CENTRE OF MASS

- Point at which weight of the body is concentrated is called 'centre of gravity'.
- Point at which entire mass of the body appears to be concentrated is called 'centre of mass'.
- Centre of mass undergoes translatory motion, when a constant resultant force acts on the body and it represents the motion of the entire body.
- Centre of mass obeys newtons laws of motion At the centre of mass actual mass needn't be present.
- Internal forces can't produce acceleration in centre of mass.
- Location of centre of mass is independent of co-ordinate system.
- In uniform gravitational fields and for small bodies centre of mass and centre of gravity coincide.
- Coordinates of C.M. of a system of particles $m_1(x_1y_1z_1)$, $m_2(x_2y_2z_2)$ ....

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

$$y_{cm} = \frac{m_1y_1 + m_2y_2 + ...}{m_1 + m_2 + ...}$$

$$z_{cm} = \frac{m_1z_1 + m_2z_2 + ...}{m_1 + m_2 + ...}$$

In vector notation

$$\bar{r}_{cm} = \frac{\sum m_1 \bar{r}_1}{m_1} \text{ where } r_1 = x_1\hat{i} + y_1\hat{i} + z_1\hat{k}$$

- Velocity of centre of mass is

$$v_{CM} = \frac{m_1v_1 + m_2v_2 + ...}{m_1 + m_2 + ...}$$

$$= \frac{total \text{ momentum}}{total \text{ mass}}$$

- Acceleration of centre of mass is

$$a_{CM} = \frac{m_1a_1 + m_2a_2 + ...}{m_1 + m_2 + ...} = \frac{net\ \ force}{total \text{ mass}}$$

- To a system of particles $m_1(x_1y_1)$, $m_2(x_2y_2)$ another particle of mass m_3 is added so that centre of mass shifts to the origin then coordinates of third particle are

$$x_3 = -\frac{(m_1x_1 + m_2x_2)}{m_3} ; y_3 = -\frac{(m_1y_1 + m_2y_2)}{m_3}$$

- To a circular disc of radius R_1 another of radius R_2 and of the same material is added then shift in the CM is $x = \frac{R_2^{\,2}(R_1 + R_2)}{R_1^{\,2} + R_2^{\,2}}$
- From a disc of radius R a disc of radius r is removed from one end. Then shift in its centre of mass is $x = \frac{r^2 (R - r)}{R^2 - r^2}$
- Out of a uniform solid sphere of radius R, if a sphere of radius r is removed, then the shift in centre of mass is $\frac{r^3(R-r)}{(R^3 - r^3)}$
- In case of two bodies, the ratio of distance of centre of mass from the bodies is in the inverse ratio of their masses. If m_1 and m_2 are masses of two bodies separated by a distance 'd' then

$$x_1 = \frac{m_2 d}{m_1 + m_2}, \quad x_2 = \frac{m_1 d}{m_1 + m_2}$$

x_1, x_2 are the distances of CM, from m_1, m_2

CONCEPTUAL QUESTIONS

1. Centre of mass is a
   1. point 2.mass 3.vector 4.scalar
2. Centre of mass does not depend on
   1. masses of particles
   2. position of particles
   3. internal forces 4. external forces
3. The moon moves around the earth in circular orbit and earth moves around the sun in an elliptical orbit. The Centre of mass of earth–moon system moves around the sun in
   1. a circular orbit 2. an elliptical orbit
   3. hyperbolic path 4. parabolic path
4. A cricket ball is thrown upwards by a spin bowler
   1. the path of the particle on the surface of the ball is a parabola
   2. the path of the Centre of mass of the ball is a parabola
   3. the path of a particle on the surface is complex one
   4. 2 and 3 are correct

5. When a force is applied on a body, Newton's second law is applicable to
   1. Centre of mass 2. any part of the body
   3. centre of gravity 4. None
6. Centre of mass of the earth–moon system lies
   1. on the surface of earth
   2. on the surface of the moon
   3. within the earth
   4. at the mid–point of the line joining their centres
7. A wooden sphere and a copper sphere of same radius are kept in contact with each other. Their centre of mass will be
   1. at their point of contact
   2. within the wooden sphere
   3. within the copper sphere
   4. outside the spheres
8. There are five bodies with their centre of mass lying on x–axis. Then their combined centre of mass
   1. lies only y–axis 2. lies on z–axis
   3. lies on x–axis 4. may be anywhere
9. Three identical spheres each of radius r are placed touching each other on a horizontal table. The centre of mass of the system is located.
   1. at one of the centres of the spheres
   2. at the mid point joining the medians of any two spheres
   3. at the point of intersection of the medians of the triangle formed by the centres of the spheres
   4. at the mid point of a median of the triangle formed by the centres of the two spheres.
10. Two balls are thrown at the same time in air, while they are in air, the acceleration of their centre of mass
    1. depends on masses of the balls
    2. depends on the direction of motion of the balls
    3. depends on speeds of the balls
    4. is equal to acceleration due to gravity
11. A cylinder is completely filled with water. If $\frac{1}{4}$ th of the volume of water leaks out, its centre of mass
    1. moves up 2. moves down
    3. does not change 4.moves towards one wall
12. The Na^+ and Cl^- ions which are initially at certain distance apart start moving towards each other due to mutual attraction. As they are moving nearer, their centre of mass
    1. shifts nearer to Na^+ 2. shifts nearer to Cl^-
    3. remains in the same position 4. none
13. 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', the distance by which the second one should be pushed towards the centre of mass to keep the centre of mass at the same position is
    1. d 2. $\frac{m_1 d}{m_2}$ 3. $\frac{m_2 d}{m_1}$ 4. $\frac{m_2 d}{m_1 + m_2}$

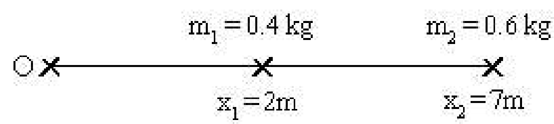
KEY

1. 1	2. 3	3. 4	4. 4	5. 1
6. 3	7. 3	8. 3	9.3	10.4
11. 2	12. 3	13. 4		

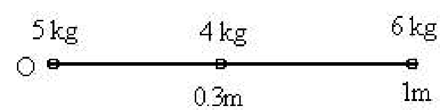
LEVEL - I

1. 10gm., 30gm and 60gm are at 20cm, 40cm and 80cm on light metre scale. The position of the centre of mass of the system is
   1. 0 2. 62cm 3. 74 cm 4. 100cm
2. A system consists of two masses connected by a massless rod that lies along x–axis. The distance of centre of mass from O is

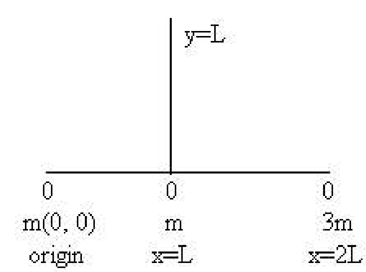
   m_1 = 0.4 kg m_2 = 0.6kg
   O X X X
   x_1 = 2m x_2 = 7m



   1. 0 2. 2m 3. 5m 4. 7m
3. The distance of centre of mass from '0' is
   5kg 4 kg 6kg
   O 0 0 0
   0.3m 1 m

