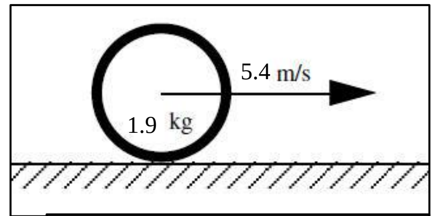
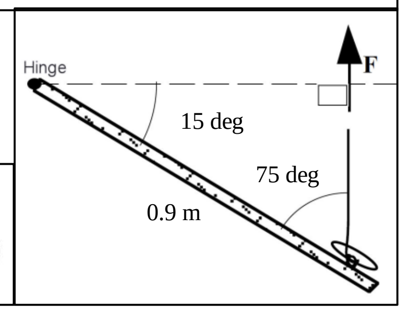
Physics

Unit 4: Statics, Torque, and Rotational Motion

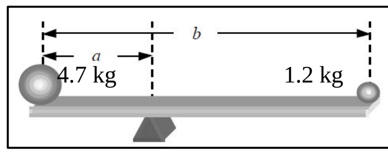
1. *Meanings and concepts of terms like center of gravity, equilibrium, machine, simple machine, mechanical advantage, angular velocity, angular acceleration, tangential acceleration, angular momentum, torque, moment of inertia, rotational kinetic energy*



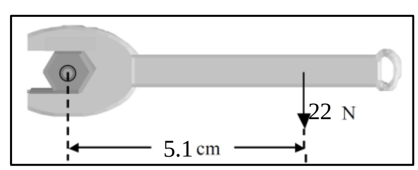
2. *A 1.9-kg hoop rolls without slipping on a horizontal surface so that its center proceeds to the right with a constant linear speed of 5.4 m/s. Its radius is 0.5 m. What is its angular momentum?*
3. *A wrench is used to tighten a nut. A 10-N force is applied 20 cm from the axis of rotation. What is the torque due to the applied force?*



4. *A string is tied to a doorknob 0.9 m from the hinge as shown in the figure. At the instant shown, the force applied to the string is 50 N. What is the torque on the door?*



5. *A 4.7-kg ball and a 1.2-kg ball are placed at opposite ends of a massless beam so that the system is in equilibrium as shown.* ***Note****: The drawing is not drawn to scale. If length a is 2 m, what is the length b?*
6. *A meter stick is pivoted at the 0.50-m line. A 5-kg object is hung from the 0.1-m line. Where should a 8-kg object be hung to achieve equilibrium?*
7. *Marshall wants to remove a tree stump from the ground. To do this, he puts one end of a long beam under the stump and puts all of his weight on the other end. His weight is just enough to lift the stump. The stump weighs 500 N. Marshall weighs 150 N. What is the mechanical advantage of the lever Marshall is using?*
8. *A system of pulleys allows a mechanic to lift an 500 N engine. The mechanic can lift the engine with a MA of 4. How much force is required to lift the engine?*
9. *During the spin-dry cycle of a washing machine, the motor slows from 100 rad/s to 10 rad/s while the turning the drum through an angle of 90 radians. What is the magnitude of the angular acceleration of the motor?*
10. *A wheel, originally rotating at 10 rad/s undergoes a constant angular deceleration of 2 rad/s^2. What is its angular speed after it has turned through an angle of 15 radians?*
11. *A grindstone, initially at rest, is given a constant angular acceleration so that it makes 5 rev in the first 10 s. What is its angular acceleration?*
12. *A string is wrapped around a pulley of radius 1 m and moment of inertia 5 kg•m^2. If the string is pulled with a force* ***F****, the resulting angular acceleration of the pulley is 50 rad/s^2. Determine the magnitude of the force* ***F****.*
13. *A certain merry-go-round is accelerated uniformly from rest at a rate of 10 rad/s^2 for 30 s. If the net applied torque is 600 N•m, what is the moment of inertia of the merry-go-round?*
14. *A 100-kg rider on a moped of mass 80 kg is traveling with a speed of 20 m/s. Each of the two wheels of the moped has a radius of 1 m and a moment of inertia of 2 kg•m^2. What is the total rotational kinetic energy of the wheels?*



15. *A wrench is used to tighten a nut as shown in the figure. A 100-N force is applied 10 cm from the axis of rotation. What is the work done to the turn the nut through 1.5 radians?*
16. *A 5-kg solid sphere with radius 1 m, rolls down a 5-m high hill starting from rest. What is the final velocity of the sphere at the bottom of the hill?*

2. $m = 1.9\ kg, v = 5.4\frac{m}{s}, r = 0.5\ m$

$v = r\omega$

$5.4\frac{m}{s} = (0.5\ m)\omega$

$\omega = 10.8\frac{rad}{s}$

$I = MR^2$

$I = (1.9\ kg)(0.5\ m)^2 = 0.475\ kg \cdot m^2$

$L = I\omega$

$L = (0.475\ kg \cdot m^2)\left(10.8\frac{rad}{s}\right) = \mathbf{5.13\ kg\frac{m^2}{s^2}}$

