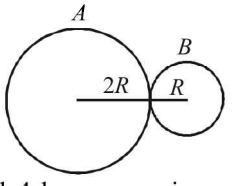
6 System of Particles and Rotational Motion

Conceptual MCQs

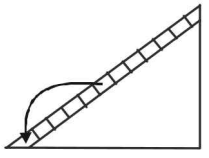
1. Two spheres A and B of masses m and $2m$ and radii $2R$ and R respectively are placed in contact as shown. The COM of the system lies

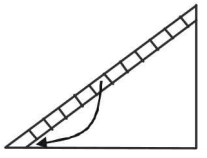


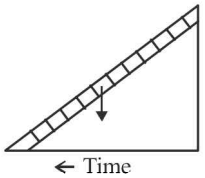
(a) inside A
(b) inside B
(c) at the point of contact
(d) None of these

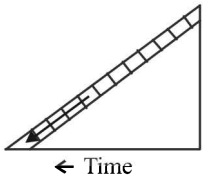
2. Two bodies of masses 2 kg and 4 kg are moving with velocities 2 m/s and 10 m/s respectively along same direction. Then the velocity of their centre of mass will be
(a) 8.1 m/s (b) 7.3 m/s (c) 6.4 m/s (d) 5.3 m/s

3. A ladder is leaned against a smooth wall and it is allowed to slip on a frictionless floor. Which figure represents trak of its centre of mass?

(a) 

(b) 

(c) 

(d) 

4. A wheel has angular acceleration of 3.0 rad/sec^2 and an initial angular speed of 2.00 rad/sec. In a time of 2 sec it has rotated through an angle (in radian) of
(a) 10 (b) 12 (c) 4 (d) 6

5. A wheel has moment of inertia 5×10^{-3} kg m^2 and is making 20 rev/s. The torque needed to stop it in 10 s is
(a) $2\pi \times 10^{-2}$ N-m (b) $2.5\pi \times 10^{-2}$ N-m
(c) $4\pi \times 10^{-2}$ N-m (d) $4.5\pi \times 10^{-2}$ N-m

6. A ring of mass 10 kg and diameter 0.4m is rotated about its axis. If it makes 2100 revolutions per minute, then its angular momentum will be
(a) 44 kg m^2/s (b) 88 kg m^2/s
(c) 4.4 kg m^2/s (d) 0.4 kg m^2/s

7. A circular thin disc of mass 2 kg has a diameter 0.2 m. Calculate its moment of inertia about an axis passing through the edge and perpendicular to the plane of the disc (in kg-m^2)
(a) 0.01 (b) 0.03 (c) 0.02 (d) 3

8. If a hollow cylinder and a solid cylinder are allowed to roll down an inclined plane, which will take more time to reach the bottom?
(a) Hollow cylinder
(b) Solid cylinder
(c) Same for both
(d) One whose density is more

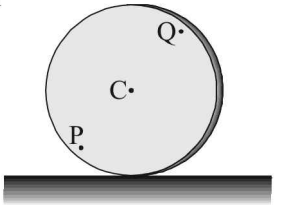
9. A solid sphere is rotating in free space. If the radius of sphere is increased keeping mass same which one of the following will not be affected?
(a) Angular velocity (b) Angular momentum
(c) Moment of inertia (d) Rotational kinetic energy

10. A thin uniform circular ring is rolling down an inclined plane of inclination 30° without slipping. Its linear acceleration along the inclined plane will be

(a) $\frac{g}{2}$ (b) $\frac{g}{3}$ (c) $\frac{g}{4}$ (d) $\frac{2g}{3}$

11. A disc of mass 2 kg and radius 0.2 m is rotating with angular velocity 30 rad/s. What is angular velocity, if a mass of 0.25 kg is put on periphery of the disc ?
(a) 24 rad/s (b) 36 rad/s
(c) 15 rad/s (d) 26 rad/s

12. A disc is rolling (without slipping) on a horizontal surface. C is its centre and Q and P are two points equidistant from C. Let v_P, v_Q and v_C be the magnitude of velocities of points P, Q and C respectively, then



(a) $v_Q > v_C > v_P$
(b) $v_Q < v_C < v_P$
(c) $v_Q = v_P$, $v_C = \frac{v_P}{2}$
(d) $v_Q < v_C > v_P$