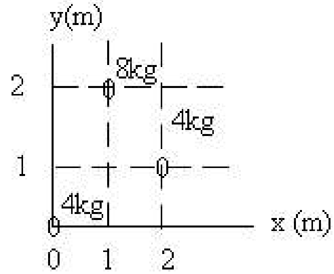


   1. 0.21m 2.0.35m 3.0.42m 4.0.48 m
4. Coordinates of centre of mass of the following system are



   1. (0, 0) 2. (L, 0)
   3. (1.33L, 1.67L) 4. (1.33L, 0.167L)

5. The coordinates of centre of mass in the figure are



1. (0, 0)2. (1, 1) 3. (1, 1.5) 4. (1, 1.25)

6. A 1000kg automobile is moving along a straight highway at $10ms^{-1}$. Another car with mass 2000kg and speed $20ms^{-1}$ is 30m ahead of the first. The position of the centre of mass of the system from the first is

1. 0 2. 10m 3. 20m 4. 30m

7. In the above problem the velocity of centre of mass of the system is

1. 14.2 ms^{-1} 2. 15 ms^{-1}
3. 18.5 ms^{-1} 4. 16.7 ms^{-1}

8. A 2kg body and 3kg body are moving along the x–axis. At a particular instant the 2kg body is 1m from the origin and has a velocity of 3 ms^{-1} and 3kg body is 2m from the origin and has a velocity of –1 ms^{-1}. The position of the centre of mass of the system is

1. 1m 2. 1.6m 3. 2.2 m 4. 0

9. In the above problem, the velocity of centre of mass of the system is

1.0 2.0.6 ms^{-1}
3.1 ms^{-1} 4. 1.8 ms^{-1}

10. In the above problem the momentum of the centre of mass of the system is

1. 6kg ms^{-1} 2. 9kg ms^{-1}
3. 3kg ms^{-1} 4. 0

11. A 4kg mass travelling at 6 ms^{-1} along the x–axis collides with a stationary 2kg mass at rest. The velocity of centre of mass of the system is

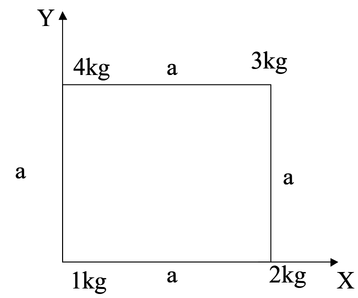
1. 0 2. 6 ms^{-1} 3. 3 ms^{-1} 4. 4 ms^{-1}

KEY

1. 2	2. 3	3. 4	4. 4	5. 4
6. 3	7. 4	8. 2	9. 2	10. 3
11. 4				

LEVEL – II

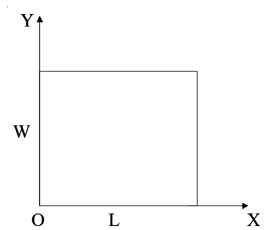
1. Four bodies of masses 1, 2, 3, 4 kg respectively are placed at the comers of a square of side 'a'. Coordinates of centre of mass are



1. $\left(\frac{7a}{10}, \frac{a}{2}\right)$ 2. $\left(\frac{a}{2}, \frac{7a}{10}\right)$

3. $\left(\frac{a}{2}, \frac{3a}{10}\right)$ 4. $\left(\frac{7a}{10}, \frac{3a}{2}\right)$

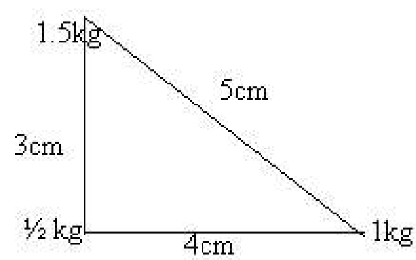
2. A uniform wire is bent into the form of a rectangle of length L and width W. The coordinates of its centre of mass are



1. (0, 0 2. $\left(\frac{L}{2}, W\right)$

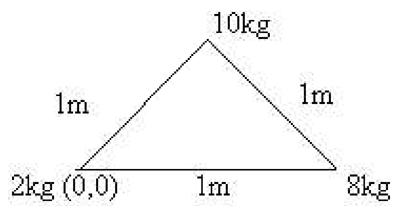
3. $\left(L, \frac{W}{2}\right)$ 4. $\left(\frac{L}{2}, \frac{W}{2}\right)$

3. The coordinates of centre of mass of the system in the figure are



1. (1.3, 1.5) 2. (2.5, 3.2)
3. 0.8, 1.4) 4. (0, 0)

4. The coordinates of centre of mass of the system in the figure are

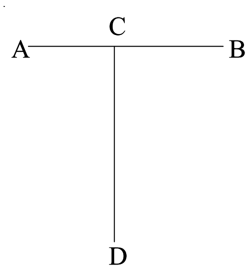


1. (0.433, 0.65) 2. (0.65, 0.433)
3. (0.65, 0.51) 4. (0.5, 0.65)

5. If three particles of masses 2kg, 1kg and 3kg are placed at corners of an equilateral triangle of perimeter 6m then the distance of centre of mass of particles from 1kg mass is (approximately)

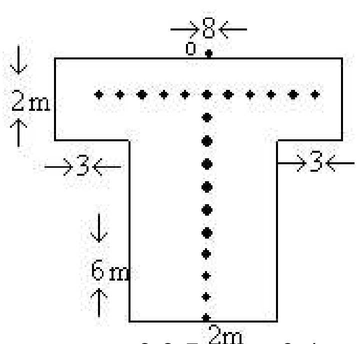
1. $\sqrt{76}m$ 2. $\sqrt{2}m$ 3. $\frac{1}{\sqrt{2}}m$ 4.2m

6. Two identical thin uniform rods of length L each are joined to form T shape as shown in the figure. The distance of centre of mass from D is



1. 0 2. $\frac{L}{4}$ 3. $\frac{3L}{4}$ 4.L

7. The distance of the centre of mass of the T–shaped plate from 'O' is



1. 7 m 2.2.7m 3.4m 4.1m

8. The coordinates of a centre of mass of a system having masses 2kg (3, 2), 3kg (1, –4) and 4kg (–3, 5) are

1. $\left(\frac{1}{3},\frac{4}{3}\right)$ 2. $\left(\frac{4}{3},\frac{1}{3}\right)$ 3. $\left(\frac{-1}{3},\frac{4}{3}\right)$ 4. $\left(\frac{4}{3},\frac{-1}{3}\right)$

9. A bomb of mass 'm' at rest at the original of coordinates explodes into three equal pieces. At a certain instant one piece is on the x–axis at x=40cm and another is at x=20cm, y = –60cm. The position of the third piece is
1. x = 60cm, y=60cm
2. x = –60cm, y=–60cm
3. x = –60cm, y=60cm
4. x = 60cm, y=–60cm

10. The distance between carbon and oxygen atoms in carbon monoxide molecule is 1.12 A^0. The distance of the centre of mass of the molecule from the carbon atom is
1. 0.48A° 2. 0.56A° 3. 0 4. 0.64A°

11. In equilibrium, the potassium (39) and iodine (127) atoms of KI are separated by approximately 3A°. The centre of mass of KI from potassium is
1. 1.2A° 2. 2.13A° 3. 2.28A° 4. 1.8A°

12. The separation between hydrogen (1) and chlorine (35) atoms in the hydrogen chloride molecule (HCl) is about 0.13nm. The distance of centre of mass of HCl molecule from hydrogen atom is
1. 0.126 nm 2. 0.11nm
3. 0.128 nm 4. 0

