3.2 Measuring Circular Motion

1. (a) A wheel of radius 22 ft. is rotating 11 RPM counterclockwise. What is the angular speed ω and the linear speed v?

   (b) A wheel of radius 8 in. is rotating 15^o/sec. What is the linear speed v, the angular speed in RPM and the angular speed in rad/sec?

   (c) You are standing on the equator of the earth (radius 3960 miles). What is your linear and angular speed?

   (d) An auto tire has radius 12 inches. If you are driving 65 mph, what is the angular speed in rad/sec and the angular speed in RPM?

2. An drip irrigation arm is 28 feet long and pivots about a center one revolution each hour. A "drip hole" H is located 28 feet from the pivot point.

   (a) What is the linear speed of H in units of feet/hour, feet/minute, feet/second, inches/second.

   (b) What is the required drip rate (in drips/second) if we want 4 drips for every 1 inch H travels.

   (c) Suppose 10 drips = 1 cc (cubic centimeter). How many liters flow from H after 25 minutes, assuming the drip rate computed in b.? (1 liter = 1000 cc.)

   (d) How much water flows from H after the arm has made 3 complete revolutions?

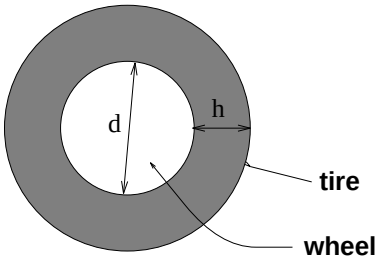
3. The restaurant in the Space Needle in Seattle rotates at the rate of one revolution per hour.

   (a) Through how many radians does it turn in 100 minutes?

   (b) How long does it take the restaurant to rotate through 4 radians?

   (c) How far does a person sitting by the window move in 100 minutes if the radius of the restaurant is 21 meters?

4. Your car's speedometer is geared to accurately give your speed using a certain size tire. Suppose your car has d =14 inch diameter wheels and the height of the tire is h =4.5 inches.



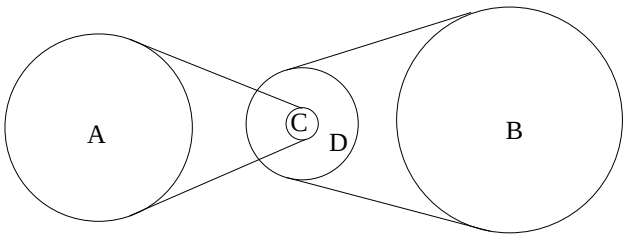
   (a) You buy a new set of tires with $h = 5.5$ inches and $d = 14$ inches. On a trip to Spokane, you maintain a constant speed of 65 mph, according to your speedometer. However, as luck would have it, you are stopped for speeding. Explain how this could happen. What did the radar gun display as your true speed?

   (b) You are furious over the speeding ticket and return to the tire dealer, demanding new tires which are the correct size. The dealer only has "low profile tires" in stock, which are $h = 3.75$ inches high. If you accept these and drive away from the dealer with your speedometer reading 35 mph, how fast are you really going?

5. You are riding a bicycle along a level road. Assume each wheel is 26 inches in diameter, the rear sprocket has radius 3 inches and the front sprocket has radius 7 inches. How many revolutions per minute of the front sprocket produces a speed of 35 mph?

6. You are riding a bicycle along a level road. Assume each wheel is 28 inches in diameter, the rear sprocket has radius 3 inches and the front sprocket has radius r inches. Suppose you are pedaling the front sprocket at the rate of 1.5 rev/sec and your forward speed is 11 mph on the bike. What is the radius of the front sprocket?

7. You are designing a system of wheels and belts as pictured below. You want wheel A to rotate 20 RPM while wheel B rotates 42 RPM. Wheel A has a radius of 6 inches, wheel B has a radius of 7 inches and wheel C has a radius of 1 inch. Assume wheels C and D are rigidly fastened to the same axle. What is the radius r of wheel D?



8. The LP record was discussed in Example 3.2.3. Two other vinyl record formats have been used in the past. This exercise discusses these.

   (a) A *singles* record (popular in the 1950's and 1960's) spins at a constant $45RPM$ and has a diameter of 6 inches. If the needle is on the lead in groove 3 inches from the center, what is the linear speed of the record below the needle? How about the linear speed at the exit groove 1 inch from the center? Is there a location so that the linear speed at the needle is 0.5 mph? Justify your answer.

   (b) Another popular format, prior to the 1950's, was the "78". These records spin at a constant $78RPM$ and have a diameter of 10 inches. If the needle is on the lead in groove 5 inches from the center, what is the linear speed of the record below the needle? How about the linear speed at the exit groove 1 inch from the center? Is there a location so that the linear speed at the needle is 1 mph? Justify your answer.

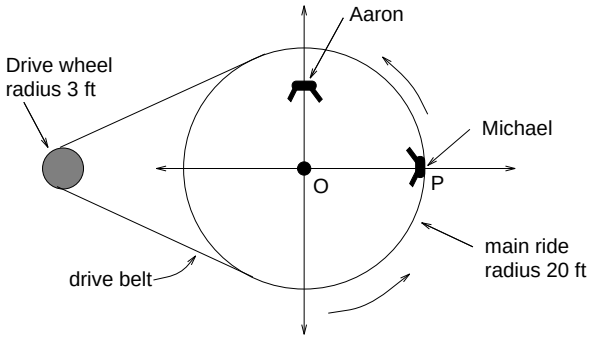
9. One thing that affects the quality of sound of an LP record is the ability of the turntable to spin the record at a very constant angular speed of $33\frac{1}{3}RPM$; any error here leads to what is called "wow and flutter", which can be quite audible. Refer to the calculations in Example 3.2.4. Suppose the angular speed varies from $33\frac{1}{3}RPM$ to $34RPM$. Determine the percent error in linear speed at the lead in and exit grooves of the LP. Is angular speed error affecting the sound quality more at the beginning or end of a record?