13. For the same total mass, which of the following will have the largest moment of inertia about an axis passing through the centre of gravity and perpendicular to the plane of body?
(a) a ring of radius ℓ
(b) a disc of radius ℓ
(c) a square lamina of side 2ℓ
(d) four rods forming square of side 2ℓ

14. A ring of radius 0.5 m and mass 10 kg is rotating about its diameter with angular velocity of 20 rad/s. Its rotational kinetic energy is

(a) 10 J (b) 100 J (c) 500 J (d) 250 J

15. If the angular momentum of any rotating body increases by 200%, then the increase in its kinetic energy is

(a) 400% (b) 800%

(c) 200% (d) 100%

Application Based MCQs

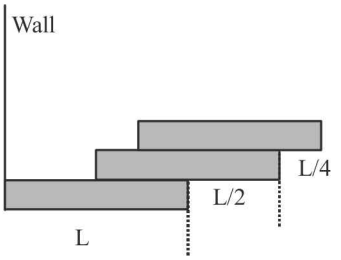
16. Three bricks each of length L and mass M are arranged as shown from the wall. The distance of the centre of mass of the system from the wall is

(a) $\frac{L}{4}$

(b) $\frac{L}{2}$

(c) $\left(\frac{3}{2}\right)L$

(d) $\left(\frac{11}{12}\right)L$



17. A particle moves along a circle of radius $\frac{20}{\pi}$ m with constant tangential acceleration. If the velocity of the particle is 80 m/s at the end of the second revolution after motion has begin, the tangential acceleration is

(a) 640π m/s^2 (b) 160π m/s^2

(c) 40π m/s^2 (d) 40 m/s^2

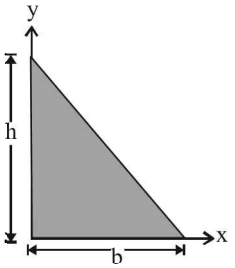
18. The centre of mass of triangle system shown in figure has coordinates, if three equal masses placed at three vertices of the triangle :

(a) $x=\frac{h}{2}, y=\frac{b}{2}$

(b) $x=\frac{b}{2}, y=\frac{h}{2}$

(c) $x=\frac{b}{3}, y=\frac{h}{3}$

(d) $x=\frac{h}{3}, y=\frac{b}{3}$



19. A rigid body is rotating about a stationary axis according to the following angular displacement $\theta = 12t - t^3$. Then, the average angular speed between $t = 0$ second and the time when the body comes to instantaneous rest is

(a) 8 rad/s (b) 16 rad/s (c) 24 rad/s (d) 0 rad/s

20. The wheel of a car is rotating at the rate of 1200 revolutions per minute. On pressing the accelerator for 10 seconds. It starts rotating at 4500 revolutions per minute. The angular acceleration of the wheel is

(a) 30 radians/second^2 (b) 1880 degree/second^2

(c) 40 radians/second^2 (d) 1980 degree/second^2

21. If the earth is a point mass of 6×10^{24} kg revolving around the sun at a distance of 1.5×10^8 km and in time $T = 3.14 \times 10^7$ s, is then the angular momentum of the earth around the sun

(a) 1.2×10^{18} kg m^2/s (b) 1.8×10^{29} kg m^2/s

(c) 1.5×10^{37} kg m^2/s (d) 2.7×10^{40} kg m^2/s

22. A torque of 30 N-m is applied on a 5 kg wheel whose moment of inertia is 2 kg–m^2 for 10 sec. The angle covered by the wheel in 10 sec will be

(a) 750 rad (b) 1500 rad

(c) 3000 rad (d) 6000 rad

23. A ballet dancer, dancing on a smooth floor is spinning about a vertical axis with her arms folded with an angular velocity of 20 rad/s. When she stretches her arms fully, the spinning speed decreases by 10 rad/s. If I is the initial moment of inertia of the dancer, the new moment of inertia is

(a) $2I$ (b) $3I$ (c) $I/2$ (d) $I/3$

24. Three point masses each of mass m are placed at the corners of an equilateral triangle of side 'a'. Then the moment of inertia of this system about an axis passing along one side of the triangle is

(a) ma^2 (b) $3ma^2$ (c) $\frac{3}{4}ma^2$ (d) $\frac{2}{3}ma^2$

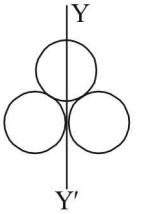
25. The moment of inertia of a sphere of mass M and radius R about an axis passing through its centre is $\frac{2}{5}MR^2$. The radius of gyration of the sphere about a parallel axis to the above and tangent to the sphere is