13. Two circular plates of radii 8cm and 6cm are cut from a uniform metal sheet. They are placed side by side, touching each other lying in the same plane. The position of the centre of mass of the system from the centre of the larger dics is
1. 4.08 cm 2. 5.4 cm
3. 5.04 cm 4. 6.2 cm

14. Three identical spheres each of mass 'm' and radius 'R' are placed touching each other so that their centres A, B and C lie on a straight line. The position of their centre of mass from centre of A is

1. $\frac{2R}{3}$ 2. 2R 3. $\frac{5R}{3}$ 4. $\frac{4R}{3}$

15. Three identical spheres each of mass 1kg are placed touching each other with the centres on a straight line. The centres are marked as A, B and C respectively. The distance of centre of mass from A is

1. $\frac{AB+BC}{3}$ 2. $\frac{AB+AC}{3}$
3. $\frac{AB+BC}{2}$ 4. $\frac{AB+AC}{2}$

16. A rigid body consists of a 3kg mass located at $\vec{r}_1 = (2\hat{i} + 5\hat{j})$ m and a 2kg mass located at $\vec{r}_2 = (4\hat{i} + 2\hat{j})$ m. The position of centre of mass is

1. $\frac{14}{5} + \frac{19}{5}m$ 2. $\frac{14}{5}\hat{i} + \frac{19}{5}\hat{j}m$

3. $\frac{19}{5}\hat{i} + \frac{14}{5}\hat{j}m$ 4. 0

17. Two charged particles of masses m and 2m are placed at a distance d apart on a smooth horizontal table. The position of centre of mass from lighter one is

1. 0 2. $\frac{d}{3}$ 3. $\frac{2d}{3}$ 4. d

18. Two charged particles of masses m and 2m are placed at a distance d apart on a smooth horizontal table. Because of their mutual attraction, they move towards each other and collide. Where will the collision occur from lighter one?

1. 0 2. $\frac{d}{3}$ 3. $\frac{2d}{3}$ 4. d

19. Two boats of masses 400kg and 500kg are connected by a long rope. A boy of mass 50kg in the first boat pulls other boat by means of a rope with a force 950N. With what acceleration does the centre of mass of the system of boats move?

1. 0 2. 1 m/s^2 3. 2 m/s^2 4. 0.5 m/s^2

20. In a system of two identical particles, one of the particles is at rest and the other has an acceleration a, then the centre of mass has an acceleration

1. 0 2. ½ a 3. a 4. 2a

21. A boy of mass 50kg is standing at one end of a boat of length 9m and mass 400kg. He runs to the other end. The distance through which the centre of mass of the boat boy system moves is

1. 0 2. 1m 3. 2m 4. 3m

22. A boy of mass 50kg is standing at one end of a boat of length 9m and mass 400kg. He runs to the other end. The distance through which the boat moves back is

1. 0 2. 1m 3. 2m 4. 3m

23. A boat of mass 60kg is floating in still water. A boy of mass 20kg walks from one end to the other end. If the length of the boat is 3m, the distance through which the boat moves is

1. 1m 2. 0.75m 3. 0.5m 4. 0.9m

24. Two particles A and B of masses 2kg and 3kg are at rest separated by 10m. If they move towards each other under a mutual force of attraction, the distance of the point from the initial position of A where they meet is

1. 5m 2. 4m 3. 6m 4. 8m

25. Two particles having masses m and 2m are travelling along x–axis on a smooth surface with velocities u_1 and u_2 collide. If their velocities after collision are v_1 and v_2, then the ratio velocities of their centre of mass before and after collision is

1. 2:1 2. 2 : 3 3. 1 : 1 4. 1:2

26. Two particles of masses 4kg and 6kg are at rest separated by 20m. If they move towards each other under mutual force of attraction, the position of the point where they meet is

1. 12m from 4kg body
2. 12m from 6kg body
3. 8m from 4kg body
4. 10m from 4kg body

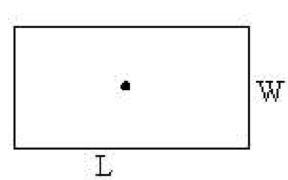
KEY

1. 2	2. 4	3. 1	4. 2	5. 2
6. 3	7. 2	8. 3	9. 3	10. 4
11. 3	12. 1	13. 3	14. 2	15. 2
16. 2	17. 3	18. 3	19. 1	20. 2
21. 1	22. 2	23. 2	24. 3	25. 3
26. 1				

1. The coordinates of masses are 1 (0,0), 2(a, 0) 3(a, a) and 4 (0, a).

$$X_{cm} = \frac{\sum m_i x_i}{\sum m_i};\ Y_{cm} = \frac{\sum m_i y_i}{\sum m_i}$$

2. Coordinate of centre of mass are $\left(\frac{L}{2}, \frac{W}{2}\right)$



3. The coordinates are ½ (0, 0), 1(4, 0) and 1.5 (0, 3) $X_{cm} = \frac{\sum m_i x_i}{\sum m_i};\ Y_{cm} = \frac{\sum m_i y_i}{\sum m_i}$

4. See problem 3.

5. Take 1kg mass at the origin, and calculate the coordinates of c.m. and find the distance

6. c.m. is located at a distance $\frac{L}{4}$ from c

distance from $D = \frac{L}{4} + \frac{L}{2} = \frac{3L}{4}$

7. Moment are equal about c.m., and mass is proportional to area

$\therefore\ m_1x_1 = m_2x_2$

$8 \times 2x = 6 \times 2(4-x)$ (or) $x = \frac{12}{7}$

$\therefore$ **c.m.** from $O = \frac{12}{7} + 1 = \frac{19}{7}$ m

8. $X_{cm} = \frac{\sum m_i x_i}{\sum m_i}$; $Y_{cm} = \frac{\sum m_i y_i}{\sum m_i}$

9. $\vec{r_1} = 40\,\vec{i}$

$\vec{r_2} = 20\,\vec{i} - 60\,\vec{j}$; $\vec{r_3} = ?$

$\vec{r_1} + \vec{r_2} + \vec{r_3} = 0$

$60\,\vec{i} - 60\,\vec{j} + \vec{r_3} = 0$ (or) $\vec{r_3} = -60\,\vec{i} + 60\,\vec{j}$

$\therefore$ x = –60cm; y = 60cm

10. $X_c = \frac{m_o}{m_c + m_o}.x_w$

11. See problem 10

12. See problem 10

13. $x = \frac{r_2^{\ 2}}{r_1^{\ 2} + r_2^{\ 2}}(r_1 + r_2)$

14. $X = \frac{AB + AC}{3} = \frac{2R + 4R}{3} = \frac{6R}{3} = 2R$

15. See problem

16. $\vec{r}_{cm} = \frac{m_1\vec{r_1} + m_2\vec{r_2}}{m_1 + m_2}$

17. See problem 10

18. Collision occurs at **c.m.**

19. Position of **c.m.** remains stationary

20. $a_{cm} = \frac{m_1a_1 + m_2a_2}{m_1 + m_2}$

21. **c.m.** of the system remains stationary

22. (400 + 50)d = 50x9

23. See problem 22

24. Equal to the distance of **c.m.**

25. The velocity of **c.m.** of particles in a closed system does not depend upon individual velocities of particles in a collision

26. $x = x = \frac{6}{4+6}x20$ $\left(x = \frac{m_2}{m_1 + m_2}.AB\right)$

<u>LEVEL – III</u>

1. A circular disc of radius 20cm is cut from one edge of a larger circular disc of radius 50cm. The shift of centre of mass is
   1. 5.7 cm 2. (–5.7cm) 3. 3.2 cm 4. –3.2 cm

