CENTRE OF MASS

1. When no external force is acting on a system of particles, the centre of mass of the system

1) Remains at rest only
2) moves with constant velocity only
3) Moves with constant velocity or will be at rest
4) moves with variable velocity

2. Centre of mass of a body

1) always lies inside the body
2) always lies outside the body
3) always lies on the surface of the body
4) may lie inside or outside the body

3. A shell moving in a parabolic path explodes. The centre of mass of the fragments move

1) vertically down wards
2) vertically upwards
3) horizontally
4) in the same parabolic path

4. A bomb at rest explodes. The centre of mass of the system

1) describes a parabola
2) vertically upwards
3) horizontally
4) is at rest

5. When an external force is applied at the centre of mass of a system of particles, then it undergoes

1) Only translatory motion
2) Only rotatory motion
3) both translatory and rotatory motion
4) an oscillatory motion

6. A bomb moving in a parabolic path explodes into two fragments of equal masses. The acceleration of the centre of mass of the fragments when both are in air is equal to

1) g/2
2) 2g
3) g
4) zero

7. Two bodies of masses m_1 and m_2 are at distances x_1 and x_2 from their centre of mass. Then, the correct statement of the following is

1) $\frac{m_1}{m_2} = \frac{x_1}{x_2}$
2) $\frac{m_1}{m_2} = \sqrt{\frac{x_1}{x_2}}$
3) $\frac{m_1}{m_2} = \frac{x_2}{x_1}$
4) $\frac{m_1}{m_2} = \sqrt{\frac{x_2}{x_1}}$

8. A uniform metre stick is placed vertically on a horizontal frictionless surface and released. As the stick is in motion, the centre of mass moves

1) Vertically up
2) vertically down
3) in a parabolic path
4) horizontally

9. Choose the correct statement

1) Centre of mass of two particles will be nearer to lighter particle.
2) Centre of mass of the rigid body depends on reference frame used.
3) Centre of mass of the system of particles depends on the masses of the particles.
4) Centre mass must lie with in the body.

10. Distance of centre of mass of a thin uniform semi circular disc of radius R from its centre is

1) $\frac{R}{\pi}$ 2) $\frac{2R}{\pi}$ 3) $\frac{4R}{3\pi}$ 4) $\frac{3R}{4\pi}$

11. Choose the wrong statement

1) In the process of explosion some changes may occur in momentum of individual fragments due to internal forces but the motion of the centre of mass is unaltered.
2) Motion of centre of mass depends upon the external force.
3) The location of centre of mass depends on the reference frame used locate it
4) The position of centre of mass depends upon the shape of the body and the distribution of mass.

12. A bomb travelling in a parabolic path under the effect of gravity explodes in mid air. The centre of mass of fragments will

1) Move vertically upwards and then vertically downwards
2) Move vertically upwards
3) Move in an irregular path
4) Move in the parabolic path the unexploded bomb would have travelled.

13. a) Algebraic sum of moments of masses about centre of mass is zero
b) For small bodies centre of mass coincides with centre of gravity
c) Position of centre of mass depends on co-ordinate system
d) Position of centre of mass is independent of mass distribution

1) a and b are correct 2) b and c are correct
3) a, b and c are correct 4) a, b, c and da are correct

14. A disc of radius 'r' is removed from the disc of radius 'R' then
a) The minimum shift in centre of mass is zero
b) The maximum shift in centre of mass cannot be greater than $\frac{r^2}{(R+r)}$
c) Centre of mass must lie where mass exists
d) The shift in centre of mass is $\frac{r^2}{(R+r)}$

1) Only a and b are correct 2) only a and c are correct
3) Only a, b and d are correct 4) all are correct

15. Statements: a) Algebraic sum of moments of mass about centre of mass is equal to zero

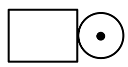
b) x – coordinate of centre of mass of system of particles in a plane is represented by $x_{cm} = \frac{1}{M}\sum m_i x_i$

c) x – coordinate of a rigid body of continuous mass distribution represented by $x_{cm} = \frac{1}{M}\int x.dm$

1) a and b are true 2) b and c are true

3) a and c are true 4) All a, b, c are true

16. A square plate and a circular plate made up of same material are placed touching each other on a horizontal table. If the side length of square plate is equal to diameter of the circular plate then the centre of mass of the system will be



