Circular Motion and Gravitation

Additional Practice E

Givens	*Solutions*
1. $d = 1.60$ m $\tau = 4.00 \times 10^2$ N • m $\theta = 80.0°$	$F = \frac{\tau}{d(\sin\theta)} = \frac{4.00 \times 10^2 \text{ N}\bullet\text{m}}{(1.60 \text{ m})(\sin 80.0°)}$ $F = \boxed{254 \text{ N}}$
2. $\tau_{net} = 14.0$ N • m $d' = 0.200$ m $\theta' = 80.0°$ $\tau = 4.00 \times 10^2$ N • m	$\tau_{net} = \tau - \tau'$ $\tau' = F_g d'(\sin\theta') = \tau - \tau_{net}$ $F_g = \frac{\tau - \tau_{net}}{d'(\sin\theta')} = \frac{4.00 \times 10^2 \text{ N}\bullet\text{m} - 14. \text{ N}\bullet\text{m}}{(0.200 \text{ m})(\sin 80.0°)}$ $F_g = \frac{386 \text{ N}\bullet\text{m}}{(0.200 \text{ m})(\sin 80.0°)} = \boxed{1.96 \times 10^3 \text{ N}}$
3. $d = 2.44$ m $\tau = 50.0$ N • m $\theta = 90°$	$F = \frac{\tau}{d(\sin\theta)} = \frac{50.0 \text{ N}\bullet\text{m}}{(2.44 \text{ m})(\sin 90°)}$ $F = \boxed{20.5 \text{ N}}$
4. $\tau = 1.4$ N • m $d = 0.40$ m $\theta = 60.0°$	$F = \frac{\tau}{d(\sin\theta)} = \frac{1.4 \text{ N}\bullet\text{m}}{(0.40 \text{ m})(\sin 60.0°)}$ $F = \boxed{4.0 \text{ N}}$ τ_{max} is produced when $\theta = 90°$, or $\tau_{max} = Fd = (4.0 \text{ N})(0.40 \text{ m}) = \boxed{1.6 \text{ N}\bullet\text{m}}$
5. $F_{max} = 2.27 \times 10^5$ N • m $r = 0.660$ m $d = \frac{1}{2}r$	$\tau_{max} = F_{max}d = \frac{F_{max}r}{2}$ $\tau_{max} = \frac{(2.27 \times 10^5 \text{ N}\bullet\text{m})(0.660 \text{ m})}{2} = \boxed{7.49 \times 10^4 \text{ N}\bullet\text{m}}$
6. $m = 1.6$ kg $\ell = 43$ cm $x = 15$ cm $\theta = 90°$ $g = 9.81$ m/s^2	$\tau = Fd(\sin\theta) = mg(\ell - x)(\sin\theta)$ $\tau = (1.6 \text{ kg})(9.81 \text{ m/s}^2)(0.43 \text{ m} - 0.15 \text{ m})(\sin 90°) = (1.6 \text{ kg})(9.81 \text{ m/s}^2)(0.28 \text{ m})$ $\tau = \boxed{4.4 \text{ N}\bullet\text{m}}$

Givens	*Solutions*
7. $\tau = 0.46$ N • m $F = 0.53$ N $\theta = 90°$	$d = \dfrac{\tau}{F(\sin\theta)} = \dfrac{0.46 \text{ N} \bullet \text{m}}{(0.53 \text{ N})(\sin 90°)}$ $d = \boxed{0.87 \text{ m}}$
8. $\tau = 8.25 \times 10^3$ N • m $F = 587$ N $\theta = 65.0°$	$d = \dfrac{\tau}{F(\sin\theta)} = \dfrac{8.25 \times 10^3 \text{ N} \bullet \text{m}}{(587 \text{ N})(\sin 65.0°)}$ $d = \boxed{15.5 \text{ m}}$
9. $m = 28$ kg $g = 9.81$ m/s^2 $\theta = 89°$ $\tau = 1.84 \times 10^4$ N • m	$d = \dfrac{\tau}{F(\sin\theta)} = \dfrac{\tau}{mg(\sin\theta)} = \dfrac{1.84 \times 10^4 \text{ N} \bullet \text{m}}{(28 \text{ kg})(9.81 \text{ m/s}^2)(\sin 89°)}$ $d = \boxed{67 \text{ m}}$
10. $F_b = 1.200 \times 10^3$ N $\theta_b = 90.0°$ $m = 60.0$ kg $g = 9.81$ m/s^2 $\theta_g = 87.7°$ $\tau_{net} = -2985$ N • m	$\tau_{net} = \tau_g - \tau_b = F_g d(\sin\theta_g) - F_b d(\sin\theta_b)$ $d = \dfrac{\tau_{net}}{F_g(\sin\theta_g) - F_b(\sin\theta_b)} = \dfrac{\tau_{net}}{mg(\sin\theta_g) - F_b(\sin\theta_b)}$ $d = \dfrac{-2985 \text{ N} \bullet \text{m}}{(60.0 \text{ kg})(9.81 \text{ m/s}^2)(\sin 87.7°) - (1.200 \times 10^3 \text{ N})(\sin 90.0°)}$ $d = \dfrac{-2985 \text{ N} \bullet \text{m}}{588 - 1.200 \times 10^3 \text{ N}}$ $d = \dfrac{-2985 \text{ N} \bullet \text{m}}{-612 \text{ N}} = \boxed{4.88 \text{ m}}$

Circular Motion and Gravitation

Problem E

TORQUE

PROBLEM

While driving an automobile, the driver makes a left turn. To perform this maneuver, the driver exerts a torque with a magnitude of 3.5 N•m on the rim of the steering wheel. If the radius of the wheel is 0.15 m, what is the magnitude of the force applied by the driver?

