CBSE

SYSTEM OF PARTICLES AND ROTATIONAL MOTION WS 8

Class 11 - Physics

Section A

1. A disc is rolling on the inclined plane. What is the ratio of its rotational KE to the total KE? **[1]**

   a) 2 : 1 b) 1 : 3

   c) 3 : 1 d) 1 : 2

2. From a circular disc of radius R and mass 9 M, a small disc of mass M and radius $\frac{R}{3}$ is removed concentrically. The moment of inertia of the remaining disc about an axis perpendicular to the plane of the disc and passing through its centre is **[1]**

   a) $\frac{40}{9}MR^2$ b) 4 MR^2

   c) MR^2 d) $\frac{4}{9}MR^2$

3. A uniform metallic rod rotates about its perpendicular bisector with constant angular speed. If it is heated uniformly to raise its temperature slightly, then **[1]**

   a) its speed of rotation increases b) its speed increases because its moment of inertia increases

   c) its speed of rotation remains same d) its speed of rotation decreases

4. If a solid sphere of mass 1 kg and radius 0.1 m rolls without slipping at a uniform velocity of 1 m/s along a straight line on a horizontal floor, the kinetic energy is **[1]**

   a) $\frac{7}{10}J$ b) 1J

   c) $\frac{2}{5}J$ d) $\frac{7}{5}$ J

5. A rod of length L is hinged from one end. It is brought to a horizontal position and released. The angular velocity of the rod, when it is in vertical position is **[1]**

   a) $\sqrt{\frac{3g}{L}}$ b) $\sqrt{\frac{8}{L}}$

   c) $\sqrt{\frac{2g}{L}}$ d) $\sqrt{\frac{g}{2L}}$

6. Two rings of radii R and nR made from the same wire have the ratio of moments of inertia about an axis passing through their centre equal to 1 : 8. The value of n is **[1]**

   a) 2 b) 4

   c) $2\sqrt{2}$ d) $\frac{1}{2}$

7. **Assertion:** It will be much easier to accelerate a merry-go-round full of children if they stand close to its axis than if they all stand at the outer edge. **[1]**

   Reason: For larger moment of inertia, the angular acceleration is small for a given torque.

   a) Assertion and reason both are correct b) Assertion and reason both are correct

statements and reason is correct explanation for assertion.

b) Both A and R are true but R is not the correct explanation of A.

c) Assertion is correct statement but reason is wrong statement.

d) Assertion is wrong statement but reason is correct statement.

8. **Assertion (A):** There are very small sporadic changes in the period of rotation of the earth. **[1]**
Reason (R): Shifting of large air masses in the earth's atmosphere produces a change in the moment of inertia of the earth causing its period of rotation to change.

a) Both A and R are true and R is the correct explanation of A.

b) Both A and R are true but R is not the correct explanation of A.

c) A is true but R is false.

d) A is false but R is true.

9. **Assertion (A):** If the ice caps of the pole melts, the day length will shorten. **[1]**
Reason (R): Ice flows towards the equator and decreases the moment of inertia of the earth and hence increases the frequency of rotation of the earth.

a) Both A and R are true and R is the correct explanation of A.

b) Both A and R are true but R is not the correct explanation of A.

c) A is true but R is false.

d) A is false but R is true.

10. **Assertion:** For the purpose of calculation of moment of inertia, body's mass can be assumed to be concentrated at its centre of mass. **[1]**
Reason: Moment of inertia of a rigid about an axis passing through its centre of mass is zero.

a) Assertion and reason both are correct statements and reason is correct explanation for assertion.

b) Assertion and reason both are correct statements but reason is not correct explanation for assertion.

c) Assertion is correct statement but reason is wrong statement.

d) Assertion is wrong statement but reason is correct statement.

11. **Assertion (A):** It is most difficult to rotate a rod about an axis passing through one of its ends. **[1]**
Reason (R): Moment of inertia about an axis passing through one end of the rod is more than the moment of inertia about an axis passing its through centre.

a) Both A and R are true and R is the correct explanation of A.

b) Both A and R are true but R is not the correct explanation of A.