1) inside the square plate 2) inside the circular plate

3) at the point of contact 4) outside the system

17. Match the following:

a. Position of centre of mass e. Is zero

b. The algebraic sum of moments of all the masses about centre of mass f. In non uniform gravitational field

c. Centre of mass and centre of gravity coincide g. is independent of frame of reference

d. Centre of mass and centre of gravity do not coincide h. in uniform gravitational field

1. a ➡ e; b ➡ g; c ➡ f; d ➡ h 2. a ➡ g; b ➡ e; c ➡ f; d ➡ h

3. a ➡ g; b ➡ e; c ➡ h; d ➡ f 4. a ➡ h; b ➡ e; c ➡ f; d ➡ g

18. Consider a two particle system with the particles having masses m_1 and m_2. If the first particle is pushed towards the centre of mass through a distance 'd', by what distance should the second particle be moved, so as to keep the centre of mass at the same position?

1. d 2. $\frac{m_2 d}{m_1}$ 3. $\frac{m_1 d}{m_1 + m_2}$ 4. $\frac{m_1 d}{m_2}$

19. A wooden sphere and a cooper sphere of same radius are kept in contact with each other. Their centre of mass will be

(1) at their point of contact (2) outside the spheres

(3) with in copper sphere (4) outside the spheres

20. (A): A shell moving in a parabolic path explodes in mid air. The centre of mass of the fragments will follow the same parabolic path.

(R): Explosion is due to internal forces, which can not alter the state of motion of a body.

(1) Both (A) and (R) are true and (R) is the correct explanation of (A)

(2) Both (A) and (R) are true and (R) is not the correct explanation of (A)

(3) (A) is true but (R) is false

(4) (A) is false but (R) is true

21. (A): Standing of the passengers in upper part of a double decker bus is not permitted.

(R): Standing of passengers will raise the centre of gravity of system, leading to instability.

(1) Both (A) and (R) are true and (R) is the correct explanation of (A)

(2) Both (A) and (R) are true and (R) is not the correct explanation of (A)

(3) (A) is true but (R) is false

(4) (A) is false but (R) is true

22. The distance between the centres of carbon and oxygen atoms in the carbon monoxide gas molecule is 1.13 x 10^{-10}m. The distance of centre of mass of the molecule relative to carbon atom is

1) 0.48 x 10^{-10}m 2) 0.64 x 10^{-10}m 3) 0.56 x 10^{-10}m 4) 0.36 x 10^{-10}m

23. The co-ordinates of centre of mass of particles of mass 10, 20 and 30 gm are (1, 1, 1) cm. The position co-ordinates of mass 40 gm which when added to the system, the position of combined centre of mass be at (0, 0, 0) are,

1) (3/2, 3/2, 3/2) 2) (-3/2, -3/2, -3/2) 3) (3/4, 3/4, 3/4) 4) (-3/4, -3/4, -3/4)

24. One end of a thin uniform rod of length L and mass M_1 is riveted to the centre of a uniform circular disc of radius 'r' and mass M_2 so that both are coplanar. The centre of mass of the combination from the centre of the disc is (Assume that the point of attachment is at the origin)

1) $\frac{L(M_1+M_2)}{2M_1}$ 2) $\frac{LM_1}{2(M_1+M_2)}$ 3) $\frac{2(M_1+M_2)}{LM_1}$ 4) $\frac{2LM_1}{(M_1+M_2)}$

25. Two uniform rods A and B of lengths 5 m and 3 m are placed end to end. If their linear densities are 3 kg/m and 2 kg/m, the position of their centre of mass from their interface is

1) 19/14 m on the side of heavier rod 2) 8/7 m on the side of lighter rod

3) 2 m on the side of heavier rod 4) 2 m on the side of lighter rod.

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

1) $\frac{(2n+1)l}{3}$ 2) $\frac{l}{n+1}$ 3) $\frac{n(n^2+1)l}{2}$ 4) $\frac{2l}{n(n^2+1)}$

27. Four particles, each of mass 1kg, is placed at the corners of a square OABC of side 1m. 'O' is at the origin of the coordinate system. OA and OC are aligned along positive x-axis and positive y-axis respectively. The position vector of the centre of mass is (in 'm')

1) $\hat{i}+\hat{j}$ 2) $\frac{1}{2}(\hat{i}+\hat{j})$ 3) $(\hat{i}-\hat{j})$ 4) $\frac{1}{2}(\hat{i}-\hat{j})$