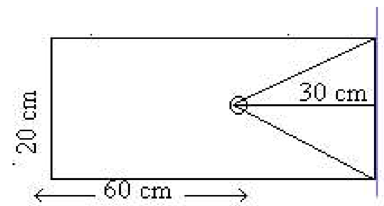
2. A circular plate has a uniform thickness and has a diameter 56cm. A circular disc of diameter 42cm is removed from one edge of the plate. The distance of the centre of mass of the remaining portion from the centre of mass of the plate is
   1. 18 cm 2. 9cm 3. 27cm 4. 4.5 cm

3. A uniform disc of radius R is put over another uniform disc of radius 2R of same thickness and density. The peripheries of the two discs touch each other. The position of their centre of mass is
   1. at $\frac{R}{3}$ from the centre of the bigger disc towards the centre of the smaller disc
   2. at $\frac{R}{5}$ from the centre of the bigger disc towards the centre of the smaller disc
   3. at $\frac{2R}{5}$ from the centre of the bigger disc towards the centre of the smaller disc
   4. None

4. From a sphere of radius 1m, a sphere of radius 0.5m is removed from the edge. The position of centre of mass of the remaining portion from centre of the sphere is
   1. $\frac{13}{6}m$ 2. $\frac{16}{13}m$ 3. $\frac{14}{13}m$ 4. $\frac{1}{14}m$

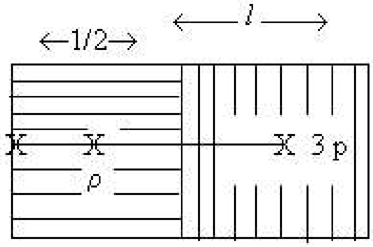
5. From a uniform circular plate of radius R, a circular plate of diameter R is removed such that the centre of the hole is at a distance $\frac{R}{3}$ from original centre. Shift in centre of mass is
   1. $\frac{R}{6}$ 2. $\frac{R}{14}$ 3. $\frac{R}{9}$ 4. $\frac{R}{3}$

6. As shown in figure from a uniform rectangular sheet a triangular sheet is removed from one edge. The shift of centre of mass is



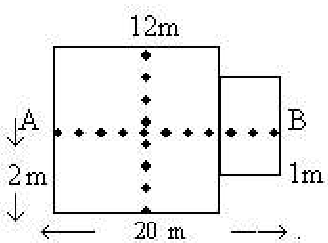
1. 4.2 cm 2. –4.2cm 3. 6.67 cm 4. –6.67 cm

7. Half of the rectangular plates of length l as shown in the figure is made up of a material of density ρ and the other half of density 3 ρ. The distance of centre of mass from O is



1. 0 2. $\frac{1}{2}$ 3. $\frac{5}{8}l$ 4. 1

8. A machine part is shown in cross section in figure consists of two homogenous solid, co–axial cylinders AB as the common axis. Where is its centre of mass from A? ...in m



1. $\frac{1}{7}$ 2. $\frac{2}{7}$ 3. $\frac{52}{7}$ 4. $\frac{5}{7}$

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

1. 1m 2. 2.5m 3. 3.5m 4. 2.1m

10. On a large tray of mass M, an ice cube of mass m, edge L is kept. If the ice melts completely, the centre of mass of the system comes down by

1. $\frac{mL}{2(M+m)}$ 2. $\frac{(M-m)L}{2(M+m)}$

3. $\frac{(M+2m)L}{2(M+m)}$ 4. $\frac{2ML}{2(M+m)}$

11. If two particles of masses 3kg and 6kg which are at rest are separated by a distance of 15m. The two particles are moving towards each other under a mutual force of attraction. Then the ratio of distances travelled by the particles before collision is

1. 2 : 1 2. 1: 2 3. 1 : 3 4. 3 :1

12. In the above problem, the ratio of accelerations acquired by the particles is

1. 2 : 1 2. 1: 2 3. 1 : 3 4. 3 :1

13. In the above problem, the ratio of velocities acquired by the particles before collision is

1. 4 : 1 2. 1 : 2 3. 1 : 9 4. 2 : 1

14. If two particles of masses 3kg and 6kg which are at rest are separated by a distance of 15m. The two particles are moving towards each other under a mutual force of attraction. Then the ratio of final momenta of two particles before collision is

1. 2 : 1 2. 1: 3 3. 1 : 1 4. 1 :2

15. Masses 8, 2, 4, 2 kg are placed at the corners A, B, C, D respectively of a square ABCD of diagonal 80 cm. The distance of centre of mass from A is

1. 30cm 2. 15 cm 3. 40cm 4. 60 cm

16. Three particles each of mass 2kg are at the corners of an equilateral triangle of side √3m. If one of the particles is removed, the shift in the centre of mass is

1. 0.2 2. 0.5 3. 0.4 4. 0.3

17. A uniform rod of length one metre is bent at its mid point to make 90^o. The distance of centre of mass from the centre of the rod is

1. 20.2 cm 2. 13.4 cm
3. 15 cm 4. 17.68 cm

18. A uniform thin rod of length 1m and mass 3kg is attached to a uniform thin circular disc of radius 30cm and mass 1kg at its centre perpendicular to its plane. The centre of mass of the combination from the centre of disc is

1. 0.375m 2. 0.25m 3. 0.125m 4. 0.475

19. A dog weighing 5kg is standing on a flat boat so that he is 10 metres from the shore. He walks 4m on the boat towards the shore and then hatts. The boat weighs 20kg and one can assume that there is no friction between it and water. The dog from the shore at the end of this time is

1. 3.4 m 2. 6.8m 3. 12.6 m 4. 10 m

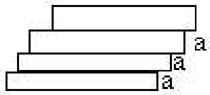
20. A man weighing 80kg is standing on a trolley weighing 320 kg. The trolley is resting on frictionless horizontal rails. The displacement relative to ground after 4s, if the man starts walking on the trolley along the rails at a speed of $1ms^{-1}$. is

1. 1.6m 2. 2.8m 3. 3.2m 4. 4.6 m

21. A circular plate of diameter 'a' is kept in contact with a square plate of side 'a'. The density of the material and the thickness are the same every where. The centre of mass of the system will be

1. at the point of contact of the bodies
2. inside the circular plate
3. inside the square plate 4. outside the system

22. Four identical planks each of lengths 'L' are arranged one above the other over a table as shown. Each projects a distance 'a' beyond the edge of the one that is below it. What is the maximum possible value of 'a' for the system to be in equilibrium without tripping forward?