(a) $\frac{7}{5}R$ (b) $\frac{3}{5}R$ (c) $\left(\sqrt{\frac{7}{5}}\right)R$ (d) $\left(\sqrt{\frac{3}{5}}\right)R$

26. Three rings each of mass M and radius R are arranged as shown in the figure. The moment of inertia of the system about YY′ will be

(a) $3MR^2$ (b) $\frac{3}{2}MR^2$

(c) $5MR^2$ (d) $\frac{7}{2}MR^2$



27. The moment of inertia of uniform rectangular plate about an axis passing through its mid-point and parallel to its length l is (b = breadth of rectangular plate)

(a) $\frac{Ml^2}{4}$ (b) $\frac{Mb^3}{6}$

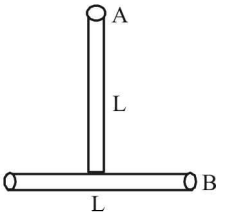
(c) $\frac{Ml^3}{2}$ (d) $\frac{Mb^2}{12}$

28. A T joint is formed by two identical rods A and B each of mass m and length L in the XY plane as shown. Its moment of inertia about axis coinciding with rod A is

(a) $\frac{2mL^2}{3}$

(b) $\frac{mL^2}{12}$

(c) $\frac{mL^2}{6}$



(d) None of these

29. A solid cylinder of mass m and radius R rolls down an inclined plane of height h without slipping. The speed of its centre of mass when it reaches the bottom is

(a) $\sqrt{(2gh)}$ (b) $\sqrt{4gh/3}$

(c) $\sqrt{3gh/4}$ (d) $\sqrt{4g/h}$

30. A thin bar of length L is suspended from one end and rotated at a speed of n revolutions per second. The rotational kinetic energy of the bar is

(a) $2\,ML^2\pi^2n^2$ (b) $1/2\,ML^2\pi^2n^2$

(c) $2/3\,ML^2\pi^2n^2$ (d) $1/6\,ML^2\pi^2n^2$

31. Two discs of moment of inertia I_1 and I_2 and angular speeds ω_1 and ω_2 are rotating along collinear axes passing through their centre of mass and perpendicular to their plane. If the two are made to rotate combindly along the same axis the rotational KE of system will be

(a) $\frac{I_1\omega_1 + I_2\omega_2}{2(I_1 + I_2)}$ (b) $\frac{(I_1 + I_2)(\omega_1 + \omega_2)^2}{2}$

(c) $\frac{(I_1\omega_1 + I_2\omega_2)^2}{2(I_1 + I_2)}$ (d) None of these

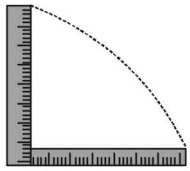
32. A metre stick of length 1m is held vertically with one end in contact of the floor and is then allowed to fall. If the end touching the floor is now allowed to slip, the other end will hit the ground with a velocity of ($g = 9.8\ m/s^2$)

(a) 3.2 m/s

(b) 5.4 m/s

(c) 7.6 m/s

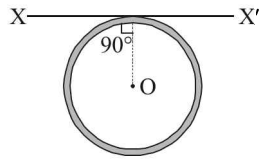
(d) 9.2 m/s



33. A thin wire of length L and uniform linear mass density ρ is bent into a circular loop with centre at O as shown. The moment of inertia of the loop about the axis XX′ is

(a) $\frac{\rho L^3}{8\pi^2}$ (b) $\frac{\rho L^3}{16\pi^2}$

(c) $\frac{5\rho L^3}{16\pi^2}$ (d) $\frac{3\rho L^3}{8\pi^2}$



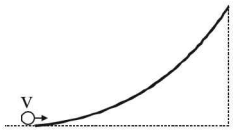
34. A small object of uniform density rolls up a curved surface with an initial velocity v. It reaches up to a maximum height of $\frac{5v^2}{6g}$ with respect to the initial position. The object is

(a) Ring

(b) Solid sphere

(c) Hollow sphere

(d) Disc



35. A thin circular ring of mass M and radius r is rotating about its axis with a constant angular velocity ω. Four objects each of mass m, are kept gently to the opposite ends of two perpendicular diameters of the ring. The angular velocity of the ring will be

