Physics 100A – Summer 2016
<u>Chapter 10</u>

Solutions are provided only for problems from your textbook. The other problems already have so much guidance and notes that you should be able to understand where you have gone wrong.

Problems

1. **Picture the Problem**: This is a units conversion problem.

Strategy: Multiply the angle in degrees by $\left(\frac{\pi \text{ radians}}{180°}\right)$ to get radians.

Solution:

$30°\left(\frac{\pi \text{ rad}}{180°}\right) = \boxed{\frac{\pi}{6}\text{ rad}}$ $\quad 45°\left(\frac{\pi \text{ rad}}{180°}\right) = \boxed{\frac{\pi}{4}\text{ rad}}$ $\quad 90°\left(\frac{\pi \text{ rad}}{180°}\right) = \boxed{\frac{\pi}{2}\text{ rad}}$ $\quad 180°\left(\frac{\pi \text{ rad}}{180°}\right) = \boxed{\pi \text{ ra}}$

Insight: The quantity π is the circumference of a circle divided by its diameter. $\pi = 3.1415926536 \ldots$

6. **Picture the Problem**: The tire rotates about its axis through a certain angle.

Strategy: Use equation 10-2 to find the angular displacement.

Solution: Solve equation 10-2 for θ: $\quad \theta = \frac{s}{r} = \frac{1.95 \text{ m}}{0.33 \text{ m}} = \boxed{5.9 \text{ rad}}$

Insight: This angular distance corresponds to 339° or 94% of a complete revolution.

27. **Picture the Problem**: Jason is a distance *R* from the axis of rotation of a merry-go-round and Betsy is a distance 2*R* from the axis.

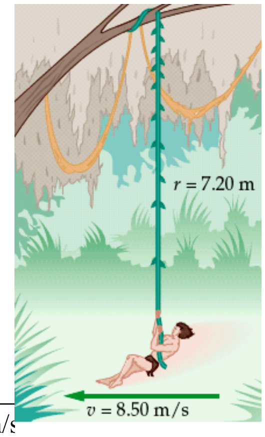
Strategy: Use an understanding of rotational motion to answer the conceptual question.

Solution: 1. (a) Although the linear speeds of Jason and Betsy are different, their angular speeds are the same because they both ride on the same merry-go-round. Because each completes one revolution in the same amount of time, the rotational period of Jason is equal to the rotational period of Betsy.

2. (b) The best explanation is **III.** It takes the same amount of time for the merry-go-round to complete a revolution for all points on the merry-go-round. Statements I and II are each false.

Insight: Jason has a smaller linear speed $v_t = r\omega$ and a smaller centripetal acceleration $a_{cp} = r\omega^2$ than does Betsy.

34. Picture the Problem: Jeff clings to a vine and swings along a vertical arc as depicted in the figure at right.



Strategy: Use equation 10-12 to find the angular speed from the knowledge of the linear speed and the radius. Use equation 6-15 to find the centripetal acceleration from the speed and the radius of motion.

Solution: 1. (a) Solve equation 10-12 for ω:

$$\omega = \frac{v_t}{r} = \frac{8.50\ \text{m/s}}{7.20\ \text{m}} = \boxed{1.18\ \text{rad/s}}$$

2. (b) Apply equation 6-15 directly:

$$a_{cp} = \frac{v_t^2}{r} = \frac{(8.50\ \text{m/s})^2}{7.20\ \text{m}} = \boxed{10.0\ \text{m/s}}$$

3. (c) The centripetal force required to keep Jeff moving in a circle is provided by $\boxed{\text{the vine}}$.

Insight: The vine must actually do two things, support Jeff's weight and provide his centripetal force. That is why it is possible that the vine is strong enough to support him when he is hanging vertically but not strong enough to support him while he is swinging. There's no easy way for him to find out without trying… but he should wear a helmet!

39. Picture the Problem: The Ferris wheel rotates at a constant rate, with the centripetal acceleration of the passengers always pointing toward the axis of rotation. The acceleration of the passenger is thus upward when they are at the bottom of the wheel and downward when they are at the top of the wheel.

Strategy: Use equation 10-13 to find the centripetal acceleration. The centripetal acceleration remains constant (as long as the angular speed remains the same) and points toward the axis of rotation.

Solution: 1. (a) Apply equation 10-13 directly:

$$a_{cp} = r\omega^2 = (9.5\ \text{m})\left(\frac{2\pi\ \text{rad}}{36\ \text{s}}\right)^2 = \boxed{0.29\ \text{m/s}^2}$$

2. When the passenger is at the top of the Ferris wheel, the centripetal acceleration points $\boxed{\text{downward}}$ toward the axis of rotation.

3. (b) The centripetal acceleration remains $\boxed{0.29\ \text{m/s}^2}$ for a passenger at the bottom of the wheel because the radius and angular speed remain the same, but here the acceleration points $\boxed{\text{upward}}$ toward the axis of rotation.