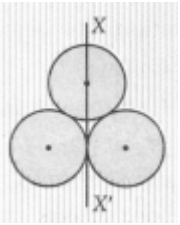
c) A is true but R is false.

d) A is false but R is true.

12. **State True or False:** **[1]**

(a) Moment of inertia is also called rotational inertia. **[1]**

13. Three identical spherical shells, each of mass m and radius r are placed as shown in the figure. Consider an axis XX' which is touching to two shells and passing through diameter of third shell. Moment of inertia of the system consisting of these three spherical shells about XX' axis is **[1]**



a) $\frac{11}{5}mr^2$ b) $\frac{16}{5}mr^2$

c) $4\ mr^2$ d) $3\ ml^2$

14. A solid sphere of radius R is placed on smooth horizontal surface. A horizontal force F is applied at height h from the lowest point. For the maximum acceleration of centre of mass, which is correct? **[1]**

a) h = 2R b) h = 0

c) h = R d) no relation between h and R

15. In a flywheel, most of the mass is concentrated at the rim. Explain why? **[1]**

16. If a cube is melted and is casted into a sphere, does moment of inertia about an axis through centre of mass increases or decreases. **[1]**

17. On what factors does radius of gyration of body depend? **[1]**

18. The moment of inertia of two rotating bodies A and B are l_A and l_B ($l_A > l_B$) and their angular momenta are equal. Which one has a greater kinetic energy? **[1]**

19. About which axis would a uniform cube have minimum rotational inertia? **[1]**

20. Which physical quantity is represented by the product of the moment of inertia and angular velocity? **[1]**

21. Why is the moment of inertia also called rotational inertia? **[1]**

22. Is the moment of inertia a scalar or a vector quantity? **[1]**

23. Give the physical significance of moment of inertia. **[1]**

24. About which axis, the moment of inertia of a body is minimum? **[1]**

25. Is centre of mass and centre of gravity body always coincide? **[1]**

26. Does the radius of gyration depend upon the speed of rotation of the body? **[1]**

27. Define moment of inertia. On what factors does it depend? **[1]**

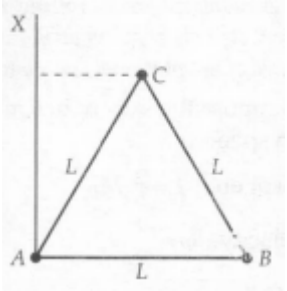
28. What is the analogous of mass in rotational motion? Write unit of that physical quantity also. **[1]**

Section B

29. The radius of a wheel of a car is 0.4 m. The car is accelerated from rest by an angular acceleration of 1.5 rad s^{-2} for 20 s. How much distance the wheel covers in this time interval and what will be its linear velocity? **[2]**

30. The Moment of inertia of a disc about an axis passing through its centre and perpendicular to its plane is $\frac{1}{2}MR^2$. Derive the values of moment of inertia of the disc about its diameter and about an axis tangential to the disc lying on its plane? **[2]**

31. Three particles, each of mass m, are situated at the vertices of an equilateral $\triangle ABC$ of side L, as shown in Fig.Find the moment of inertia of the system about the line AX perpendicular to AB and in the plane of $\triangle ABC$ **[2]**



32. A ring of diameter 0.4 m and of mass 10 kg is rotating about its axis at the rate of 2100 rpm. Find **[2]**

i. moment of inertia

ii. angular momentum and

iii. rotational K.E. of the ring.

