μF (micro-farad) with air filled in the gap between the plates. Now one half of the space between the plates is filled with a dielectric of dielectric constant 4, as shown in the figure. The capacity of the capacitor changes to



(a) 25μF (b) 20μF
(c) 40μF (d) 5μF

Skill Based MCQs

41. A point charge +Q is placed just outside an imaginary hemispherical surface of radius R as shown in the figure. Which of the following statements is correct?



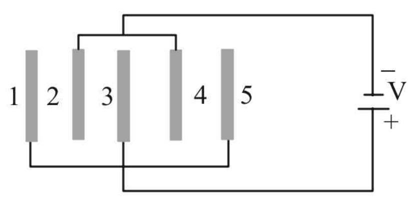
(a) Total flux through the curved and the flat surface is $\frac{Q}{\varepsilon_0}$

(b) The component of the electric field normal to the flat surface is constant over the surface

(c) The circumference of the flat surface is an equipotential

(d) The electric flux passing through the curved surface of the hemisphere is $-\frac{Q}{2\varepsilon_0}\left(2-\frac{1}{\sqrt{2}}\right)$.

42. Five identical plates each of area A are joined as shown in the figure. The distance between plates is *d*. The plates are conected to a potential difference of V *volts*. The charge on plates 1 and 4 will be



(a) $\frac{\varepsilon_0 AV}{d}, \frac{2\varepsilon_0 AV}{d}$
(b) $\frac{\varepsilon_0 AV}{d}, \frac{2\varepsilon_0 AV}{d}$

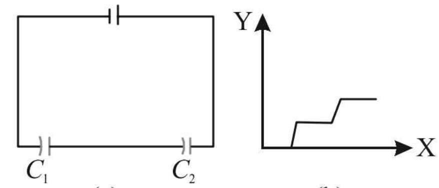
(c) $\frac{\varepsilon_0 AV}{d}, \frac{-2\varepsilon_0 AV}{d}$
(d) $\frac{-\varepsilon_0 AV}{d}, \frac{-2\varepsilon_0 AV}{d}$

43. Three concentric metal shells A, B and C of respective radii *a*, *b* and *c* ($a < b < c$) have surface charge densities $+\sigma, -\sigma$ and $+\sigma$ respectively. The potential of shell B is

(a) $\frac{\sigma}{\epsilon_0}\left[\frac{a^2-b^2}{a}+c\right]$
(b) $\frac{\sigma}{\epsilon_0}\left[\frac{a^2-b^2}{b}+c\right]$

(c) $\frac{\sigma}{\epsilon_0}\left[\frac{b^2-c^2}{b}+a\right]$
(d) $\frac{\sigma}{\epsilon_0}\left[\frac{b^2-c^2}{c}+a\right]$

44. Figure (a) shows two capacitors connected in series and joined to a battery. The graph in figure (b) shows the variation in potential as one moves from left to right on the branch containing the capacitors, if



(a) (b)

(a) $C_1 > C_2$

(b) $C_1 = C_2$

(c) $C_1 < C_2$

(d) None of these

45. A uniformly charged solid sphere of radius R has potential V_0 (measured with respect to ∞) on its surface. For this sphere the equipotential surfaces with potentials $\frac{3V_0}{2}, \frac{5V_0}{4}, \frac{3V_0}{4}$ and $\frac{V_0}{4}$ have radius R_1, R_2, R_3 and R_4 respectively. Then

(a) $R_1 = 0$ and $R_2 < (R_4 - R_3)$

(b) $2R = R_4$

(c) $R_1 = 0$ and $R_2 > (R_4 - R_3)$

(d) $R_1 \neq 0$ and $(R_2 - R_1) > (R_4 - R_3)$

46. A slab of material of dielectric constant K has the same area as the plates of a parallel plate capacitor but has a thickness $\left(\frac{3}{4}\right)d$, where d is the separation of the plates. The ratio of the capacitance C (in the presence of the dielectric) to the capacitance C_0 (in the absence of the dielectric) is