SOLUTION

1. **DEFINE**

Given: $\tau = 3.5$ N•m

$d = 0.15$ m

Unknown: $F = ?$

2. **PLAN** **Choose the equation(s) or situation:** Apply the definition of torque. Note that the force is applied to the rim of a wheel, so that the angle between the force and the lever arm (radius) is always 90.0°.

$$\tau = Fd(\sin \theta) = Fd$$

Rearrange the equation(s) to isolate the unknown(s):

$$F = \frac{\tau}{d}$$

3. **CALCULATE** **Substitute the values into the equation(s) and solve:**

$$F = \frac{3.5 \text{ N}\bullet\text{m}}{0.15 \text{ m}}$$

$$F = \boxed{23 \text{ N}}$$

4. **EVALUATE** Note that the magnitude of torque is not a good indicator of the force that produces the torque. A small torque can be the product of a large force acting on a small lever arm, or a small force acting on a large lever arm.

ADDITIONAL PRACTICE

1. A lever is used to lift a boulder. The fulcrum is placed 1.60 m away from the end at which you exert a downward force, producing a torque with a magnitude of 4.00×10^2 N•m. If the angle between the force and the lever is 80.0°, what is the magnitude of the applied force? Assume that the lever is massless.

2. Suppose the applied force in problem 1 produces a counterclockwise torque. If the net torque exerted on the lever in problem 1 is 14.0 N•m counterclockwise, what is the weight of the boulder? Assume that the lever arm between the boulder's center of mass and the fulcrum is 0.200 m and that the angle between the boulder's weight and the lever arm is 80.0°.
3. Small windmills have been used for over a century to pump water on farms and ranches in the United States. The rotors of these mills consist of 18 metal blades called "sails." Even a small wind can provide enough torque for drawing water from underground wells. If the length of a sail is 2.44 m and the torque exerted by the wind is 50.0 N• m counterclockwise, what is the magnitude of the wind's force? Assume that this force is exerted perpendicular to the blade and at the blade's tip.
4. A force is applied to a door at an angle of 60.0°and 0.40 m from the hinge. What force produces a torque with a magnitude of 1.4 N•m? How large is the maximum torque this force can exert?
5. The force exerted by the driving rods of a steam locomotive has a magnitude of 2.27×10^5 N.Each rod is connected to one of the driving wheels at a point halfway between the center and the rim of the wheel. Suppose the driving wheel has a radius of 0.660 m. How large is the maximum torque exerted on the driving wheels by the driving rods?
6. The world's narrowest street, which is located in a small Italian village, is only 43 cm wide . Suppose a fish with a mass of 1.6 kg is hung from a string attached to a stick. The stick, slightly longer than the street is wide, is placed horizontally across the narrow street with each end resting on a windowsill. The fish hangs a horizontal distance of 15 cm from the windowsill on the right. If the axis of rotation for the stick is taken to be the end farthest from the fish, what is the magnitude of the torque produced by the fish? Assume the stick has negligible mass.
7. A golfer produces a torque with a magnitude of 0.46 N•m on a golf club. If the club exerts a force with a magnitude of 0.53 N on a stationary golf ball, what is the length of the club?
8. In 1902, fresh water was provided to San Francisco, California, by two large Dutch-style windmills on the western edge of the city. Though not in use, both mills are still standing. Suppose a worker is restoring one of these windmills when the ladder shifts to the side. The worker grabs the end of one of the rotor vanes and hangs onto it until fellow workers come to the rescue. The worker hangs at an angle of 65.0° to the vane, exerting a counterclockwise torque of 8.25×10^3 N•m. If the worker weighs 587 N, what is the length of the windmill vane?

9. A Foucault pendulum consists of a large balanced mass hanging on the end of a long wire. The pendulum swings freely, so that the rotation of Earth causes the pendulum's surroundings to slowly shift position with respect to the pendulum's motion .The pendulum's apparent path during one rotation of Earth is an indication of both Earth's rotation and the location of the pendulum on Earth's surface. At the point where a 28-kg pendulum has the greatest potential energy, the angle between the pendulum's weight and the wire is 89°. What is the wire's length if the magnitude of the torque exerted by the pendulum's weight at this position is 1.84×10^4 N•m?

10. At the moment before a diver jumps from a diving board, a force of 1.200×10^3 N is exerted on the diver at an angle of 90.0° to the board. This force produces a torque in the clockwise direction. At the same time, the diver's weight produces a torque in the counterclockwise direction .The diver's mass is 60.0 kg, and the angle between the diver's weight and the board is 87.7°. If the net torque acting on the diver is 2985 N•m clockwise, what is the length of the diving board?