(a) $\frac{(M-4m)\omega}{M+4m}$ (b) $\frac{M\omega}{4m}$

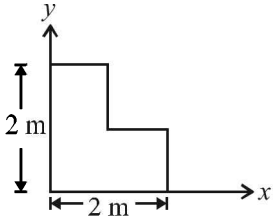
(c) $\frac{M\omega}{M+4m}$ (d) $\frac{(M+4m)\omega}{M}$

36. They x,y coordinates of the centre of mass of a uniform L-shaped lamina of mass 3 kg is

(a) $\left(\frac{5}{6}m, \frac{5}{6}m\right)$

(b) (1 m, 1 m)

(c) $\left(\frac{6}{5}m, \frac{6}{5}m\right)$



(d) (2 m, 2 m)

37. The moment of inertia of a rod about an axis through its centre and perpendicular to it is $\frac{1}{12}ML^2$ (where, M is the mass and L is the length of the rod). The rod is bent in the middle so that the two halves make an angle of 60°. The moment of inertia of the bent rod about the same axis would be

(a) $\frac{1}{48}ML^2$ (b) $\frac{1}{12}ML^2$

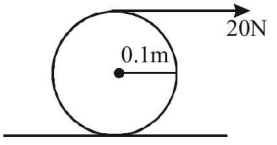
(c) $\frac{1}{24}ML^2$ (d) $\frac{ML^2}{8\sqrt{3}}$

38. Particles of masses m, 2m, 3m, ..., nm grams are placed on the same line at distance ℓ, 2ℓ, 3ℓ, ..., $n\ell$ cm, from a fixed point. The distance of centre of mass of the particles from the fixed point in centimetre is

(a) $\frac{(2n+1)\ell}{3}$ (b) $\frac{\ell}{n+1}$

(c) $\frac{n(n^2+1)\ell}{2}$ (d) $\frac{2\ell}{n(n^2+1)}$

39. A tangential force of 20 N is applied on a cylinder of mass 4 kg and moment of inertia 0.02 kg m^2 about its own axis. If the cylinder rolls without slipping, then linear acceleration of its centre of mass will be



(a) 6.7 m/s^2
(b) 10 m/s^2
(c) 3.3 m/s^2
(d) None of these

40. A solid cylinder rolls down an inclined plane of height 3 m and reaches the bottom of plane with angular velocity of $2\sqrt{2}$ rad.s^{-1}. The radius of cylinder must be (Take g = 10 ms^{-2})

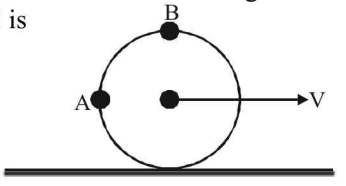
(a) 5 cm (b) 0.5 cm (c) $\sqrt{10}cm$ (d) $\sqrt{5}\ m$

41. The angular velocity of a body changes from ω_1 to ω_2 without applying a torque but by changing the moment of inertia about its axis of rotation. The ratio of its corresponding radii of gyration is

(a) $\omega_1 : \omega_2$ (b) $\sqrt{\omega_1} : \sqrt{\omega_2}$

(c) $\omega_2 : \omega_1$ (d) $\sqrt{\omega_2} : \sqrt{\omega_1}$

42. A ring is rolling on a rough horizontal surface without slipping with a liner speed *v*. The ratio of magnitude of velocity of point *B* and *A* is



(a) 1 : 1
(b) 1 : 2
(c) $\sqrt{2} : 1$
(d) $1 : \sqrt{2}$

43. A thin uniform rod of length *l* and mass *m* is swinging freely about a horizontal axis passing through its end. Its maximum angular speed is ω. Its centre of mass rises to a maximum height of

(a) $\frac{1}{3}\frac{l^2\omega^2}{g}$ (b) $\frac{1}{6}\frac{l\omega}{g}$ (c) $\frac{1}{2}\frac{l^2\omega^2}{g}$ (d) $\frac{1}{6}\frac{l^2\omega^2}{g}$

44. A mass *m* hangs with the help of a string wrapped around a pulley on a frictionless bearing. The pulley has mass *m* and radius *R*. Assuming pulley to be a perfect uniform circular disc, the acceleration of the mass *m*, if the string does not slip on the pulley, is

(a) g (b) $\frac{2}{3}g$ (c) $\frac{g}{3}$ (d) $\frac{3}{2}g$

45. A thin horizontal circular disc is rotating about a vertical axis passing through its centre. An insect is at rest at a point near the rim of the disc. The insect now moves along a diameter of the disc to reach its other end. During the journey of the insect, the angular speed of the disc

(a) continuously decreases
(b) continuously increases
(c) first increases and then decreases
(d) remains unchanged

46. A hoop of radius r and mass m rotating with an angular velocity ω_0 is placed on a rough horizontal surface. The initial velocity of the centre of the hoop is zero. What will be the velocity of the centre of the hoop when it ceases to slip ?

