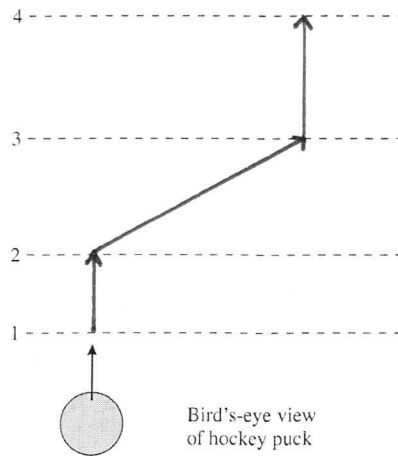


8

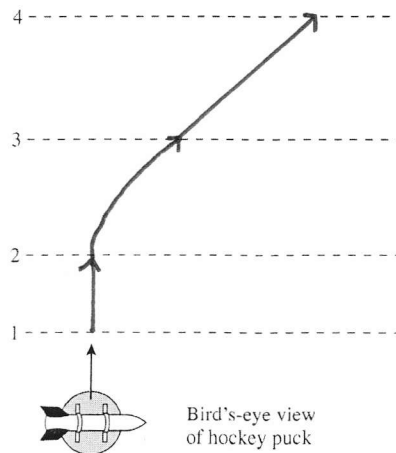
Dynamics II: Motion in a Plane

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.

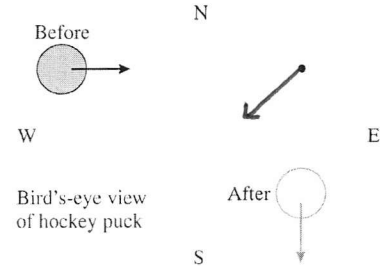


2. A rocket motor is taped to an ice hockey puck, oriented so that the thrust is to the left. The puck is given a push across frictionless ice in the direction shown. The rocket will be turned on by remote control as the puck crosses line 2, then turned off as it crosses line 3. Sketch the puck's trajectory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

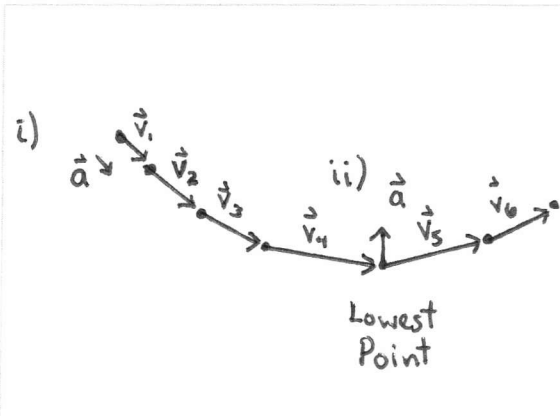
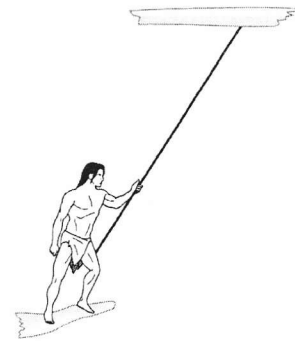


3. An ice hockey puck is sliding from west to east across frictionless ice. When the puck reaches the point marked by the dot, you're going to give it *one* sharp blow with a hammer. After hitting it, you want the puck to move from north to south at a speed similar to its initial west-to-east speed.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

The blow will be at 45° South of West in order to stop the eastward motion and impart an equal southward motion.



4. Tarzan swings through the jungle by hanging from a vine.
- 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} :
 - Immediately after stepping off the branch, and
 - At the lowest point in his swing.



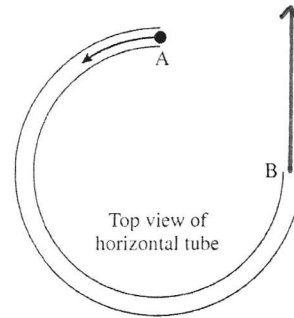
- At the lowest point in the swing, is the tension T in the vine greater than, less than, or equal to Tarzan's weight? Explain, basing your explanation on Newton's laws.

For the acceleration to be upwards, the net force must be upwards. The only two forces are the upward tension and the weight. Therefore, the tension must be greater than the weight.