10. A *laser video disc*, called an LVD, is the video counterpart of the musical CD; it is the digital version of the VCR tape player. Again, a LVD is a thin plastic disc with a silver coating on one side, but now the diameter is 12 inches. Just as with the CD, information is read off using a laser and the LVD is designed to spin at a constant linear speed below the laser; this speed is 1.2 meters/sec = 2835 inches/minute. The laser begins $\frac{3}{4}$ inch from the center of the spinning disc and works it way out to the end (5.5 inches from the center).

    (a) Find the angular speed of the LVD at the beginning and end of the LVD; i.e. when the laser is $\frac{3}{4}$ inch and 5.5 inches from the center.

    (b) Describe the location of the laser if the angular speed is 100 RPM.

11. Michael and Aaron are on the "UL-Tossum" ride at *Funworld*. This is a merry-go-round of radius 20 feet which spins counterclockwise 60 RPM. The ride is driven by a belt connecting the outer edge of the ride to a drive wheel of radius 3 feet:

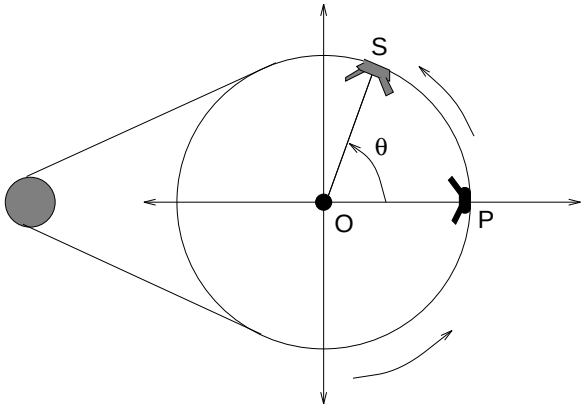


(a) Assume Michael is seated on the edge of the ride, as pictured. What is Michael's linear speed in mph and ft/sec?

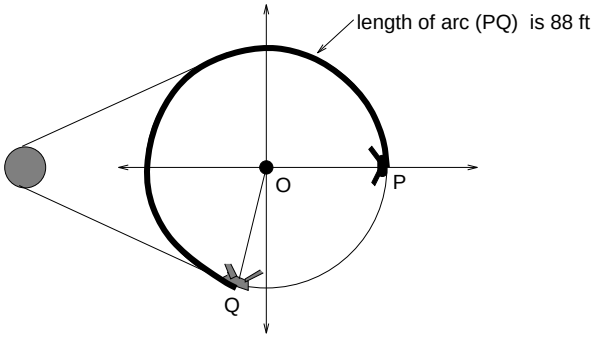
(b) What is the angular speed of the drive wheel in RPM?

(c) Suppose Aaron is seated 16 feet from the center of the ride. What is the angular speed of Aaron in RPM? What is the linear speed of Aaron in ft/sec?

(d) After 0.23 seconds Michael will be located at S as pictured. What is the angle $\angle POS$ in degrees? What is the angle $\angle POS$ in radians? How many feet has Michael traveled?



(e) Assume Michael has traveled 88 feet from the position P to a new position Q. How many seconds will this take? What will be the angle swept out by Michael?



12. Cherie is running around the perimeter of a circular track at a rate of 10 ft/sec. The track has a radius of 100 yards. After 10 seconds, Cherie turns and runs along a radial line to the center of the circle. Once she reaches the center, she turns and runs along a radial line to her starting point on the perimeter. Assume Cherie does not slow down when she makes these two turns.

(a) Sketch a picture of the situation.

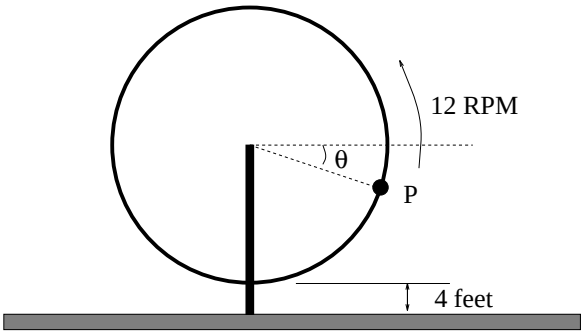
(b) How far has Cherie traveled once she returns to her starting position?

(c) Find the area of the pie shaped sector enclosed by Cherie's path.

13. Nora is running at a constant speed around the same track as Lee in the previous problem. She runs along the perimeter of the circular track. After 35 seconds, she turns and runs along a radial line to the center of the circle, then turns and runs along a radial line out to her starting point on the perimeter. Assume the area of the pie shaped sector enclosed by Nora's

path is 50,000 ft^2. If Nora runs at a constant speed, what is it? When does she get back to her starting position? (Again, assume she does not slow down when she makes the two turns.)

14. John has been hired to design an exciting carnival ride. Tiff, the carnival owner, has decided to create the worlds greatest ferris wheel. Tiff isn't into math; she simply has a vision and has told John these constraints on her dream: (i) the wheel should rotate counterclockwise with an angular speed of 12 RPM; (ii) the linear speed of a rider should be 200 mph; (iii) the lowest point on the ride should be 4 feet above the level ground.



(a) Find the radius of the ferris wheel.

(b) Once the wheel is built, John suggests that Tiff should take the first ride. Assume the wheel starts turning when Tiff is at the location P and it takes her 1.3 seconds to reach the top of the ride. Find the angle θ pictured.

(c) Poor engineering causes Tiff's seat to fly off in 6 seconds. Describe where Tiff is located (an angle description) the instant she becomes a human missile.