1. L/5 2. L/ 4 3. L/3 4. L

23. Two masses 'm_1' and 'm_2' (m_1>m_2) are connected to the ends of a light inextensible string which passes over the surface of a smooth fixed pulley. If the system is released from rest, the acceleration of the centre of mass of the system will be (g = acceleration due to gravity)

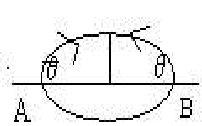
1. $\frac{g(m_1 - m_2)}{(m_1 + m_2)}$ 2. $\frac{g(m_1 - m_2)^2}{(m_1 + m_2)^2}$

3. $\frac{g(m_1 + m_2)}{(m_1 - m_2)}$ 4. $\frac{g(m_1 + m_2)}{(m_1 - m_2)}$

24. Three identical particles each of mass 0.1kg are arranged at three corners of a square of side $\sqrt{2}$ m. The distance of the centre of mass from the fourth corner is
1. 2/3 m 2. 4/3 m 3. 1m 4.8/3m

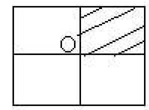
25. ABCD is a square of side "L". Two masses each of 1kg are placed at the corners C and D. Where should a mass of 2kg be placed, so that the centre of mass of the system coincides with the centre of the square?
1. at the corner A 2. at the corner B
3. at the mid point of AB
4. at the mid point of AC

26. Two identical particles each of mass 'm' are projected from points A and B on the ground with same initial speed 'u' making an angle 'θ' as shown in the figure, such that their trajectories are in the same vertical plane. The initial velocity of the centre of mass is



1. u cos θ 2. 2u cos θ3. u sin θ 4. 2u sin θ

27. Figure shows a square plate of uniform thickness and side length $\sqrt{2}$ m. One fourth of the plate is removed as indicated. The distance of centre of mass of the remaining portion from the centre of the original square plate is



1. 1/3m 2. 1/2 m 3.1/6 m 4. 1/8m

28. Two spheres made of copper have radii 'r' and '2r'. They are arranged to touch each other. The distance of the centre of mass of the system from the point of contact of the two spheres is
1. 3r/2 2. 5r/3 3. 8r/3 4. 2r

29. Two particles of masses "p" and "q" (p>q) are separated by a distance "d". The shift in the centre of mass when the two particles are interchanged is
1. d(p+q) / (p–q) 2. d(p–q) / (p+q)
3. d p/(p–q) 4. d q/ (p–q)

30. A force of 15N is acting on a particle of mass 3kg towards north and a force of 20N is acting on another particle of mass 2kg towards east. The acceleration of the centre of mass of the two particle system is
1. 7 m/s^2 2. 5 m/s^2 3.1 m/s^2 4.Zero

31. Six identical particles each of mass **½ kg** are arranged at the corners of a regular hexagon of side length **½m**. If one of the particles is removed, the shift in the centre of mass is
1. 1/10m 2. 1/12m 3.1/14m 4.1/8m

32. Two particles of masses 1kg and 2kg are separated by a distance of 60cm. If the 1kg particle moves towards the 2kg particle over a distance of 15cm, the shift in the centre of mass will be
1. 5cm 2. 10cm 3. 7.5 cm 4. 15cm

33. A uniform hemisphere has radius 'R'. The centre of mass lies on the line perpendicular to its base. The height of the centre of mass above the centre of the base is
1. 3 R/ 8 2. R / 2 3.5R / 8 4. 3R / 4

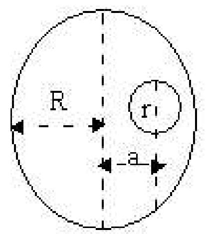
34. Two bodies of masses (M+m) and (M–m) are connected to the ends of a light inextensible string and the string is laid over a smooth fixed pulley. The system is released from rest. The velocity of the centre of mass of the two body system 't' seconds after the release is

1. $gt\frac{m}{M}$ 2. $2gt\frac{m^2}{M^2}$ 3. $gt\frac{m^2}{M^2}$ 4. Zero

35. Two bodies of masses 'm_1' and 'm_2' are moving with velocity 'v_1' and 'v_2' respectively in the same direction. The total momentum of the system in the frame of reference attached to the centre of mass is (v is relative velocity between the masses)

1. $\frac{m_1 m_2 v}{m_1 - m_2}$
2. $\frac{2 m_1 m_2 v}{m_1 + m_2}$
3. zero
4. $\frac{4 m_1 m_2 v}{m_1 + m_2}$

36. A circular hole of radius 'r' is made in a disk of radius 'R' and of uniform thickness at a distance 'a' from the centre of the disk. The distance of the new centre of mass from the original centre of mass is



1. $\frac{aR^2}{R^2 - r^2}$
2. $\frac{ar^2}{R^2 - r^2}$
3. $\frac{a(R^2 - r^2)}{r^2}$
4. $\frac{a(R^2 - r^2)}{R^2}$

37. A smooth string passes over a fixed light pulley and masses 1kg and 2kg are tied to the two ends of the string. The system is held at rest and then released. The centre of mass of the system
1. remains in the same position
2. moves down 3. moves up
4. first moves up and then moves down

38. Four identical particles each of mass 1kg are arranged at the corners of a square of side length $2\sqrt{2}$ m. If one of the particles is removed, find the shift in the centre of masses?
1. 8/3 m 2. 4/3m 3. 2/3 m 4. 2m

39. Two particles of masses 0.2kg and 0.3kg are initially at a distance 1.5m apart. The 0.2 kg mass is moved towards the 0.3kg mass over a distance of 30cm. By how much distance the 0.3kg mass is to be moved towards the 0.2kg mass, if the centre of mass of the system is to remain at the original position?
1. 0.6 2. 0.72 3. 0.12 4. 0.36

40. Two particles of masses 2kg and 3kg are at a distance of 5m apart. If half of the mass of the lighter particle is removed from it and added to the heavier mass, the shift in the centre of mass
1. 3 m 2. 4m 3. 1m 4. '0'

41. Four identical particles each of mass 'm' are arranged at the corners of a square of side length "l". If the masses of the particles at the end of a side are doubled, the shift in the centre of mass of the system?

1. $\frac{l}{4\sqrt{2}}$ 2. $\frac{l}{6\sqrt{2}}$ 3. $\frac{l}{\sqrt{2}}$ 4. $\frac{l}{5\sqrt{2}}$

42. Six identical particles each of mass 'm' are arranged at the corners of a regular hexagon of side length "L". If the mass of one of the particles is doubled, the shift in the centre of mass?
1. L 2. 6L / 7 3. L / 7 4. L / √3

43. A bomb shell of mass 3kg is moving with a velocity of 10m/s on the ground. Suddenly it explodes in to two pieces of masses 1kg and 2kg. The 2kg mass continues to move in the same direction with a velocity of 8 m/s. The velocity of the centre of mass of the bomb after the explosion?
1. 8 m/s 2. 16 m/s 3. 10 m/s 4. 2 m/s

44. Three particles each of mass 'm' are arranged at the corners of an equilateral triangle of side "L". If one of the masses is doubled, the shift in the centre of mass of the system.

1. $\frac{L}{\sqrt{3}}$ 2. $\frac{L}{4\sqrt{3}}$ 3. $\frac{\sqrt{3}L}{4}$ 4. $\frac{L}{2\sqrt{3}}$

45. Four identical particles each of mass "m" are arranged at the corners of a square of side length "L". If the masses of the particles at the end of a diagonal are doubled the shift in the centre of mass of the system?