33. Explain if the ice on the polar caps of the earth melts, how will it affect the duration of the day? **[2]**

34. Two circular discs A and B of same mass and same thickness are made of two different metals whose densities are ρ_A and ρ_B $(\rho_A > \rho_B)$. Their moments of inertia about the axis passing through their centre of gravity and perpendicular to their planes are I_A and I_B. Which is greater I_A or I_B? **[2]**

35. Find the moment of inertia of a rectangular bar magnet about an axis passing through its centre and parallel to its thickness. Mass of the magnet is 100 g, the length is 12 cm, breadth is 3 cm and thickness is 2 cm. **[2]**

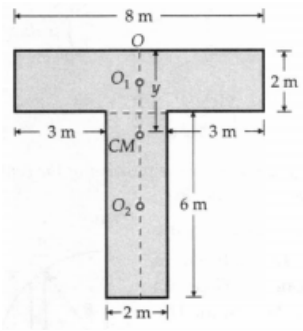
36. The radius of a sphere is 5 cm. Calculate the radius of gyration about **[2]**

    i. its diameter and

    ii. about any tangent.

37. The moment of inertia of a uniform circular disc about a tangent in its own plane is $\frac{5}{4}MR^2$, where M is mass and R is the radius of the disc. Find its moment of inertia about an axis through its centre and perpendicular to its plane. **[2]**

38. Find the position of the centre of mass of the T-shaped plate from O in the figure. **[2]**



39. What is the moment of inertia of a uniform circular disc of radius R and mass M about an axis passing through its centre and normal to the disc? The moment of inertia of the disc about any of its diameters is given to be $(\frac{1}{4})$ MR^2. **[2]**

40. A thin wire of length L and uniform linear mass density p is bent into a circular loop with centre at O as shown in Fig. What is the moment of inertia of the loop about the axis XX'? **[2]**

41. Calculate the radius of gyration of a cylindrical rod of mass M and length L about an axis of rotation perpendicular to its length and passing through its centre. **[2]**

42. A uniform disc rotating freely about a vertical axis makes 90 revolutions per minute. A small piece of wax of mass m gram falls vertically on the disc and sticks to it at a distance of r cm from the axis. If the number of rotations per minute reduces to 60, find the moment of inertia of the disc. **[2]**

43. One quarter sector is cut from a uniform circular disc of radius R. This sector has mass M. It is made to rotate about a line perpendicular to its plane and passing through the centre of the original disc. What is its moment of inertia about the axis of rotation? **[2]**

44. An energy of 484 J is spent in increasing the speed of a flywheel from 60 rpm to 360 rpm. Calculate moment of inertia of the flywheel. **[2]**

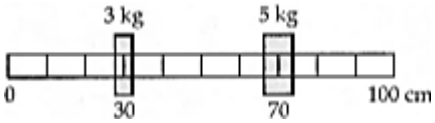
45. Establish the relation between torque and angular acceleration. Hence define moment of inertia. **[2]**

46. If ice on poles melts, then what is the change in duration of day? **[2]**

Section C

47. Two masses of 3 kg and 5 kg are placed at 30 cm and 70 cm marks respectively on a light wooden metre scale, as shown in Fig. What will the moment of inertia of the system about an axis through (i) 0 cm mark and (ii) 100 **[3]**

cm mark, and perpendicular to the metre scale?



48. A cord is wound around the circumference of a wheel of diameter 0.3 m. The axis of the wheel is horizontal. A mass of 0.5 kg is attached at the end of the cord and it is allowed to fall from rest. If the weight falls 1.5 m in 4s, what is the angular acceleration of the wheel? Also find out the moment of inertia of the wheel. **[3]**

49. Deduce an expression for the moment of inertia of a hollow cylinder of mass M and radius R about its own axis. **[3]**

50. State and prove the theorem of perpendicular axes on the moment of inertia. **[3]**

51. What is the difference between rotational kinetic energy and rolling kinetic energy? Show that rolling kinetic energy of a rolling body is given by $\frac{1}{2}mv_{cm}^2\left(1+\frac{k^2}{R^2}\right)$, where R is the radius of the body and k the radius of gyration of the body. **[3]**

52. A particle describes a horizontal circle on the smooth surface of an inverted cone. The height of the plane of the circle above the vertex is 9.8 cm. Find the speed of the particle. Take g = 9 .8 ms^{-2} . **[3]**

53. Four spheres of diameter 2a and mass M each are placed with their centres on the four corners of a square of side b. Calculate the moment of inertia of the system about one side of the square taken as its axis. **[3]**