28. The mass of a uniform ladder of length 5 m is 20 kg. A person of mass 60 kg stands on the ladder at a height of 2 m from the bottom. The position of centre of mass of the ladder and man from the bottom nearly is

1) 1 m 2) 2.5 m 3) 3.5 m 4) 2.125 m

29. A circular plate has a uniform thickness and has a diameter 56 cm. A circular disc of diameter 42 cm is removed from one edge of the plate. The distance of centre of mass of the remaining portion from the centre of the circular plate is

1) 18 cm 2) 9 cm 3) 27 cm 4) 4.5 cm

30. A man of 50kg is standing at one end on a boat of length 25m and mass 200kg. If he starts running and when he reaches the other end, he has a velocity 2ms^{-1} with respect to the boat. The final velocity of the boat is (in ms^{-1})

1) $\frac{2}{5}$ 2) $\frac{2}{3}$ 3) $\frac{8}{5}$ 4) $\frac{8}{3}$

31. A baloon of mass M is stationary in air. It has a ladder on which a man of mass m is standing. If the man starts climbing up the ladder with a velocity v relative to ladder, the velocity of balloon is

1) $\frac{m}{M}v$ Upwards 2) $\frac{mv}{(M+m)}$ downwards 3) $\frac{mv}{(M+m)}$ upwards 4) $\frac{Mv}{(M+m)}$ downwards

32. A uniform wire of length L is bent in the form of a circle. The shift in its centre of mass is

1) $\frac{L}{\pi}$ 2) $\frac{2L}{\pi}$ 3) $\frac{L}{2\pi}$ 4) $\frac{L}{3\pi}$

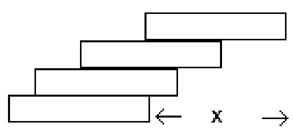
33. Two particles of equal mass have velocities $\overline{V_1} = 4\bar{i}$ and $\overline{V_2} = 4\bar{j}$ ms^{-1}. First particle has an acceleration $\overline{a_1} = (5\bar{i} + 5\bar{j})$ ms^{-2} while the acceleration of the other particle is zero. The centre of mass of the two particles moves in a path of

1) Straight line 2) Parabola 3) Circle 4) Ellipse

34. A shell in flight explodes into n equal fragments, k of the fragments reach the ground earlier than the other fragments. The acceleration of their centre of mass subsequently will be

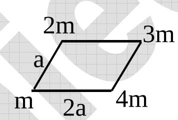
1) g 2) (n-k)g 3) $\frac{(n-k)g}{k}$ 4) $\frac{(n-k)}{n}g$

35. Four identical blocks of length L are arranged one over the other as shown. The maximum distance of the uppermost block from the edge of the lowermost block is x such that no block tumbles. Then x is



1) $\frac{4L}{3}$ 2) $\frac{3L}{4}$ 3) $\frac{11L}{12}$ 4) 2L

36. Four particles of masses m, 2m, 3m and 4m are at the verticies of a parallelogram in x – y plane with one of the adjacent angle 60^0 and smaller side 'a' and larger side 2a. The mass 'm' is at the origin and mass 4m x-axis. The centre of mass of the system is



1) $\left(\frac{3a}{2}; \frac{a}{2}\right)$ 2) $\left(\frac{a}{2}; \frac{3a}{2}\right)$ 3) $\left(1.65a; \frac{\sqrt{3}a}{4}\right)$ 4) $\left(\frac{\sqrt{3}a}{4}; 0.82a\right)$

37. Two blocks of masses 10 kg and 30 kg are placed along a vertical line. The first block is raised through a height of 7 cm. By what distance should the second mass be moved to raise the centre of mass by 1 cm?

1) 1 cm upward 2) 1 cm downward
3) 2 cm downward 4) 2 cm upward

38. A uniform square sheet has a side length of

2R. A circular sheet of maximum possible area is removed from one of the quadrants of the square sheet. The distance of centre of mass of the remaining portion from the centre of the original sheet is

1) $\frac{\pi R}{\sqrt{2}[16-\pi]}$ 2) $\frac{R}{[16-\pi]}$ 3) $\frac{R}{\pi[16-\pi]}$ 4) $\frac{R\pi}{16-\pi}$

39. Two balls of masses 5m and m have radii 2R and R. Their centres of masses are separated by 12R. They move towards each other under their gravitational force. The distance moved by the centre of smaller sphere when the spheres touch each other is