3. $F = 10\ N,\ r = 0.20\ m, \theta = 90°$

$\tau = rF\ sin\ \theta$

$\tau = (0.20\ m)(10\ N)\ sin\ 90° = \mathbf{2\ N \cdot m}$

4. $F = 50\ N, r = 0.9\ m, \theta = 75°$

$\tau = rF\ sin\ \theta$

$\tau = (0.9\ m)(50\ N)\ sin\ 75° = \mathbf{43.5\ N \cdot m}$

5. $m_1 = 4.7\ kg, m_2 = 1.2\ kg, r_1 = 2\ m$

$\tau_{net} = rF\ sin\ \theta = 0$ *for equilibrium*

$-(2\ m)\left(4.7\ kg \cdot 9.8\frac{m}{s^2}\right) + r_2\left(1.2\ kg \cdot 9.8\frac{m}{s^2}\right) = 0$

$-92.12\ N \cdot m + r_2(11.76\ N) = 0$

$r_2 = 7.83\ m$

$b = a + r_2 = 2\ m + 7.83\ m = \mathbf{9.83\ m}$

6. $m_1 = 5\ kg, r_1 = 0.5m - 0.1m = 0.4\ m, m_2 = 8\ kg$

$\tau_{net} = rF\ sin\theta = 0$ *for equilibrium*

$-(0.4\ m)\left(5\ kg \cdot 9.8\frac{m}{s^2}\right) + r_2\left(8\ kg \cdot 9.8\frac{m}{s^2}\right) = 0$

$-19.6\ N \cdot m + r_2(78.4\ N) = 0$

$r_2 = 0.25\ m$

$0.5\ m + 0.25\ m = \mathbf{0.75\ m}$

7. $F_o = 500\ N, F_i = 150\ N$

$MA = \frac{F_o}{F_i}$

$MA = \frac{500\ N}{150\ N} = \mathbf{3.33}$

8. $F_o = 500\ N, MA = 4$

$MA = \frac{F_o}{F_i}$

$4 = \frac{500\ N}{F_i}$

$F_i = \frac{500\ N}{4} = \mathbf{125\ N}$

9. $\omega_0 = 100\frac{rad}{s}, \omega = 10\frac{rad}{s}, \theta = 90\ rad$

$\omega^2 = \omega_0^2 + 2\alpha\theta$

$\left(10\frac{rad}{s}\right)^2 = \left(100\frac{rad}{s}\right)^2 + 2\alpha(90\ rad)$

$100\frac{rad^2}{s^2} = 10000\frac{rad^2}{s^2} + (180\ rad)\alpha$

$-9900\frac{rad^2}{s^2} = (180\ rad)\alpha$

$\alpha = \mathbf{-55\frac{rad}{s^2}}$

10. $\omega_0 = 10\frac{rad}{s}, \alpha = -2\frac{rad}{s^2}, \theta = 15\ rad$

$\omega^2 = \omega_0^2 + 2\alpha\theta$

$\omega^2 = \left(10\frac{rad}{s}\right)^2 + 2\left(-2\frac{rad}{s^2}\right)(15\ rad)$

$\omega = \mathbf{6.32\frac{rad}{s}}$

11. $\omega_0 = 0, \theta = 5\ rev = 10\pi\ rad, t = 10\ s$

$\theta = \omega_0 t + \frac{1}{2}\alpha t^2$

$10\pi\ rad = 0(10\ s) + \frac{1}{2}\alpha(10\ s)^2$

$10\pi\ rad = \alpha(50\ s^2)$

$\alpha = \mathbf{0.628\frac{rad}{s^2}}$

12. $r = 1\ m, I = 5\ kg \cdot m^2, \alpha = 50\frac{rad}{s^2}$

$\tau = I\alpha$

$(1\ m)F = (5\ kg \cdot m^2)\left(50\frac{rad}{s^2}\right)$

$F = \mathbf{250\ N}$

13. $\omega_0 = 0, \alpha = 10\frac{rad}{s^2}, t = 30\ s, \tau_{net} = 600\ N \cdot m$

$\tau_{net} = I\alpha$

$600\ N \cdot m = I\left(10\frac{rad}{s^2}\right)$

$I = \mathbf{60\ kg \cdot m^2}$

14. $m_r = 100\ kg, m_m = 80\ kg, v = 20\frac{m}{s}, r = 1\ m, I = 2\ kg \cdot m^2$

$v = r\omega$

$20\frac{m}{s} = (1\ m)\omega$

$\omega = 20\frac{rad}{s}$

$KE_{rot} = \frac{1}{2}I\omega^2$

$KE_{rot} = \frac{1}{2}(2\ kg \cdot m^2)\left(20\frac{rad}{s}\right)^2 = \mathbf{400\ J}$

15. $F = 100\ N, r = 0.10\ m, \theta = 1.5\ rad$

$W_{net} = \tau_{net}\theta$

$W_{net} = (0.10\ m)(100\ N)(1.5\ rad) = \mathbf{15\ J}$

16. $m = 5\ kg, r = 1\ m, h_0 = 5\ m$

$E_0 = E_f$

$KE_0 + KE_{rot0} + PE_0 = KE_f + KE_{rotf} + PE_f$

$0 + 0 + mgh_0 = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2 + 0$

$I = \frac{2MR^2}{5} = \frac{2m(1\ m)^2}{5} = \frac{2m}{5}\ m^2$

$mg(5\ m) = \frac{1}{2}mv^2 + \frac{1}{2}\left(\frac{2m}{5}\ m^2\right)\left((1\ m)v\right)^2$

$g(5\ m) = \frac{1}{2}v^2 + \frac{1}{5}v^2$

$g(5\ m) = \frac{7}{10}v^2$

$v = \mathbf{8.47\ m/s}$