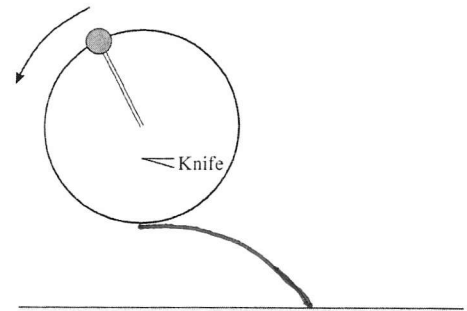
8.2 Uniform Circular Motion

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



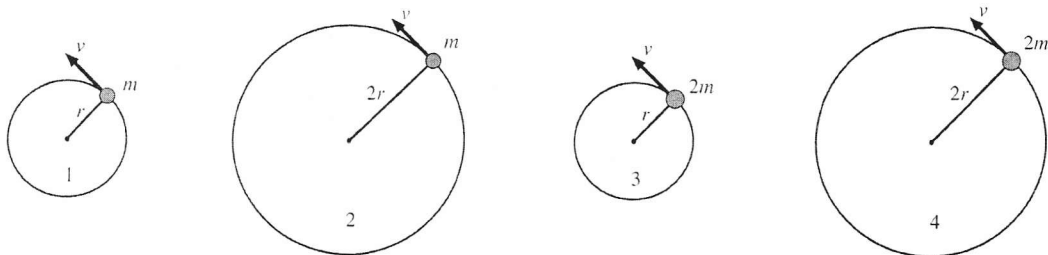
The marble continues in a straight line (towards the top of the page).

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.



The trajectory is parabolic, like that of a horizontally launched projectile.

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



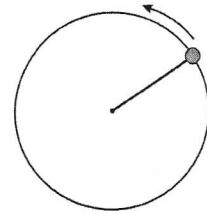
Order: $T_3 > T_1 = T_4 > T_2$

Explanation:

$$T = \frac{mv^2}{r}$$

Case 3 combines a larger mass and smaller radius.
Case 4 is the same as Case 1 because both the mass and the radius are doubled.

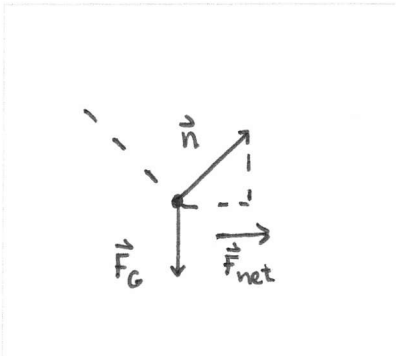
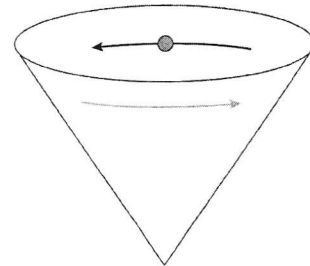
8. A ball on a string moves in a vertical circle. When the ball is at its lowest point, is the tension in the string greater than, less than, or equal to the ball's weight? Explain. (You may want to include a free-body diagram as part of your explanation.)



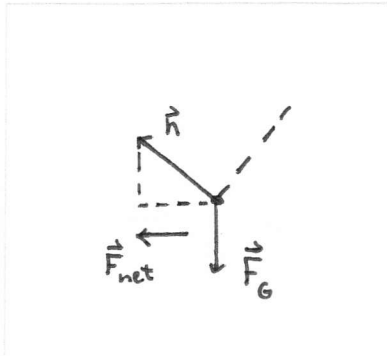
At the lowest point, the acceleration is upward. Thus, the tension must be greater than the weight for the net force to be upward.



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.



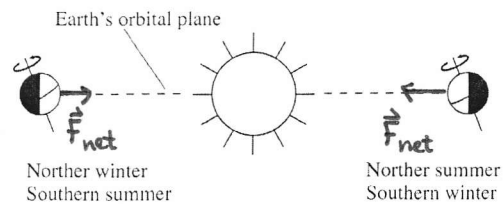
On left side



On right side

8.3 Circular Orbits

10. The earth has seasons because the axis of the earth's rotation is tilted 23° away from a line perpendicular to the plane of the earth's orbit. You can see this in the figure, which shows an edge view of the earth's orbit around the sun. For both positions of the earth, draw a force vector to show the net force acting on the earth or, if appropriate, write $\vec{F} = \vec{0}$.



11. 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.

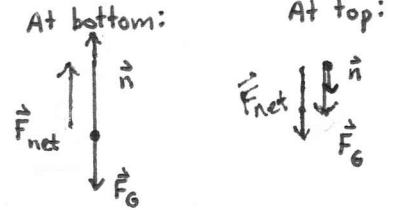
The bug is weightless in the sense that it is in freefall with the projectile. The bug still has the force of gravity acting on it.

$$\vec{F}_G = m_{\text{bug}} \vec{g}$$

8.4 Fictitious Forces

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

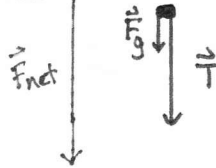
The pilot feels heaviest at the bottom of the vertical loop. At that point, the normal force on the pilot is greatest.



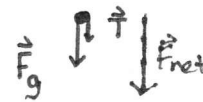
This analysis assumes the pilot is moving at comparable speed throughout.

13. You can swing a ball on a string in a vertical circle if you swing it fast enough.
- 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



- 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?

