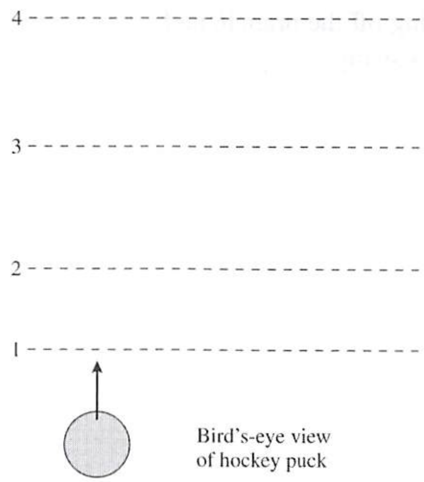
8 Dynamics II: Motion in a Plane

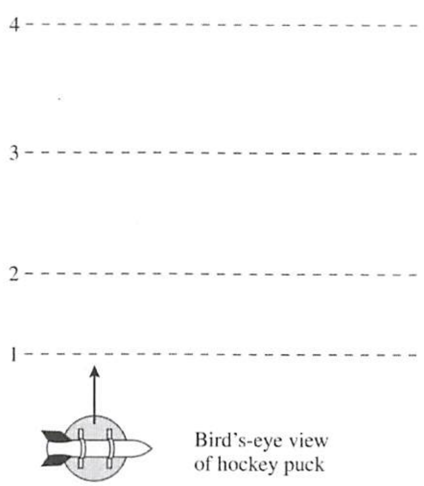
8.1 Dynamics in Two Dimensions

1. An ice hockey puck is pushed across frictionless ice in the direction shown. The puck receives a sharp, very short-duration kick toward the right as it crosses line 2. It receives a second kick, of equal strength and duration but toward the left, as it crosses line 3. Sketch the puck's trajectory from line 1 until it crosses line 4.



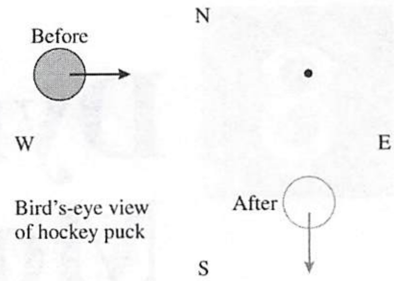
Bird's-eye view of hockey puck

2. A rocket motor is taped to an ice hockey puck, oriented so that the thrust is to the left. The puck is given a push across frictionless ice in the direction shown. The rocket will be turned on by remote control as the puck crosses line 2, then turned off as it crosses line 3. Sketch the puck's trajectory from line 1 until it crosses line 4.

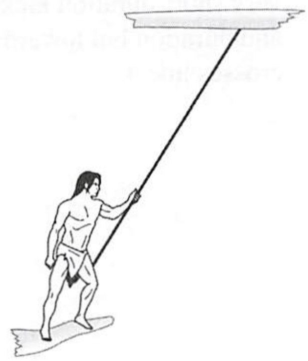


Bird's-eye view of hockey puck

3. An ice hockey puck is sliding from west to east across frictionless ice. When the puck reaches the point marked by the dot, you're going to give it *one* sharp blow with a hammer. After hitting it, you want the puck to move from north to south at a speed similar to its initial west-to-east speed. Draw a force vector with its tail on the dot to show the direction in which you will aim your hammer blow.



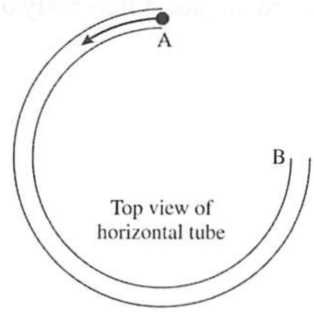
4. Tarzan swings through the jungle by hanging from a vine.
   a. Draw a motion diagram of Tarzan, as you learned in Chapter 1. Use it to find the direction of Tarzan's acceleration vector $\vec{a}$:
      i. Immediately after stepping off the branch, and
      ii. At the lowest point in his swing.



