ROTATIONAL MOTION PART 1 (PRACTICE QUESTIONS)

Take $g = 9.8\ m/s^2$

1. A turntable has a constant angular speed of 45 r.p.m. Express this in radians per second and degrees per second. If the radius of the turntable is 0.5 m, what is the linear speed of a point on its rim? **(4.71 rad/s; 270°/s; 2.355 m/s)**

2. The extremity of the hour hand of a clock moves $\frac{1}{20}$ th as fast as the minute hand. What is the length of the hour hand if the minute hand is 10 cm long? **(6 cm)**

3. Calculate the angular velocities of the three hands of a clock.

(0.105 rad/s; 1.74×10^{-3} rad/s; 1.454×10^{-4} rad/s)

4. What is the angular velocity of the minute hand of a clock? What is its angular displacement in 20 minutes? If the minute hand is 5 cm long, what is the linear velocity of its tip? **(1.74×10^{-3} rad/s; 2.1 rad; 8.7×10^{-5} m/s.)**

5. The linear velocity of a point on the rim of a rotating disc is 3 times greater than at a point on the disc 8 cm from the rim. What is the diameter of the disc? **(24 cm)**

6. A disc has a diameter of one metre and rotates about an axis passing through its centre and at right angles to its plane at the rate of 120 rev/min. What are the angular and linear velocities of a point on the rim and at a point halfway to the centre?

(4π rad/s; 6.28 m/s; 4π rad/s; 3.14 m/s)

7. A body rotates in a circular path of radius 0.25 m at 240 r.p.m. Find its angular and linear speeds. If the angular speed changes to 330 r.p.m. in 10s, find the angular and linear accelerations. **(8π rad/s; 2π m/s; 0.3π rad s^{-2}; 0.075π m/s^2)**

8. The angular acceleration of a body rotating about a given axis is 1 rad/s^2. Through what angle does it rotate during the time in which its angular velocity increases from 5 rad/s to 15 rad/s? **(100 rad)**

9. A disc rotating about an axis passing through its centre and at right angles to its plane has its angular speed reduced from 50 to 25 r.p.s. in 5 s. How many revolutions does it make during this time? How much time does it take and how many more revolutions does it make before coming to rest? **(187.5; 5 s; 62.5)**

10. A satellite revolves around the earth in a circular orbit of radius 7000 km. If its period of revolution is 2 hours, calculate its angular and linear speeds and its centripetal acceleration. **(8.7×10^{-4} rad/s; 6.09 km/s; 5.31 m/s^2)**

11. To simulate the acceleration of large rockets, astronauts are spun at the end of a long rotating beam of radius 9.8 m. Find the angular velocity required to generate a centripetal acceleration 8 times the acceleration due to gravity. **(2.82 rad/s)**

12. A body of mass 2 kg is tied to the end of a string of length 1.5m and revolved uniformly about the other end (kept fixed) in a horizontal circle. If it makes 300 rev/min, calculate the linear velocity, the acceleration and the force acting upon the body.

(47.13 m/s; 1481 m/s^2; 2962 N)

13. A certain string breaks under a tension of 45 kg-wt. A mass of 100 g is attached to one end of a piece of this string 5 m long and rotated in a horizontal circle. Neglecting the effect of gravity, find the greatest number of revolutions which the string can make without breaking. **(4.73 rev/s)**

14. A 0.5 kg mass is tied to one end of a string and rotated in a horizontal circle of 1.25 m radius about the other end. What is the tension in the string if the period of revolution is 5 s? What is the maximum speed of rotation and the corresponding period if the string can withstand a maximum tension of 150 N? **(59 N; 19.36 m/s; 0.16 s)**

15. Find the speed at which the points on the equator move as the earth rotates about its axis. Take radius of earth as 6400 km. **(465 m/s)**

16. Prove that if a body moves on the circumference of a circle with a speed equal to that which it would acquire by falling freely through half the radius of the circle, the centripetal acceleration must be equal to the acceleration in a free fall.

17. How fast should the earth rotate about its axis so that the apparent weight of a body at the equator be zero? How long would a day be then? Take radius of earth = 6400 km.

(1.237×10^{-3} rad/s; 5077 s)

18. A motor cyclist rides in a vertical circle in a hollow sphere of radius 12.8 m. Find the minimum speed required so that he does not lose contact with the sphere at the highest point. **(11.2 m/s)**

19. Find the angle which the bicycle and its rider make with the vertical when going at 27 km/h around a curve of 10 m radius. **(29° 51')**

20. A motor cyclist goes along a circular course at 120 km/h. How far from the vertical must he lean inwards for balance if the track is 3 km long? $g = 9.8$ m/s^2 **(13° 20')**

21. Calculate the maximum speed at which a car can be driven safely along a curved road of radius 30 m and banked at 30° with the horizontal. $g = 9.8$ m/s^2 **(13.03 m/s)**

22. A circular racing track of radius 600 m is designed for cars driving at an average maximum speed of 180 km/h. What is the angle of banking of the track bed? $g = 9.8$ m/s^2 **(23° 2')**

23. A vehicle enters a circular bend of radius 200 m at 72 km/h. The road surface at the bend is banked at 10°. Is it safe? At what angle should the road surface be ideally banked for safe driving at this speed? If the road is 5 m wide, what should be the elevation of the outer edge of road surface above the inner edge?