(a) $\frac{r\omega_0}{4}$ (b) $\frac{r\omega_0}{3}$ (c) $\frac{r\omega_0}{2}$ (d) $r\omega_0$

47. Distance of the centre of mass of a solid uniform cone from its vertex is z_0. If the radius of its base is R and its height is h then z_0 is equal to :

(a) $\frac{5h}{8}$ (b) $\frac{3h^2}{8R}$ (c) $\frac{h^2}{4R}$ (d) $\frac{3h}{4}$

48. When a ceiling fan is switched on, it makes 10 rotations in the first 3 seconds. Assuming a uniform angular acceleration, how many rotation it will make in the next 3 seconds?

(a) 10 (b) 20 (c) 30 (d) 40

49. A solid sphere rolls down on an inclined plane of inclination θ. What is the acceleration as the sphere reaches the bottom?

(a) $\frac{5}{7}g\sin\theta$ (b) $\frac{3}{5}g\sin\theta$

(c) $\frac{2}{7}g\sin\theta$ (d) $\frac{2}{5}g\sin\theta$

50. If the moment of inertia of a disc about an axis tangential and parallel to its surface be *I*, then what will be the moment of inertia about the axis tangential but perpendicular to the surface?

(a) $\frac{6}{5}I$ (b) $\frac{3}{4}I$ (c) $\frac{3}{2}I$ (d) $\frac{5}{4}I$

Skill Based MCQs

51. A particle of mass m is projected with velocity v making an angle of 45° with the horizontal. The magnitude of the angular momentum of the particle about the point of projection when the particle is at its maximum height, is

(a) $m\sqrt{2gh^3}$ (b) $\frac{mv^3}{\sqrt{2g}}$ (c) $\frac{mv^3}{4\sqrt{2g}}$ (d) zero

52. A small disc of radius 2 cm is cut from a disc of radius 6 cm. If the distance between their centres is 3.2 cm, what is the shift in the centre of mass of the disc?

(a) 0.4 cm (b) 2.4 cm (c) 1.8 cm (d) 1.2 cm

53. If the four objects rings, disc, hollow sphere and solid sphere are of same mass, same radius having the same coefficient of friction and are released from the same height on an incline plane then at the bottom the object which will have least K.E. (when friction is insufficient to provide pure rolling) will be

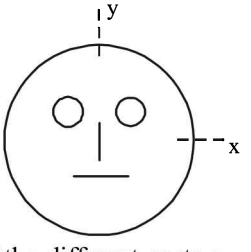
(a) hollow sphere (b) solid sphere
(c) ring (d) disc

54. Three particles of masses 1 kg, $\frac{3}{2}$ kg, and 2 kg are located at the vertices of an equilateral triangle of side a. The x, y coordinates of the centre of mass are

(a) $\left(\frac{5a}{9}, \frac{2a}{3\sqrt{3}}\right)$ (b) $\left(\frac{2a}{3\sqrt{3}}, \frac{5a}{9}\right)$

(c) $\left(\frac{5a}{9}, \frac{2a}{\sqrt{3}}\right)$ (d) $\left(\frac{2a}{\sqrt{3}}, \frac{5a}{9}\right)$

55. Look at the drawing given in the figure which has been drawn with ink of uniform line-thickness. The mass of ink used to draw each of the two inner circles, and each of the two line segments is m. The mass of the ink used to draw the outer circle is $6m$.