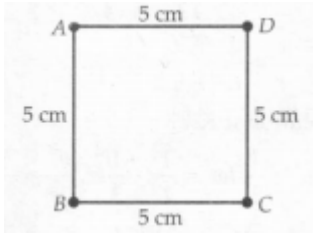
54. Calculate moment of inertia of a circular disc of radius 10 cm, thickness 5 mm and uniform density 8 g cm^{-3}, about a transverse axis through the centre of the disc. **[3]**

55. A circular plate of uniform thickness has a diameter of 56 cm. A circular portion of diameter 42 cm is removed from one edge of the plate. Find CM of the remaining portion. **[3]**

56. Four point masses of 20 g each are placed at the corners of a square ABCD of side 5 cm, as shown in Fig. Find the moment of inertia of the system **[3]**

    i. about an axis coinciding with the side BC and

    ii. about an axis through A and perpendicular to the plane of the square.



57. If the earth were to suddenly contract to half of its present radius (without any external torque on it), by what duration would the day be decreased? Assume earth to be a perfect solid sphere of the moment of inertia. **[3]**

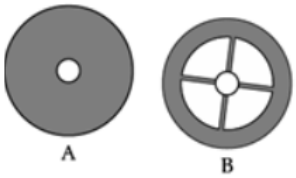
58. Two point masses of 2 kg and 10 kg are connected by a weightless rod of length 1.2 m. Calculate the M.I. of the system about an axis passing through the centre of mass and perpendicular to the system. **[3]**

Section D

Question No. 59 to 63 are based on the given text. Read the text carefully and answer the questions: **[5]**

Flywheel and sewing machine: There is a difference between inertia and moment of inertia of a body. Inertia depends on the mass of the body but the moment of inertia about an axis depends on the mass of the body and the distribution of its mass about the axis.

In the following figure, the masses of the two wheels are exactly equal but in the wheel (A) the mass is uniformly distributed and in the wheel (B) most of the mass is situated at the rim. Both the wheels rotate about axis passing through the centre. It is noticed that while the two wheels are set in rotation and left, wheel (B) continues rotating for a longer time.



This means that the moment of inertia of wheel (B) is greater than the wheel (A). Also greater is the part of the mass of the body away from the axis of rotation, greater the moment of inertia of the body about the axis. Such a wheel is known as flywheel. Consider a foot operated sewing machine. It has two wheels - one big and the other small. The wheels are connected by a rope. The bigger wheel acts as flywheel. The rope transfers the motion from this flywheel to the smaller wheel. Smaller wheel works as a pulley and also as a small flywheel.

We see even we stop supply of driving force to the bigger wheel it still continues to run for a short time because of its moment of inertia.

So, flywheel acts as an energy reservoir by storing and supplying mechanical energy when required. The kinetic energy stored in a flywheel is

E = $\frac{1}{2}I\omega^2$

where, I = moment of inertia and ω = angular velocity.

59. Which of the following statement is true?

a) Moment of inertia depends on the total mass and the distribution of mass from the axis of rotation

b) As mass of an object is distributed away from the axis of rotation, the moment of inertia decreases

c) If the masses of two objects are equal then their moment of inertia are also equal

d) Inertia depends on the total mass and the distribution of mass from the axis of rotation

60. How many flywheels are there in foot operated sewing machine?

a) One

b) Three

c) Two

d) Zero

61. We see even we stop supply of driving force to the bigger wheel of foot operated sewing machine, it still continues to tun for a short time. If the rim of this wheel is imade thicker then