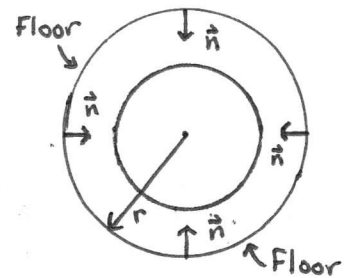
$\vec{F}_{net} = m \frac{v^2}{r} = m \omega^2 r$. The minimum downward force is the weight, so $mg = m r \omega_{min}^2$ or $\omega_{min}^2 = g/r$ $\omega_{min} = \sqrt{g/r}$

- 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.

$\vec{T} = 0$. At the smallest frequency, the only radially inward force is the force of gravity, mg .

14. It's been proposed that future space stations create "artificial gravity" by rotating around an axis.
 a. How would this work? Explain.

The outside wall of the station would provide the floor and the normal force required to keep the occupants and contents rotating would be the weight of the object in this artificial gravity.

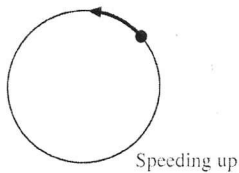


- b. Would the artificial gravity be equally effective throughout the space station? If not, where in the space station would the residents want to live and work?

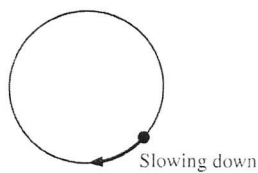
The sensation of weight is due to an inward normal force provided by the outward wall. As one moves inward, the artificial gravity would become weaker due to the smaller radius.
 $\vec{n} = m\omega^2 r$.

8.5 Nonuniform Circular Motion

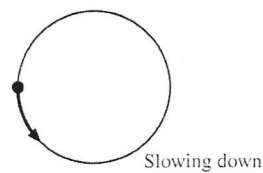
15. For each, figure determine the signs (+ or -) of ω and α .



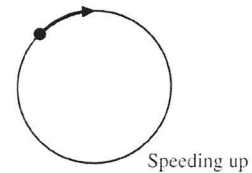
ω +
 α +



ω -
 α +



ω +
 α -

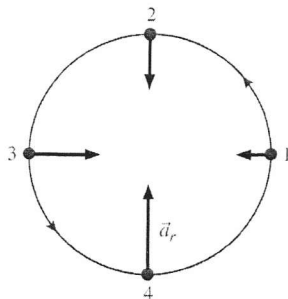


ω -
 α -

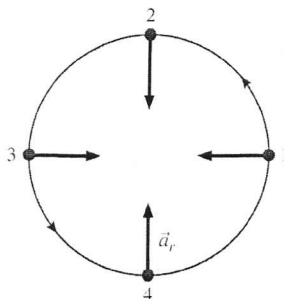
16. The figures below show the radial acceleration vector \vec{a}_r at four sequential points on the trajectory of a particle moving in a counterclockwise circle.

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

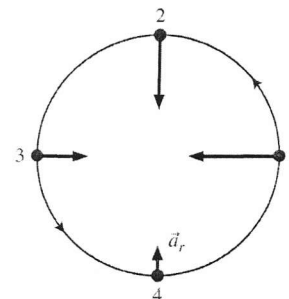
b. Determine whether a_t is positive (+), negative (-), or zero (0).



$a_t =$ (+)



$a_t =$ (0)



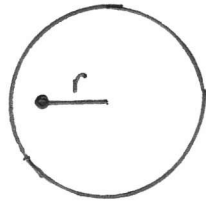
$a_t =$ (-)

17. 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”?

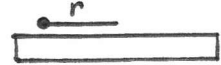
PSS 8.1

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.

Above



Edge



Known:	Find:
m	ω
r	
μ_s	
$v_0 = 0$	

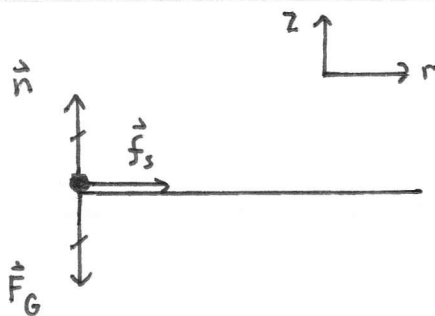
b. What direction does \vec{f}_s point? towards the center of the turntable
 Explain.

\vec{f}_s is the force causing the coin to undergo circular motion.

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

$$f_{s \max} = ma$$

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 .

$$\sum F_r = f_s = \frac{mv^2}{r}$$

$$\sum F_z = n - mg = 0$$

- 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.

$$f_{s_{\max}} = \mu_s n = \mu_s mg = \frac{mv_{\max}^2}{r}$$

$$\text{or } v_{\max} = \sqrt{\mu_s rg}$$

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

$$\omega = \frac{v}{r} = \sqrt{\frac{\mu_s g}{r}}$$