1. $\frac{L}{\sqrt{2}}$ 2. $\frac{L}{2\sqrt{2}}$ 3. '0' 4. $\frac{L}{3}$

46. Four identical particles each of mass "m" are arranged at the corners of a square of side of side length "L". If one of the masses is doubled, the shift in the centre of mass of the system. w.r.t. diagonally opposite mass

1. $\frac{L}{\sqrt{2}}$ 2. $\frac{3\sqrt{2}L}{5}$ 3. $\frac{1}{4\sqrt{2}}$ 4. $\frac{1}{5\sqrt{2}}$

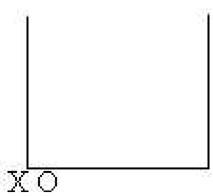
47. Three identical particles each of mass "m" are arranged at the corners of an equilateral triangle of side length "L". If two of the particles are replaced by particles of double the mass, the shift in the centre of mass of the system is

1. $\frac{L}{2\sqrt{3}}$ 2. $\frac{L}{5\sqrt{3}}$ 3. $\frac{L}{3\sqrt{3}}$ 4. $\frac{L}{4\sqrt{3}}$

48. Six identical particles each of mass "m" are arranged at the corners of a regular hexagon of side length "L". If the masses of any two adjacent particles are doubled, the shift in the centre of mass is

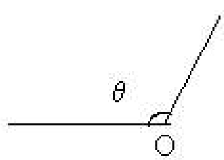
1. L / 8 2. $\sqrt{3}L/8$ 3. $\sqrt{3}L/16$ 4. $\sqrt{3}L/4$

49. Three identical rods each of length "L" and mass "m" are joined to form a U-shape as shown in the figure. The distance of the centre of mass of the system from the corner indicated?



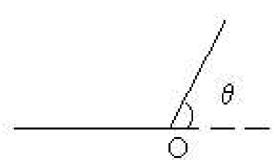
1. $\frac{L}{3}$ 2. $\frac{L}{2}$ 3. $\frac{\sqrt{13}L}{6}$ 4. $\frac{5L}{6}$

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

51. 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. $\frac{L}{4}\cos\frac{\theta}{2}$

52. Two identical rods each of length "L" and mass "m" are arranged along two sides of an equilateral triangle of side "L". The distance of the centre of mass of the system from the corner where the two rods meet each other is

1. $\frac{L}{4}$ 2. $\sqrt{3}L$ 3. $\frac{\sqrt{3}L}{4}$ 4. $\frac{\sqrt{3}L}{2}$

53. Three identical balls each of mass "m" are at the vertices of an equilateral triangle of side length "L". If the balls move under the influence of the mutual gravitational forces, the distance each ball moves before meeting the other two is

1. $\frac{L}{2}$ 2. $\frac{L}{\sqrt{3}}$ 3. $\frac{2L}{\sqrt{3}}$ 4. L

54. A bomb is initially at rest on the ground and suddenly explodes in to two fragments of equal masses. One of the fragments is found moving north with a velocity of 20 m/s. The velocity and acceleration of the centre of mass of the bomb after the explosion are

1. 20, 0 2. 20, g 3. 0, g 4. 0, 0

55. Two particles of mass "p" and "q" (p>q) are at a certain distance apart. On interchanging the position of the masses, the centre of mass of the system is found to shift through a distance "d". The distance between the two particles is

1. $\frac{d(p-q)}{q}$ 2. $\frac{d(p-q)}{p}$

3. $\frac{d(p+q)}{p-q}$ 4. $\frac{d(p-q)}{p+q}$

56. 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 centre o f mass of the remaining portion from the centre of the original sheet is at a distance of

1. $\frac{\Pi R}{\sqrt{2}[16-\Pi]}$ 2. $\frac{\Pi}{[16-\Pi]}$

3. $\frac{R}{\Pi[16-\Pi]}$ 4. $\frac{R\Pi}{16-\Pi}$

57. A uniform circular sheet has a radius r. A square sheet of diagonal length equal to radius of the plate is removed from one end of it. The distance of the centre of mass of the reminder plate from the centre of the original sheet is

1. $\frac{r}{2(2\Pi-1)}$ 2. $\frac{r}{[\Pi-2]}$

3. $\frac{2r}{\Pi-3}$ 4. $\frac{r}{2(\Pi-1)}$

58. 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. $\frac{(n-k)}{n}g$

KEY

1. 2	2. 2	3. 2	4. 4	5. 3
6. 4	7. 3	8.3	9. 4	10. 1
11. 1	12. 1	13. 4	14. 3	15. 1
16. 2	17. 4	18. 1	19. 2	20. 3
21. 3	22. 1	23.2	24. 2	25. 3
26. 3	27. 3	28. 2	29. 2	30. 2
31. 1	32. 1	33. 3	34. 3	35. 3
36. 2	37. 2	38. 3	39. 3	40. 3
41. 2	42. 3	43. 3	44. 2	45. 3
46. 4	47. 2	48. 2	49. 3	50. 4
51. 3	52. 3	53. 2	54. 3	55. 3
56. 1	57. 1	58. 4		

HINTS

1. Shift of centre of mass $x = \frac{-r^2 a}{R^2 - r^2}$

   Where r radius of removed disc
   R radius of original disc
   a distance between the centres
2. See problem 1
3. $x = \frac{r^2 a}{R^2 + r^2}$

   compare with problem 1
   New position = R – x
4. Refer problem 1
6. $O = X_{cm} = \frac{m_1 x_1 + m_2 x_2}{m_1 + m_2}$; but m = eAt

   $O = A_1X_1 + A_2X_2$ (or) $\frac{-A_2 x_2}{A_1} = \frac{A_2 x_2}{A - A_1}$

   Here A's are areas, and x_2 is the second body's centre of mass
7. $x = \frac{e_1 x_1 + e_2 x_2}{e_1 + e_2}$
8. If C is the centre of mass, then

   $$AC = \frac{m_1(AC_1) + m_2(AC_2)}{m_1 + m_2}$$

   and mass = density x volume
9. Mass of ladder acts at 2.5m
   Mass of man acts at 2m

   $\therefore x = \frac{m_1 x_1 + m_2 x_2}{m_1 + m_2}$
10. The initial position of **c.m.** is $x = \frac{mL}{2(m+M)}$

    and it shifts by the same
11. Distance travelled = Distance from centre of mass
12. $\frac{S_1}{S_2} = \frac{\frac{1}{2}a_1 t^2}{\frac{1}{2}a_2 t^2} = \frac{a_1}{a_2} = \frac{m_2}{m_1}$; F = constant
13. $\frac{v_1}{v_2} = \frac{a_1 t}{a_2 t} = \frac{m_2}{m_1}$
14. $\frac{P_1}{P_2} = \frac{m_1 v_1}{m_2 v_2}$

TRUE OR FALSE TYPE QUESTIONS :

1. Consider the following statements A and B and identify the correct answer.
   A. centre of mass lie inside or outside the body
   B. Mass must be present at centre of mass
   1. Both A & B are true
   2. A is true but B is false
   3. A is false but B is true
   4. Both A & B are false
2. Consider the following two statements A and B and identify the correct answer
   1. The centre of mass of a system of particles depends on forces on the particles.
   2. In the absence of external force, the centre of mass of system moves with uniform velocity
   1. Both A & B are true
   2. A is true but B is false
   3. A is false but B is true
   4. Both A & B are false
3. Choose the correct statement about the centre of mass (CM) of system of two particles.
   a. The C.M. lies on the line joining the two particles midway between them
   b. The C.M. lies on the line joining them at a point whose distance from each particle is inversely proportional to the mass of that particle
   c. The C.M. lies on the line joining them at a point whose distance from each particle is proportional to the square of the mass of the particle
   d. The C.M. is on the line joining them at a point whose distance from each particle is proportional to the mass of that particle
   1. a is correct 2. b is correct
   3. c is correct 4. d is correct

4. Consider the two statements A and B and identify the correct answer

1. A wooden sphere and a copper sphere of same radius are kept in contact with each other the centre of mass will be with in the wooden sphere.

b. Three identical spheres each of radius R are placed touching each other on horizontal table. The centre of mass of the system is located at the point of intersection of the medians of the triangle formed by the centres of spheres.