a) It will run for shorter period when the

b) lt will run for the same period when the

driving force is stopped

c) It will run for longer period when the driving force is stopped

d) It will stop immediately when the driving force is stopped

62. Energy stored in flywheel is:

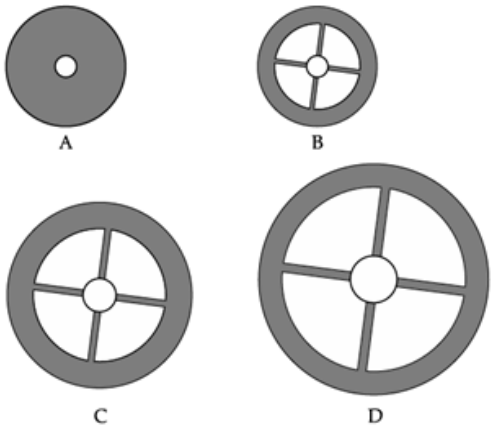
a) $\frac{1}{2}mv^2$

b) $\frac{1}{2}Iv^2$

c) $\frac{1}{2}m\omega^2$

d) $\frac{1}{2}I\omega^2$

63. Which one of the following wheel (having same mass) will have highest moment of inertia about axis passing through the centre?



a) Option (A)

b) Option (C)

c) Option (B)

d) Option (D)

64. Show that the moment of inertia of a body about the given axis of rotation is equal to twice the kinetic energy of rotation of the body rotating with unit angular velocity. **[5]**

65. Calculate the moment of inertia of uniform circular disc of mass 500 g, radius 10 cm about **[5]**

i. diameter of the disc

ii. the axis tangent to the disc and parallel to its diameter and

iii. the axis through the centre of the disc and perpendicular to its plane.

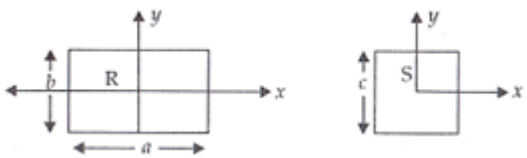
66. **[5]**

a. Find the moment of inertia of a sphere about a tangent to the sphere, given the moment of inertia of the sphere about any of its diameters to be $\frac{2MR^2}{5}$, where M is the mass of the sphere and R is the radius of the sphere.

b. Given the moment of inertia of a disc of mass M and radius R about any of its diameters to be $\frac{MR^2}{4}$, find its moment of inertia about an axis normal to the disc and passing through a point on its edge.

67. Derive an expression for the moment of inertia of a thin uniform rod about an axis passing through its one end and perpendicular to its length. Also determine the radius of gyration about the same axis. **[5]**

68. A uniform square plate S (side c) and a uniform rectangular plate R (sides b, a) have identical areas and masses (Figure). **[5]**



Show that

i. $\frac{I_{xR}}{I_{xs}} < 1$

ii. $\frac{I_{yR}}{I_{ys}} > 1$

iii. $\frac{I_{zR}}{I_{zs}} > 1$

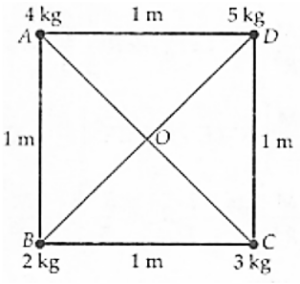
69. Derive an expression for moment of inertia of a circular disc about an axis passing through its centre and perpendicular to its plane. **[5]**

70. Prove that the acceleration of a solid cylinder rolling without slipping down an inclined plane is $\frac{2}{3}$ g sin θ. **[5]**

71. Establish the relation between moment of inertia and torque on a rigid body. **[5]**

72. A car weighs 1800 kg. The distance between its front and back axles is 1.8 m. Its centre of gravity is 1.05 m behind the front axle. Determine the force exerted by the level ground on each front wheel and each back wheel. **[5]**

73. Four particles of masses 4 kg, 7 kg, 3 kg and 5 kg are respectively located at the four corners A, B, C and D of a square of side 1 m, as shown in Fig. Calculate the moment of inertia of the system about **[5]**



i. an axis passing through the point of intersection of the diagonals and perpendicular to the plane of the square,

ii. the side AB, and

iii. the diagonal BD.

74. Define radius of gyration and mention two factors on which radius of gyration of a body depends. **[5]**

75. Define moment of inertia of a body. Give its units and dimensions. What is the physical significance of moment of inertia? **[5]**