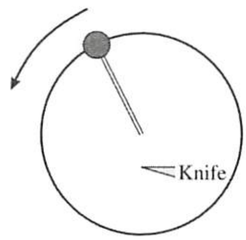
   b. At the lowest point in the swing, is the tension T in the vine greater than, less than, or equal to Tarzan's weight? Explain, basing your explanation on Newton's laws.

8.2 Uniform Circular Motion

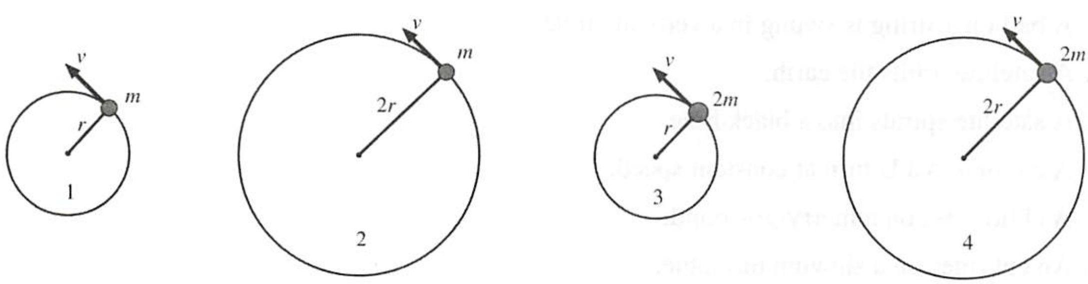
5. The figure shows a *top view* of a plastic tube that is fixed on a horizontal tabletop. A marble is shot into the tube at A. On the figure, sketch the marble's trajectory after it leaves the tube at B.



6. A ball swings in a *vertical* circle on a string. During one revolution, a very sharp knife is used to cut the string at the instant when the ball is at its lowest point. Sketch the subsequent trajectory of the ball until it hits the ground.



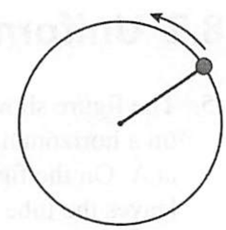
7. The figures are a bird's-eye view of particles on a string moving in horizontal circles on a tabletop. All are moving at the same speed. Rank in order, from largest to smallest, the string tensions T_1 to T_4.



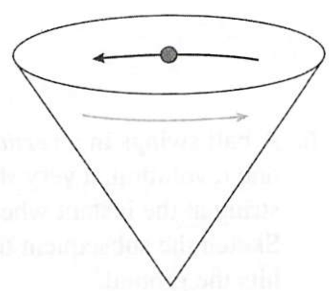
Order:

Explanation:

8. A ball on a string moves in a vertical circle. When the ball is at its lowest point, is the tension in the string greater than, less than, or equal to the ball's weight? Explain. (You may want to include a free-body diagram as part of your explanation.)



9. A marble rolls around the inside of a cone. Draw a free-body diagram of the marble when it is on the left side of the cone and a free-body diagram of the marble when it is on the right side of the cone.



On left side

On right side

10. Can the following be reasonably modeled as a central force with constant r? Answer Yes or No.
   a. A ball on a string is swung in a horizontal circle. ________
   b. A ball on a string is swung in a vertical circle. ________
   c. A satellite orbits the earth. ________
   d. A satellite spirals into a black hole. ________
   e. A car makes a U turn at constant speed. ________
   f. A child rides on a merry-go-round. ________
   g. An ant rides on a slowing turntable. ________

11. A coin of mass m is placed distance r from the center of a turntable. The coefficient of static friction between the coin and the turntable is μ_s. Starting from rest, the turntable is gradually rotated faster and faster. At what angular velocity does the coin slip and "fly off"?