1. Both A & B are correct
2. A is false but B is correct
3. A is true but B is false
4. Both A & B are false

5. Two particles of masses m_1 and m_2 ($m_1 > m_2$) attract each other with a force inversely proportional to the square of the distance between them. The particles are initially held at rest and then released. Which one is correct.

a. the c.m. moves towards m_1

b. the c.m. moves towards m_2

c. the c.m. remains at rest

d. c.m. moves at right angles to the line joining m_1 and m_2

1. a is correct　　2. b is correct
3. c is correct　　4. d is correct

6. Match the following :

LIST – I	LIST – II
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 gravi rational field
c. Centre of mas 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

The correct match is

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

7. Study the following

LIST – I	LIST – II
a. centre of mass of ring	e. mass is present
b. centre of mass of non uniform rod	f. coincides with centre of gravity
c. centre of mass of small funnel	g. on the heavier side
d. centre of mass o f a uniform disc	h. at geometric centre

1. a →f; b → e; c → g; d → h
2. a →g; b → h; c → e; d → f
3. a →h; b → g; c → f; d → e
4. a →e; b → f; c → h; d → g

8. Study the following

LIST — I	LIST — II
a. position of centre of mass of a triangle	e. at one–fourth of maxi-mum height from the base
b. Position of centre of mass of a sphere	f. at the point of intersection of medians
c. Position of centre of mass of a cone	g. at the point of intersection of diagonals
d. Position of centre of mass of square	h. at the centre

1. a →f; b → h; c → e; d → g
2. a →g; b → h; c → e; d → f
3. a →g; b → h; c → f; d → e
4. a →g; b → f; c → e; d → h

A : Assertion

R : Reason

A : Both A and R are true. R is correct explanation of A

B. Both A and R are true. But R is not correct explanation of A

C. A is true. R is false

D. Both A and R are false.

9. A : The centre of mass of a body may lie where there is no mass

R : Centre of mass of a body is a point, where the whole mass of the body is supposed to be concentrated

1. A　　2. B　　3. C　　4. D

10. A : Two particles (starting from rest) move towards each other under a mutual force of attraction. The velocity of centre of mass is zero

R : Internal forces do not alter the state of motion of centre of mass

1. A　　2. B　　3. C　　4. D

11. A : The centre of mass of a two particle system lies on the line joining them, being closer to the heavier particle.
R : The centre of mass is a point where whole mass of the system is supposed to be concentrated
1. A 2. B 3. C 4. D

12. A : particle in the system of particles has a complex motion. But its centre of mass has translatory motion
R : The centre of mass is a point where whole mass of the system is supposed to be concentrated
1. A 2. B 3. C 4. D

13. **A :** The centre of mass of an isolated system has constant velocity.
R : The proton and electron attract and move towards each other. No external force is applied, therefore their centre of mass remains at rest
1. A 2. B 3. C 4. D

14. A : When a person walks on a stationary boat in still water, centre of mass of person and boat system is not displaced
R : Internal force cannot alter the position of centre of mass
1. A 2. B 3. C 4. D

15. A : When an external force is applied at the centre of mass of a free system of particles then it undergoes translatory motion only
R : The torque of the force acting at centre of mass about that centre of mass is zero
1. A 2. B 3. C 4. D

16. A : The position of centre of mass of a body depends on its shape and size
R : Centre of mass of a body is a point where the whole mass of the body is supposed to be concentrated
1. A 2. B 3. C 4. D

17. 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 cannot alter the state of motion of a body.
1. A 2. B 3. C 4. D

18. A : When a body dropped from a height explodes in mid air, the pieces fly in such a way that their centre of mass keeps moving vertically downwards.
R : Explosion occurs under internal forces only. External forces = 0
1. A 2. B 3. C 4. D

MULTI CORRECT TYPE QUESTIONS

19. Identify the correct statements from the following
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 & b are correct 2. b & c are correct
3. a, b & c are correct 4. All are correct

20. If external forces acting on a system have zero resultant, the centre of mass
a. may move b. may accelerate
c. must not move d. must not accelerate
1. a & b are correct 2. b & c are correct
3. c & d are correct 4. a & d are correct

21. Pick out the wrong statements out of the following. In the absence of external force
a. the K.E. of the system of particles do not follow the law of conservation of kinetic energy
b. the centre of mass of the system of particles obey the Newton's law of motion.
c. the centre of mass is accelerated
d. the centre of mass always moves along a curved path
1. b & c are wrong 2. a & b are wrong
3. a, b & c are wrong 4. a, c & d are wrong

22. Identify the correct one from the following statements.
a. the position of centre of mass in a co–ordinate system does not change if a man moves from the one end to other end on a floating wooden long in still water.
b. When a man moves from one end to other end on a floating wooden log in still water, it moves in opposite direction
c. Due to action and reaction the wooden log floating in still water moves in opposite direction as the man on it moves from one end to the other end
1. b & c are true 2. a & d are true
3. a, b & c are true 4. All are correct

23. A stationary bomb explodes into two parts of masses in the ratio 2 : 3. If the heavier part moves with a velocity $6ms^{-1}$ towards east, then
a. the lighter part moves with velocity $9ms^{-1}$ towards west
b. the lighter part remains at rest
c. the velocity of the centre of mass of the two parts is zero after explosion.
d. the centre of mass moves along a parabolic path
1. b & c are true 2. a & d are true
3. a & c are true 4. a, c & d are true

24. In which of the following cases, the centre of mass of a rod is certainly not at its centre?
a. The density increases from left to right upto the centre and then decrease
b. The density decreases from left to right upto the centre and then increase
c. The density continuously increases from left to right
d. The density continuously decreases from left to right
1. a & b are correct 2. b & c are correct
3. c & d are correct 4. a & d are correct

25. Mass of a ring is non–uniformly distributed around its geometric centre. If R is radius of the ring, then
a. centre of mass does not coincide with geometric centre
b. Position centre of mass from the geometric centre will be x (0<x<R)
c. centre of mass will be nearer to the greater mass distribution
d. centre of mass may lie out side the periphery
1. only a & b are correct
2. only b & c are correct
3. a, b & c are correct 4. All the correct

26. P is the centre of mass of a system of four point masses A, B, C and D which are coplanar but not collinear
a. P may or may not coincide with one of the point masses
b. P must lie within or on the edge of at least one of the triangles formed by taking A, B, C and D three at a time
c. P must lie on a line joining two of the points A, B, C, D
d. P lies out side the quadrangle ABCD
1. a & b are correct 2. All are correct
3. All are false 4. a & c are correct

27. 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. a b are correct 2. b,c are correct
3. a, b, d are correct 4. a, b, c, d are correct

28. A trolley filled with sand moves on a smooth horizontal surface with a velocity v0. A small hole is made at the base of it from which sand is leaving out vertically down at constant rate. As the sand leaves out
a. the velocity of the trolley remains constant
b. the velocity of the trolley increases
c. the velocity of the trolley decreases
d. the momentum of trolley + leaked out sand is conserved
1. a & b are correct 2. c & d are correct
3. a & c are correct 4. b & d are correct

KEY

1. 2	2. 3	3. 4	4. 2	5. 3
6. 3	7. 3	8. 1	9. 2	10. 1
11. 1	12. 2	13. 1	14. 1	15. 2
16. 4	17. 1	18. 1	19. 1	20. 4
21. 4	22. 3	23. 3	24. 3	25. 3
26. 1	27. 1	28. 4		