(a) $\frac{3K}{K+4}$ (b) $\frac{3}{4}K$ (c) $\frac{4K}{K+3}$ (d) $\frac{4}{3}K$

47. Two positive charges of magnitude q are placed at the ends of a side 1 of a square of side 2a. Two negative charges of the same magnitude are kept at the other corners. Starting from rest, if a charge Q moves from the middle of side 1 to the centre of square, its kinetic energy at the centre of square is

(a) $\frac{1}{4\pi\varepsilon_0}\frac{2qQ}{a}\left(1-\frac{1}{\sqrt{5}}\right)$ (b) zero

(c) $\frac{1}{4\pi\varepsilon_0}\frac{2qQ}{a}\left(1+\frac{1}{\sqrt{5}}\right)$ (d) $\frac{1}{4\pi\varepsilon_0}\frac{2qQ}{a}\left(1-\frac{2}{\sqrt{5}}\right)$

48. The electric potential at a point (x, y, z) is given by $V = -x^2y - xz^3 + 4$. The electric field $\vec{E}$ at that point is

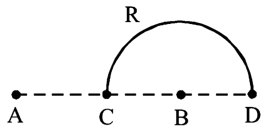
(a) $\vec{E} = \hat{i}\,2xy + \hat{j}(x^2+y^2) + \hat{k}(3xz - y^2)$

(b) $\vec{E} = \hat{i}\,z^3 + \hat{j}\,xyz + \hat{k}\,z^2$

(c) $\vec{E} = \hat{i}\,(2xy - z^3) + \hat{j}\,xy^2 + \hat{k}\,3z^2 x$

(d) $\vec{E} = \hat{i}\,(2xy + z^3) + \hat{j}\,x^2 + \hat{k}\,3xz^2$

49. Charges +q and –q are placed at points A and B respectively which are a distance 2L apart, C is the midpoint between A and B. The work done in moving a charge +Q from C to D along the semicircle CRD is



(a) $\frac{qQ}{2\pi\varepsilon_0 L}$ (b) $\frac{qQ}{6\pi\varepsilon_0 L}$ (c) $-\frac{qQ}{6\pi\varepsilon_0 L}$ (d) $\frac{qQ}{4\pi\varepsilon_0 L}$

50. Two identical thin rings, each of radius 10 cm carrying charges 10 C and 5 C are coaxially placed at a distance 10 cm apart. The work done in moving a charge q from the centre of the first ring to that of the second is

(a) $\frac{q}{8\pi\varepsilon_0}\left(\frac{\sqrt{2}+1}{\sqrt{2}}\right)$ (b) $\frac{q}{8\pi\varepsilon_0}\left(\frac{\sqrt{2}-1}{\sqrt{2}}\right)$

(c) $\frac{q}{4\pi\varepsilon_0}\left(\frac{\sqrt{2}+1}{\sqrt{2}}\right)$ (d) $\frac{q}{4\pi\varepsilon_0}\left(\frac{\sqrt{2}-1}{\sqrt{2}}\right)$

ANSWER KEY

Conceptual MCQs

1	(a)	3	(b)	5	(a)	7	(c)	9	(c)	11	(a)	13	(a)	15	(c)				
2	(d)	4	(b)	6	(a)	8	(a)	10	(c)	12	(d)	14	(a)						

Application Based MCQs

16	(c)	19	(a)	22	(d)	25	(c)	28	(d)	31	(c)	34	(d)	37	(b)	40	(a)		
17	(d)	20	(d)	23	(c)	26	(c)	29	(c)	32	(a)	35	(d)	38	(c)				
18	(b)	21	(d)	24	(d)	27	(a)	30	(d)	33	(b)	36	(a)	39	(a)				

Skill Based MCQs

41	(c)	42	(c)	43	(b)	44	(c)	45	(a)	46	(c)	47	(a)	48	(d)	49	(c)	50	(b)