The coordinates of the centres of the different parts are: outer circle (0, 0), left inner circle $(-a, a)$, right inner circle (a, a), vertical line (0, 0) and horizontal line $(0, -a)$. The y-coordinate of the centre of mass of the ink in this drawing is

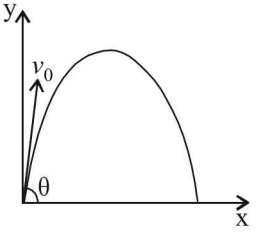
(a) $\frac{a}{10}$ (b) $\frac{a}{8}$ (c) $\frac{a}{12}$ (d) $\frac{a}{3}$

56. A circular disk of moment of inertia I_t is rotating in a horizontal plane, its symmetry axis, with a constant angular speed ω_i. Another disk of moment of inertia I_b is dropped coaxially onto the rotating disk. Initially the second disk has zero angular speed. Eventually both the disks rotate with a constant angular speed ω_f. The energy lost by the initially rotating disk to friction is

(a) $\frac{1}{2}\frac{I_b^2}{(I_t + I_b)}\omega_i^2$ (b) $\frac{I_t^2}{(I_t + I_b)}\omega_i^2$

(c) $\frac{I_b - I_t}{(I_t + I_b)}\omega_i^2$ (d) $\frac{1}{2}\frac{I_b I_t}{(I_t + I_b)}\omega_i^2$

57. A small particle of mass m is projected at an angle θ with the x-axis with an initial velocity v_0 in the x-y plane as shown in the figure. At a time $t < \frac{v_0 \sin\theta}{g}$, the angular momentum of the particle is



(a) $-mg\, v_0 t^2 \cos\theta\, \hat{j}$

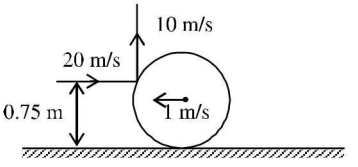
(b) $mg\, v_0 t \cos\theta \hat{k}$

(c) $-\frac{1}{2} mg v_0 t^2 \cos\theta\, \hat{k}$

(d) $\frac{1}{2} mg v_0 t^2 \cos\theta\, \hat{i}$

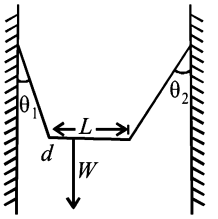
where $\hat{i}, \hat{j}$ and $\hat{k}$ are unit vectors along x, y and z-axis respectively.

58. A thin ring of mass 2 kg and radius 0.5 m is rolling without on a horizontal plane with velocity 1 m/s. A small ball of mass 0.1 kg, moving with velocity 20 m/s in the opposite direction hits the ring at a height of 0.75 m and goes vertically up with velocity 10 m/s. Immediately after the collision



(a) the ring has pure rotation about its moving CM.
(b) the ring comes to a complete stop.
(c) friction between the ring and the ground is to the left.
(d) there is no friction between the ring and the ground.

59. A non-uniform bar of weight W and length L is suspended by two strings of negligible weight as shown in figure. The angles made by the strings with the vertical are θ_1 and θ_2 respectively.

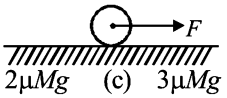


The distance d of the centre of gravity of the bar from its left end is

(a) $L\left(\frac{\tan\theta_1+\tan\theta_2}{\tan\theta_1}\right)$ (b) $L\left(\frac{\tan\theta_1}{\tan\theta_1+\tan\theta_2}\right)$

(c) $L\left(\frac{\tan\theta_2}{\tan\theta_1+\tan\theta_2}\right)$ (d) $L\left(\frac{\tan\theta_1+\tan\theta_2}{\tan\theta_2}\right)$

60. A uniform disc of mass M and radius R, is resting on a table on its rim. The coefficient of friction between disc and table is μ. Now the disc is pulled with a force F as shown in the figure. What is the maximum value of F for which the disc rolls without slipping?



(a) μMg (b) $2\mu Mg$ (c) $3\mu Mg$ (d) $4\mu Mg$

ANSWER KEY

Conceptual MCQs

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

Application Based MCQs

16	(d)	**20**	(d)	**24**	(c)	**28**	(b)	**32**	(b)	**36**	(a)	**40**	(d)	**44**	(b)	**48**	(c)	
17	(d)	**21**	(d)	**25**	(c)	**29**	(b)	**33**	(d)	**37**	(b)	**41**	(d)	**45**	(c)	**49**	(a)	
18	(c)	**22**	(a)	**26**	(d)	**30**	(c)	**34**	(c)	**38**	(a)	**42**	(c)	**46**	(c)	**50**	(a)	
19	(a)	**23**	(a)	**27**	(d)	**31**	(c)	**35**	(c)	**39**	(a)	**43**	(d)	**47**	(d)			

Skill Based MCQs

51	(c)	**52**	(a)	**53**	(c)	**54**	(a)	**55**	(a)	**56**	(d)	**57**	(c)	**58**	(c)	**59**	(b)	**60**	(c)