QUESTION FROM PREVIOUS EAMCET QUESTIONS

1. Particles of masses m, 2m, 3m .... nm grams are placed on the same line at distances, l, 2l, 3l, ... nl cm from a fixed point. The distance of centre of mass of the particles from the fixed point in centimeters in **[2002 Engg]**
1. $\frac{(2n+1)l}{3}$ 2. $\frac{l}{n+1}$
3. $\frac{n(n^2+l)l}{2}$ 4. $\frac{2l}{n(n^2+l)l}$

2. A system consists of two identical particles. One particle is at rest and the other particle has an acceleration 'a'. The centre of mass of the system has an acceleration of
1. 2a 2. a 3. $\frac{a}{2}$ 4. $\frac{a}{4}$

3. Two particles of mass 1kg and 3kg have position vectors $2\bar{i}+3\bar{j}-2\bar{k}$ and $-2\bar{i}+3\bar{j}-4\bar{k}$ respectively. The centre of mass has a position vectors **[1999 Engg]**
1. $\bar{i}+3\bar{j}-2\bar{k}$ 2. $-\bar{i}+3\bar{j}-2\bar{k}$
3. $-\bar{i}+3\bar{j}+2\bar{k}$ 4. $-\bar{i}+3\bar{j}-2\bar{k}$

4. A bomb travelling in a parabolic path under the effect of gravity explodes in mid air. The centre of mass of the fragments will **[1993]**
1. moves vertically upwards and then vertically downwards
2. move vertically upwards
3. move in irregular path
4. move in parabolic path, the unexploded bomb would have travelled

5. The two particles with masses 4kg and 2kg located at (1, 0, 1) and (2, 2, 0) respectively. Then the coordinates of their centre of mass is **[1990]**
1. $\left(\frac{4}{3},\frac{2}{3},\frac{2}{3}\right)$ 2. $\left(\frac{2}{3},\frac{2}{3},\frac{2}{3}\right)$
3. $\left(\frac{2}{3},\frac{4}{3},\frac{2}{3}\right)$ 4. $\left(\frac{2}{3},\frac{2}{3},\frac{4}{3}\right)$

6. Four particles, each of mass 1kg, are placed at the corners of a square of side one meter in the X–Y plane. If the point of intersection of the diagonals of the square is taken as the origin, the coordinates of the centre of mass are **(Med 2004)**
1. (1, 1) 2. (–1, 1) 3. (1, –1) 4. (0, 0)

7. Two particles of equal mass have velocities $\bar{V_1}$ = $4\bar{i}$ and $V_2 = 4\bar{j}$. First particle has an acceleration $\bar{a_1} = (5\bar{i} + 5\bar{j})ms^{-2}$ while the acceleration of the other particle is zero. The centre of mass of the two particles moves in a path of **[Eng 2004]**
1. Straight line 2. Parabola
3. Circle 4. Ellipse

8. One end of a thin uniform rod of length L and mass M_1 is rivetted to the centre of a uniform circular disc of of radius 'r' and mass M_2 so that both are coplanar. The centre of mass of the combination from 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. $\frac{2LM_1}{(M_1 + M_2)}$

9. Two objects of masses 200gm and 500gm have velocities of 10i m/s and 3i + 5j m/s respectively. The velocity of their centre of mass is **[2003 E]**
1. 5i–25j 2. $\frac{5}{7}i - 25j$ 3. $5i + \frac{25}{7}j$ 4. $25i - \frac{5}{7}j$

10. The centre of mass of three particle s of masses 1kg, 2kg, and 3kg is at (2, 2, 2). The position of the fourth mass of 4kg to be placed in the system so that the new centre of mass is at (0, 0, 0) is 2005 E
1. (–3, –3, –3) 2. (–3, 3, –3)
3. (2, 3, –3) 4. (2, –2, 3)

11. Three particles each 1kg mass are placed at the corners of a right angled triangle AOB, O being the origin of the co–ordinate system (OA and OB) along +ve x-direction and +ve y – direction. If the positive vector of the centre of OA = OB = 1m (in meters) **2005 M**
1. $\frac{i+j}{3}$ 2. $\frac{i-j}{3}$ 3. $\frac{2(i+j)}{3}$ 4. (i–j)

KEY

1. 1	2. 3	3. 4	4. 4	5. 1
6. 4	7. 1	8. 2	9. 3	10. 1
11. 1				

QUESTIONS FROM OTHER COMPETITIVE EXAMINATIONS

1. Four particles of masses m, 2m, 3m and 4m are at the verticies of a parallelogram in x–y palne with one of the adjacent angle 60º and smaller side 'a' and larger side 2a. The mass 'm' is at the origin and mass 4m on x–axis. The centre of mass of the system is **[MP; PMT 1999]**
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. $\left(\frac{\sqrt{3}a}{2};0.82a\right)$

2. Masses 8, 2, 4, 2 kg are placed at the corners A, B, C, D respectively of a square ABCD of diagonal 80cm. The distance of centre of mass from A is **[BHU 1998]**
1. 20 cm 2. 30cm 3. 40cm 4. 60cm

3. Two bodies of different masses 2kg and 4kg are moving with velocities 2m/s and 10m/s towards each other due to mutual gravitational attraction. Then the velocity of the centre of mass is **[CBSE 1997]**
1. $5ms^{-1}$ 2. $6ms^{-1}$ 3. $8ms^{-1}$ 4. Zero

4. The centr of mass of the system of particles does not depend on **[CPMT 1993]**
   1. masses of the particles
   2. forces on the particles
   3. position of the particles
   4. relative distances between the particles
5. Two spheres of masses 2M and M are initially at rest at a distance R apart. Due to mutual force of attrction, they approach each other. When they are at separation $\frac{R}{2}$, the acceleration of the centre of mass of spheres would be **[CPMT 1993]**
   1. zero ms^{-2} 2. g ms^{-2}
   3. 3g ms^{-2} 4. 12g ms^{-2}
6. Two particles of masses 1kg and 3kg move towards eac other under their mutual force of attraction. No other force acts on them. When the relative velocity of approach of the two particles is 2m/s, the velocity of centre of mass is 0.5m/s. When the relative velocity of approach becomes 3 m/s, the velocity of centre of mass is **[IIT 1989]**
   1. 0.75 m/s 2. 0.5 m/s
   3. 2.5 m/s 4. 0 m/s
7. Two particles A and B initially at rest move towards each other under a mutual force of attraction. At the instant when the speed of A is V and the speed of B is 2v, the speed of the centre of mass of the system is **(IIT)**
   1. 0 2. v 3. 1.5v 4. 3v
8. Two particles of masses m_1 and m_2 (m_1>m_2) attract each other with a force inversely proportional to the square of the distance between them. The particles are initially held at rest and then released
   1. the C.M. moves towards m_1
   2. the C.M. moves towards m_2
   3. the C.M. remains at rest
   4. the C.M. moves at right angles to the line joining m_1 and m_2
9. Three particles of masses 1, 4, 5 g are respectively placed at the corners of an equilateral triangle of side 10cm. Find the distance of centre of mass of the system from the corner where the particle of mass 1g is placed
   1. 7.8 cm 2. 8.7 cm
   3. 9.8 cm 4. 6.7 cm

KEY

1. 3	2. 3	3. 4	4. 2
5. 1	6. 2	7. 1	8. 3
9. 1			