Insight: In order to double the centripetal acceleration you need to increase the angular speed by a factor of $\sqrt{2}$ or decrease the period by a factor of $\sqrt{2}$. In this case a period of 25 seconds will double the centripetal acceleration.

48. Picture the Problem: The drive wheel of the tricycle rolls without slipping at constant speed.

Strategy: Because the wheel rolls without slipping, equation 10-15 describes the direct relationship between the center of mass speed and the angular velocity of the driving wheel.

Solution: Apply equation 10-15 directly: $v_t = r\omega = (0.260\text{ m})(0.373\text{ rev/s}\times 2\pi\text{ rad/rev}) = \boxed{0.60}$

Insight: This speed corresponds to about 1.4 mi/h, half the normal walking speed of an adult. The larger wheels on adult bicycles allow for higher linear speeds for the same angular speed of the driving wheel.

61. Picture the Problem: The ball rotates about its center with a constant angular velocity.

Strategy: Use equation 7-6 to find the translational kinetic energy and equation 10-17 to find the rotational kinetic energy of the curveball.

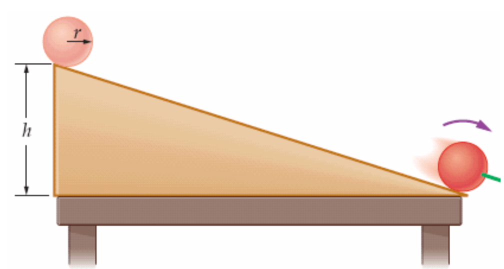
Solution: 1. Apply equation 7-6 directly: $K_t = \frac{1}{2}Mv^2 = \frac{1}{2}(0.15\text{ kg})(48\text{ m/s})^2 = \boxed{170\text{ J}}$

2. Use $I = \frac{2}{5}MR^2$ for a uniform sphere in equation 10-17:

$$K_r = \tfrac{1}{2}I\omega^2 = \tfrac{1}{2}\left(\tfrac{2}{5}MR^2\right)\omega^2 = \tfrac{1}{5}MR^2\omega^2$$
$$= \tfrac{1}{5}(0.15\text{ kg})(0.037\text{ m})^2(42\text{ rad/s})^2 = \boxed{0.072\text{ J}}$$

Insight: Only a tiny fraction of the total kinetic energy is used to spin the ball, but it has a marked effect on the trajectory of the pitch!

$\boxed{75.}$ **Picture the Problem**: The cylinder rolls down the ramp without slipping, gaining both translational and rotational kinetic energy.



Strategy: Use conservation of energy to find total kinetic energy at the bottom of the ramp. Then set that energy equal to the sum of the rotational and translational energies. Because the cylinder rolls without slipping, the equation $\omega = v/r$ can be used to write the expression in terms of linear velocity alone. Use the resulting equation to find expressions for the fraction of the total energy that is rotational and translational kinetic energy.

Solution: 1. (a) Set $E_\mathrm{i} = E_\mathrm{f}$ and solve for K_f:

$$U_\mathrm{i} + K_\mathrm{i} = U_\mathrm{f} + K_\mathrm{f}$$
$$mgh + 0 = 0 + K_\mathrm{f}$$
$$K_\mathrm{f} = mgh = (2.0\ \mathrm{kg})(9.81\ \mathrm{m/s^2})(0.75\ \mathrm{m})$$
$$= 14.7\ \mathrm{J} = \boxed{15\ \mathrm{J}}$$

2. (b) Set K_f equal to $K_\mathrm{t} + K_\mathrm{r}$:

$$K_\mathrm{f} = \tfrac{1}{2}mv^2 + \tfrac{1}{2}I\omega^2 = \tfrac{1}{2}mv^2 + \tfrac{1}{2}\left(\tfrac{1}{2}mr^2\right)(v/r)^2$$
$$= \tfrac{1}{2}mv^2 + \tfrac{1}{4}mv^2 = \tfrac{3}{4}mv^2$$

3. Determine K_r from steps 1 and 2:

$$K_\mathrm{r} = \tfrac{1}{4}mv^2 = \tfrac{1}{3}\left(\tfrac{3}{4}mv^2\right) = \tfrac{1}{3}K_\mathrm{f} = \tfrac{1}{3}(14.7\ \mathrm{J}) = \boxed{4.9\ \mathrm{J}}$$

4. (c) Determine K_t from steps 1 and 2:

$$K_\mathrm{t} = \tfrac{1}{2}mv^2 = \tfrac{2}{3}\left(\tfrac{3}{4}mv^2\right) = \tfrac{2}{3}K_\mathrm{f} = \tfrac{2}{3}(14.7\ \mathrm{J}) = \boxed{9.8\ \mathrm{J}}$$

Insight: The fraction of the total kinetic energy that is rotational energy depends upon the moment of inertia. If the object were a hoop, for instance, with $I = mr^2$, the final kinetic energy would be half translational, half rotational.