Physics Unit 3: Uniform Circular Motion and Torque Review

1. Know about uniform circular motion, centripetal acceleration, centripetal force, torque, measures of rotational motion (position angle θ, angular velocity ω, angular acceleration α), moment of inertia
2. A car engine idles at 900 rpm. What is this in rad/s?
3. A centrifuge spins test tubes in a circle. The centrifuge has a radius of 2 cm and creates 20 m/s^2 of centripetal acceleration. What is the speed of the test tube as it spins?
4. Clothes in a washing machine are spun in a circle with radius 40 cm. If the mass of the clothes is 5 kg, what is the centripetal force when the clothes are moving at 15 m/s?
5. An 80-kg ice skater goes around a 3-m radius corner. She will slip if the centripetal force exceeds 6000 N. What speed can the skater go around the corner without slipping?
6. A string is tied to the end of a lever that pivots at its other end. The lever is 2 m long and the string makes a 50° angle with the lever. If the string is pulled with a force of 20 N, what is the torque on the lever?
7. A playground seesaw has a fulcrum in the center of the board. The board is 10 m long. If a 30-kg child sits on one end, what mass child should sit 3 m from the other end to balance the board?
8. A CD disc is spinning at 100π rad/s. What angle does it spin through in 1 ms?
9. A 50-kg kid is spinning in a centrifuge-like ride with a radius of 3 m. If the angular speed change from 5 rad/s to 100 rad/s in 20 s, what is the tangential acceleration of the test tube?
10. A 100-cm radius propeller is rotating at 500 rad/s and a 0.001-kg piece of gum is stuck to the edge. What is the linear speed of the stone?
11. A 100-cm radius propeller is rotating at 500 rad/s and a 0.001-kg piece of gum is stuck to the edge. What is the centripetal force required to keep the stone from flying out?
12. How much torque is required to accelerate a hollow spherical shell rotating about its center in 4 seconds is its mass is 2 kg, its diameter is 10 cm, its initial speed was 2π rad/s and its final speed is 5π rad/s?
13. A 50-cm diameter hoop has a mass of 2 kg. A person applies 5 Nm of torque so that the hoop rotates about a diameter. What is the angular acceleration of the hoop?
14. What is the moment of inertia of a 10-kg thin rod rotated about the axis through one end perpendicular to its length if its length is 0.5m?

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Answers

2. $\frac{900 \text{ rev}}{\text{min}}\left(\frac{2\pi\ rad}{1\ rev}\right)\left(\frac{1 \text{ min}}{60\ s}\right) = \mathbf{30\pi\ rad/s}$

3. $a_c = \frac{v^2}{r}$

   $20\frac{m}{s^2} = \frac{v^2}{0.02\ m}$

   $0.4\frac{m^2}{s^2} = v^2$

   $\mathbf{0.632}\frac{\boldsymbol{m}}{\boldsymbol{s}} = v$

4. $F_c = \frac{mv^2}{r}$

   $F_c = \frac{(5\ kg)\left(15\frac{m}{s}\right)^2}{0.40\ m}$

   $F_c = \mathbf{2810\ N}$

5. $F_c = \frac{mv^2}{r}$

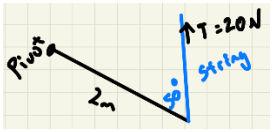
   $6000\ N = \frac{(80\ kg)v^2}{3\ m}$

   $18000\ Nm = (80\ kg)v^2$

   $225\frac{m^2}{s^2} = v^2$

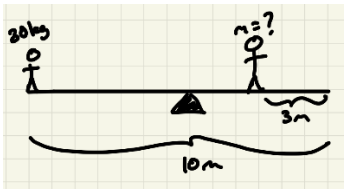
   $\mathbf{15}\frac{\boldsymbol{m}}{\boldsymbol{s}} = v$

6. $\tau = rF\sin\theta$



   $\tau = (2\ m)(20\ N)\sin 50° = \mathbf{30.6\ Nm}$

7. $\tau_{net} = 0$



   $(5\ m)(30\ kg)\left(9.8\frac{m}{s^2}\right) - (5\ m - 3\ m)m\left(9.8\frac{m}{s^2}\right) = 0$

   $1470\ Nm = m\left(19.6\frac{m^2}{s^2}\right)$

   $\mathbf{75\ kg} = m$

8. $\omega = \frac{\Delta\theta}{\Delta t}$

   $100\pi\frac{rad}{s} = \frac{\Delta\theta}{1\times10^{-3}\ s}$

   $\mathbf{0.1\pi\ rad} = \Delta\theta$

9. $\alpha = \frac{\Delta\omega}{\Delta t}$

   $\alpha = \frac{100 \text{ rad/s} - 5 \text{ rad/s}}{20\ s} = 4.75\ rad/s^2$

   $a_t = r\alpha$

   $a_t = (3\ m)\left(4.75\frac{rad}{s^2}\right)$

   $a_t = \mathbf{14.3}\frac{\boldsymbol{m}}{\boldsymbol{s^2}}$

10. $v = r\omega$

    $v = (1\ m)\left(500\frac{rad}{s}\right) = \mathbf{500}\frac{\boldsymbol{m}}{\boldsymbol{s}}$

11. $F_c = mr\omega^2$

    $F_c = (0.001\ kg)(1\ m)\left(500\frac{rad}{s}\right)^2 = \mathbf{250\ N}$

12. $\tau = I\alpha$

    $I = \frac{2MR^2}{3} = \frac{2(2\ kg)(0.05\ m)^2}{3} = \frac{1}{300}kg\ m^2$

    $\alpha = \frac{\Delta\omega}{\Delta t} = \frac{5\pi \text{ rad/s} - 2\pi \text{ rad/s}}{4s} = \frac{3\pi}{4}\frac{rad}{s^2}$

    $\tau = I\alpha = \left(\frac{1}{300}\ kg\ m^2\right)\left(\frac{3\pi}{4}\frac{rad}{s^2}\right) = \mathbf{7.85\times10^{-3}\ Nm}$

13. $\tau = I\alpha$

    $I = \frac{MR^2}{2} = \frac{(2\ kg)(0.25\ m)^2}{2} = 0.0625\ kg\ m^2$

    $\tau = I\alpha$

    $5\ Nm = (0.0625\ kg\ m^2)\alpha$

    $\mathbf{80}\frac{\boldsymbol{rad}}{\boldsymbol{s^2}} = \alpha$

14. $I = \frac{M\ell^2}{3}$

    $I = \frac{(10\ kg)(0.5\ m)^2}{3} = \mathbf{0.833\ kg\ m^2}$