1) 2. 5 R 2) 5R 3) 7.5 R 4) 10 R

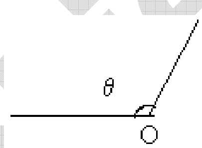
40. A boat of mass 80 kg is floating on still water. A dog of mass 20 kg on the boat is at a distance of 10m from the shore. The dog moves on the boat by a distance of 2m towards the shore. The distance of the dog from the shore is

1) 11.6 m 2) 8.4 m 3) 9.6 m 4) 10.4 m

41. A shell projected from a level ground has a range R, if it did not explode. At the highest point, the shell explodes into two fragments having masses in the ratio 1:3; with each fragment moving horizontally immediately after the explosion. If the lighter fragment falls at a distance R from the point of projection, behind the point of projection, the distance at which the other fragments falls from the point of projection is

1) 2R 2) 5R/3 3) 4R/3 4) 2R/3

42. A thin uniform rod of length "L" is bent at its mid point as shown in the figure. The distance of the centre of mass from the point "O" is



1. $\frac{L}{2}\sin\frac{\theta}{2}$ 2. $\frac{L}{2}\cos\frac{\theta}{2}$ 3. $\frac{L}{4}\sin\frac{\theta}{2}$ 4. $\frac{L}{4}\cos\frac{\theta}{2}$

KEY

1) 3	**2) 4**	**3) 4**	**4) 4**	**5) 1**	**6) 3**	**7) 3**	**8) 2**	**9)3**
10) 3	**11) 3**	**12) 4**	**13) 1**	**14) 1**	**15) 4**	**16) 1**	**17)4**	**18)3**
19)3	**20)1**	**21)3**	**22) 2**	**23) 2**	**24) 2**	**25) 1**	**26) 1**	**27)2**
28) 4	**29) 2**	**30) 1**	**31) 2**	**32) 3**	**33) 1**	**34) 4**	**35) 3**	**36)3**
37) 2	**38) 1**	**39) 3**	**40) 2**	**41) 2**	**42)4**			

HINTS

22. $x_{cm}=\dfrac{m_2 d}{m_1+m_2}$

$x_{cm}=\dfrac{16x1.12x10^{-10}}{12+16}$

$x_{cm}=0.64\text{ x }10^{-10}m$

23. $x_{cm}=\dfrac{m_1x_1+m_2x_2}{m_1+m_2}$

$0=\dfrac{60(1)+40x_2}{60+40}$

$\therefore x_2=-\dfrac{3}{2}$

$11y\quad y_2=-\dfrac{3}{2}\ and\ z_2=-\dfrac{3}{2}$

$\therefore\left(-\dfrac{3}{2},-\dfrac{3}{2},-\dfrac{3}{2}\right)$

24. By taking centre of M_2 as reference

$x_{cm}=\dfrac{m_1\left(\dfrac{L}{2}\right)}{(M_1+M_2)}$

$x_{cm}=\dfrac{LM_1}{2(M_1+M_2)}$

25. $m_1=5(3)=15kg$

$m_2=2x3=6kg$

$x_{cm}=\dfrac{m_1(-x_1)+m_2x_2}{m_1+m_2}$

$x_{cm}=\dfrac{15(-2.5)+6(1.5)}{15+6}$ $\qquad x_{cm}=\dfrac{19}{14}m$ on the side of heavier rod

26. $x_{cm}=\dfrac{m_1x_1+m_2x_2+m_3x_3---m_nx_m}{m_1+m_2+.........mn}$

$x_{cm}=\dfrac{ml+2m2l+.....mn(\ln)}{m+2m+.......+mn}$

$x_{cm}=\dfrac{ml\left(1+2^2+......+n^2\right)}{m(1+2+.....+n)}$

$x_{cm}=\dfrac{\dfrac{n(n+1)(2n+1)}{6}}{\dfrac{n(n+1)}{2}}$

$x_{cm}=\left(\dfrac{2n+1}{3}\right)l$

27. $\vec{r}_{cm}=\dfrac{1(0)+1(\hat{i})+1(\hat{i}+\hat{j})+1(\hat{j})}{1+1+1+1}$