(Safety speed limit 66.9 km/h; 11° 53' ; 1 m)

24. Find the maximum speed at which a car can be safely driven along a flat curve of 100 m radius. μ between tyres and surface of road is 0.2. **(14 m/s)**

25. The radius of a circular curve on a road is 300 m. The road is banked at an angle of 15°. Find the optimum speed of a vehicle which will avoid wear and tear on its tyres. Find also the maximum speed for safe driving if $\mu = 0.2$. **(28 m/s; 38 m/s)**

26. A vehicle of mass 2600 kg running at 100 km/h takes a turn of radius 360 m. For which angle of banking the vehicle will not skid? What should be the minimum value of coefficient of friction between the road surface and the tyres if the road were not banked? $g = 9.8$ m/s^2 **(12° 20' ; 0.2187)**

27. What is the angle of banking necessary for a curved road of 50 m radius for safe driving at 54 km/h? If the road is not banked, what is the coefficient of friction necessary between the road surface and tyres for safe driving at this speed? **(24° 40'; 0.4592)**

28. The speed at which a car is negotiating a circular turn of radius 40 m on an unbanked level road is 36 km/h. If μ between the road surface and the tyres is 0.2, will the driving be safe? **(No)**

29. A coin just remains on a disc rotating at a steady rate of 180 rev/min if kept at a distance of 2 cm from the axis of rotation. Find the coefficient of friction between the coin and the disc. **(0.7244)**

30. A small coin is placed on a turntable at a distance of 7 cm from its axis of rotation. The coin begins to slide just as the turntable reaches a speed of 60 rev/min. Calculate the rate of rotation for which sliding would commence if (a) the coin were placed 12 cm from the axis (b) the coin is placed in the original position with another similar coin stuck on top of it. $g = 9.8$ m/s^2. **(45.82 r.p.m.; 60 r.p.m.)**

31. The radius of curvature of a metre gauge railway line at a place where the train is moving at 36 km/h is 50 m. If there is no side thrust on the rails, find the elevation of the outer rail above the inner rail. **(0.2 m)**

32. Find the angle of banking of the railway track of radius of curvature 3200 m if there is no side thrust on the rails for a train running at 144 km/h. Find the elevation of the outer rail above the inner one if the distance between the rails is 1.6 m. **(2°55'; 81 mm)**

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33. A bucket containing some water is tied to one end of a rope 0.8 m long and rotated about the other end in a vertical circle. Find the minimum number of rotations the bucket can make per minute in order that water in the bucket may not spill. ($g = 9.8$ m/s^2)

(33.44 r.p.m.)

[**Hint :** The bucket is in an inverted position at the top of the circle and $R + mg = \frac{mv^2}{r}$. For minimum velocity v_{min}, the reaction R is just zero giving $v_{min} = \sqrt{rg}$. Note that for $v > v_{min}$, water will not spill out]

34. At what maximum speed can a car be safely driven along a curve of radius 40 m on a horizontal road if the coefficient of friction between the tyres and the road surface is 0.3? $g = 9.8$ m/s^2. **(10.84 m/s)**

35. The distance between two rails of a railway track is 1.6 m. When the train is rounding a curve of radius 800 m, the outer rail is raised above the inner rail by 10 cm. What is the maximum speed at which the train is running?
($g = 9.8$ m/s^2) **(22.15 m/s)**

36. A body weighing 2 kg is tied to a string 0.9 m in length and rotated in a vertical circle. If the velocity at the top of the circle is 3 m/s, find the tension in the string at (1) the top of the circular path (2) a point level with the centre (3) the bottom of the circular path.
(0.4 N; 59.2 N; 118 N)

37. A small body is tied to a point by an inextensible string of negligible mass and is rotated in a vertical circle of 0.5 m radius. (a) What is the minimum speed that it must have at the uppermost point of the circle so that the string does not slacken? (b) What would be its speed at the lowermost point of the circle if it has the above minimum speed at the uppermost point? $g = 9.8$ m/s^2. **(2.2 m/s; 4.95 m/s)**

38. A 50 g mass is attached to a string and rotated in a vertical circle of radius 1.8 m. What is the minimum speed the mass must have at the top of the circle in order that the string may not slacken? What will be the velocity of mass and the tension in the string at the bottom of the circle under the above conditions? $g = 9.8$ m/s^2.
(4.2 m/s; 9.39 m/s; 2.94 N)

39. Prove that the tension in a string tied to a mass m moving in a vertical circle at its lowest point exceeds the tension in the string at its highest point by six times mg.

40. A 'loop the loop' car runs down an incline and then around the inside of a smooth circular track of radius r, making a complete turnover. Find the minimum height above the top of the circular track from which the car must be released. **($r/2$)**

41. A 20 g mass is tied to a string and rotated in a vertical circle of radius 80 cm. If the tension in the string at the highest point of the circular path is zero, find the tension in the string when the string makes an angle of 60° with the vertical and also when the mass is at a point level with the centre of circle.

(0.882 N; 0.588N)

42. A conical pendulum has a bob of mass 200 g and a length of 50 cm. If the radius of the circle traced by the bob is 25 cm, find the velocity of the bob and the period of pendulum. $g = 9.8\ m/s^2$. **(119 cm/s; 1.32 s)**

43. A conical pendulum has a length of 1.5 m and a bob of mass 50 g. The bob completes 20 revolutions in 45 s. Find the radius of the circular path traced by the bob and the tension in the thread. $g = 9.8\ m/s^2$. **(0.82 m; 0.58 N)**

44. A vehicle moves along a circular road which is inclined to the horizontal at 10°. The maximum velocity with which it can move safely is 36 km/h. Calculate the length of the circular road. **(363.5 m)**