PSS 8.1

a. Begin with a pictorial representation. Draw the turntable both as seen from above and as an edge view with the coin on the left side coming toward you. Label radius r, make a table of known information, and indicate what you're trying to find.

b. What direction does $\vec{f}_s$ point? ______________________

Explain.

c. What condition describes the situation just as the coin starts to slip? Write this condition as a mathematical statement.

d. Now draw a free-body diagram of the coin. Following Problem Solving Strategy 8.1, draw the free-body diagram with the circle viewed edge on, the r-axis pointing toward the center of the circle, and the z-axis perpendicular to the plane of the circle. Your free-body diagram should have three forces on it.

e. Referring to Problem Solving Strategy 8.1, write Newton's second law for the r- and z-components of the forces. One sum should equal 0, the other mv^2/r.

f. The two equations of part e are valid for any angular velocity up to the point of slipping. If you combine these with your statement of part c, you can solve for the speed v_{max} at which the coin slips. Do so.

g. Finally, use the relationship between v and ω to find the angular velocity of slipping.

8.3 Circular Orbits

12. A small projectile is launched parallel to the ground at height $h = 1$ m with sufficient speed to orbit a completely smooth, airless planet. A bug rides in a small hole inside the projectile. Is the bug weightless? Explain.

8.4 Reasoning about Circular Motion

13. A stunt plane does a series of vertical loop the loops at a fairly steady speed. At what point in the circle does the pilot feel the heaviest? Explain. Include a free-body diagram with your explanation.

14. You can swing a ball on a string in a *vertical* circle if you swing it fast enough.
    a. Draw two free-body diagrams of the ball at the top of the circle. On the left, show the ball when it is going around the circle very fast. On the right, show the ball as it goes around the circle more slowly.

Very fast	Slower

    b. As you continue slowing the swing, there comes a frequency at which the string goes slack and the ball doesn't make it to the top of the circle. What condition must be satisfied for the ball to be able to complete the full circle?

    c. Suppose the ball has the smallest possible frequency that allows it to go all the way around the circle. What is the tension in the string when the ball is at the highest point? Explain.

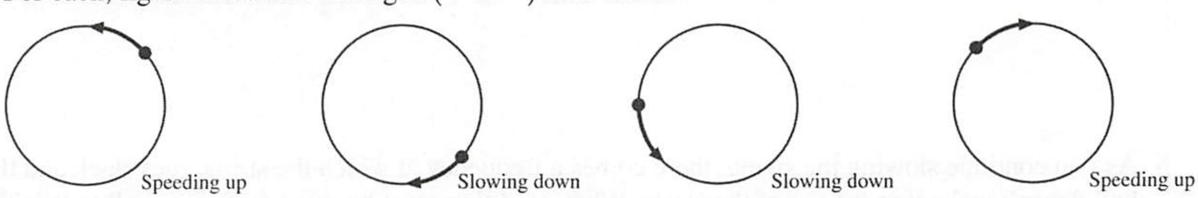
15. It's been proposed that future space stations create "artificial gravity" by rotating around an axis.

    a. How would this work? Explain.

    b. Would the artificial gravity be equally effective throughout the space station? If not, where in the space station would the residents want to live and work?

8.5 Nonuniform Circular Motion

16. For each, figure determine the signs (+ or −) of ω and α.

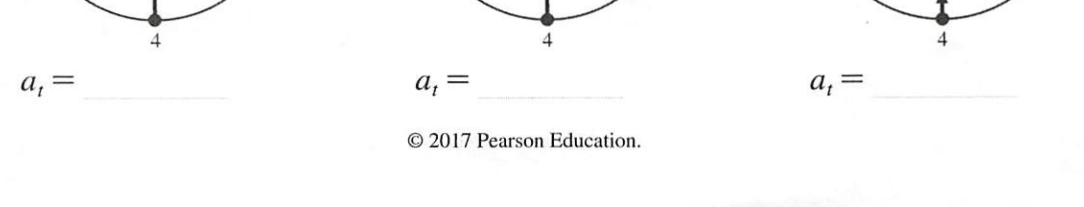


ω ______	ω ______	ω ______	ω ______
α ______	α ______	α ______	α ______

17. The figures below show the radial acceleration vector $\vec{a}_r$ at four sequential points on the trajectory of a particle moving in a counterclockwise circle.

    a. For each, draw the tangential acceleration vector $\vec{a}_t$ a at points 2 and 3 or, if appropriate, write a $\vec{a}_t = \vec{0}$.

    b. Determine whether a_t is positive (+), negative (−), or zero (0).



$a_t =$ ______ $a_t =$ ______ $a_t =$ ______