$\vec{r}_{cm}=\dfrac{2\hat{i}+2\hat{j}}{4}=\dfrac{\hat{i}+\hat{j}}{2}$

28. $m_1=\ 20kg\quad x_1=2.5m$

$m_2=\ 60kg\quad x_2=2m$

$x_{cm}=\dfrac{m_1x_1+m_2x_2}{m_1+m_2}$

$x_{cm}=\dfrac{20(2.5)+60(2)}{20+60}$

$x_{cm}=2.125m$

29. $r_1=28m\qquad r_2=21m$

$d=7$

$x_{cm}=\dfrac{r_2^2d}{r_1^2-r_2^2}$

$x_{cm}=\dfrac{(21)^2(7)}{(28)^2-(21)^2}$

$x_{cm}=9cm$

30. $m_1\vec{v}_1 + (m_1 + m_2)\vec{v}_2 = 0$

$$v_2 = \frac{m_1 v_1}{(m_1 + m_2)}$$

$$v_2 = \frac{50(2)}{50+200} = \frac{2}{5} ms^{-1}$$

31. $mv = -(M+m)V^1$

$$V^1 = -\frac{mV}{m+m}$$

$$V^1 = \frac{mV}{m+m} \text{ down wards}$$

32. $l = 2\pi x$

$$x = \frac{L}{2\pi}$$

33. $\overrightarrow{V_m} = \dfrac{m_1\overrightarrow{V_1} + m_2\overrightarrow{V_2}}{m_1 + m_2}$

$$\overrightarrow{V_m} = \frac{4i + 4j}{2}$$

$$\overrightarrow{a_m} = \frac{m_1\vec{a}_1 + m_2\vec{a}_2}{m_1 + m_2}$$

$$\overrightarrow{a_m} = 5\hat{i} + 5\hat{j}$$

$\overrightarrow{V_m}$ and $\overrightarrow{a_m}$ parallel

Path of c.m. is a straight line

34. $a_{cm} = \dfrac{m_1 a_1 + m_2 a_2}{m_1 + m_2}$

$$a_{cm} = \frac{k(O) + (n-k)g}{n}$$

$$a_{cm} = \frac{(n-k)g}{n}$$

35. $x = \frac{L}{2} + \frac{L}{4} + \frac{L}{6}$

$$x = \frac{6L + 3L + 2L}{12} = \frac{11L}{12}$$

36. $x_{cm} = \frac{m_1 x_1 + m_2 x_2 + m_3 x_3 + m_4 x_4}{m_1 + m_2 + m_3 + m_4}$

$$x_{cm} = 1.65a$$

$$x_{cm} = \frac{m_1 y_1 + m_2 y_2 + m_3 y_3 + m_4 y_4}{m_1 + m_2 + m_3 + m_4}$$

$$x_{cm} = \frac{\sqrt{3}a}{4}$$

37. $x_{cm} = \frac{m_1 x_1 + m_2 x_2}{m_1 + m_2}$

$$\Delta x_{cm} = \frac{m_1 \Delta x_1 + m_2 \Delta x_2}{m_1 + m_2}$$

$$1 = \frac{10(7) + m_2 \Delta x_2}{40}$$

$$\Delta x_2 = -1\ cm$$

i.e., 1 cm downward

38. $d = \frac{R}{\sqrt{2}}$

$$m_1 = 4R^2$$

$$m_2 = \pi R^2$$

$$x = \frac{m_2 d}{m_1 - m_2}$$

$$x = \frac{\pi R^2 \frac{R}{\sqrt{2}}}{4R^2 - \pi R^2}$$

$$x = \frac{\pi R}{\sqrt{2}(16 - \pi)}$$

39. $m_1x_1 = m_2x_2$

$mx = 5m(9R - x)$

$x = 7.5R$

40. Distance moved by the boat is

$$x = \frac{mL}{M+m} = \frac{20(2)}{100}$$

$x = 0.4m$

$\therefore$ The distance of the dog from the shore is

$S = 10 - 2 + 0.4$

$S = 8.4m$

41. $$x_{cm} = \frac{m_1x_1 + m_2x_2}{m_1 + m_2}$$

$$R = \frac{\frac{m}{4}(-R) + \frac{3m}{4}x_2}{m}$$

$$\therefore x_2 = \frac{5R}{3}$$

42. $$x_{cm} = \frac{-\frac{m}{2}(L/4) - \frac{m}{2}(\cos\theta)L/4}{m}$$

$$y_{cm} = \frac{\frac{m}{2}\sin\theta(L/4)}{m}$$ ===➔ $$r_{cm} = \sqrt{x^2{}_{cm} + y^2{}_{cm}}$$