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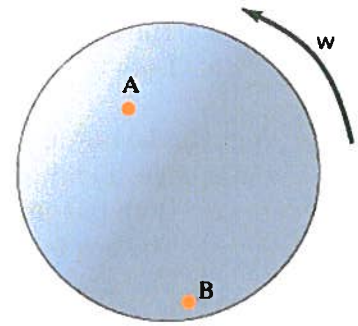
Mastering Physics 2.2 - Uniform Circular Motion

1. A merry-go-round is rotating at constant angular speed. Two children are riding the merry-go-round: Ana is riding at point A and Bobby is riding at point B.



   a. Which child moves with greater magnitude of linear velocity?
      - Ana has the greater magnitude of linear velocity. $v = \omega r$.
      - Bobby has the greater magnitude of linear velocity.
      - Both Ana and Bobby have the same magnitude of linear velocity.

   b. Who moves with greater magnitude of angular velocity?
      - Ana has the greater magnitude of angular velocity.
      - Bobby has the greater magnitude of angular velocity.
      - Both Ana and Bobby have the same magnitude of angular velocity.

   c. Who moves with greater magnitude of tangential acceleration?
      - Ana has the greater magnitude of tangential acceleration.
      - Bobby has the greater magnitude of tangential acceleration.
      - Both Ana and Bobby have the same magnitude of tangential acceleration. $= 0\ m/s^2$

   d. Who has the greater magnitude of centripetal acceleration? $a_c = \frac{v^2}{r}$ $v = \omega r$
      - Ana has the greater magnitude of centripetal acceleration.
      - Bobby has the greater magnitude of centripetal acceleration. $a = \frac{(\omega r)^2}{r}$
      - Both Ana and Bobby have the same magnitude of centripetal acceleration. $a = \omega^2 r$.

   e. Who moves with greater magnitude of angular acceleration?
      - Ana has the greater magnitude of angular acceleration.
      - Bobby has the greater magnitude of angular acceleration.
      - Both Ana and Bobby have the same magnitude of angular acceleration. $= 0$.

2. A marching band consists of rows of musicians walking in straight, even lines. When a marching band performs in an event, such as a parade, and must round a curve in the road, the musician on the outside of the curve must walk around the curve in the same amount of time as the musician on the inside of the curve. This motion can be approximated by a disk rotating at a constant rate about an axis perpendicular to its plane. In this case, the axis of rotation is at the inside of the curve. Consider two musicians, Alf and Beth. Beth is four times the distance from the inside of the curve as Alf.

   a. If Beth travels a distance s during time Δt, how far does Alf travel during the same amount of time?
      - 4 s
      - 2 s
      - ½ s
      - ¼ s
      - s

   b. If Alf moves with speed v, what is Beth's speed? Speed in this case means the magnitude of the linear velocity, not the magnitude of the angular velocity.
      - 4 v
      - v
      - ¼ v

3. A girl and a boy are riding on a merry-go-round that is turning at a constant rate. The girl is near the outer edge, and the boy is closer to the center. Who has greater angular displacement?
   - o Both the girl and the boy have zero angular displacement.
   - o The boy has greater angular displacement.
   - o The girl has greater angular displacement.
   - o Both the girl and the boy have the same nonzero angular displacement.

4. A girl and a boy are riding on a merry-go-round that is turning at a constant rate. The girl is near the outer edge, and the boy is closer to the center. Who has greater linear speed?
   - o Both the girl and the boy have the same nonzero linear speed.
   - o The boy has greater linear speed.
   - o The girl has greater linear speed.
   - o Both the girl and the boy have zero linear speed.

   $v = \omega r$.

5. You find an old record player in your attic. The turntable has two readings: 33 rpm and 45 rpm.
   a. What does the reading 33 rpm mean?

   33 rpm is 33 revolutions per minute.

   b. Express 33 rpm in rad/s.

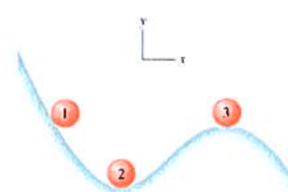
   $33 \cdot 2\pi = 66\pi$ rad/min

   $66\pi / 60 = \boxed{11\pi/10 \text{ rad/s}}$

   c. Express 45 rpm in rad/s.

   $\frac{45 \cdot 2\pi}{60} = \boxed{\frac{3\pi}{2} \text{ rad/sec}}$

6. Consider an object sliding on a frictionless ramp as depicted here. The object is already moving along the ramp toward position 2 when it is at position 1. The following questions concern the direction of the object's acceleration vector. In this problem, you should find the direction of the acceleration vector by drawing the velocity vector at two points near to the position you are asked about. Note that since the object moves along the track, its velocity vector at a point will be tangent to the track at that point. The acceleration vector will point in the same direction as the vector difference of the two velocities.?
   a. Which direction best approximates the direction of the acceleration vectors when the object is at position 1?
   - o straight up
   - o downward to the left
   - o downward to the right
   - o straight down



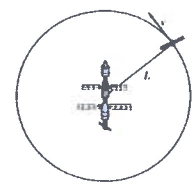
   b. Which direction best approximates the direction of the acceleration when the object is at position 2?
   - o straight up
   - o upward to the right
   - o straight down
   - o downward to the left

   c. Which direction best approximates the direction of the acceleration when the object is at position 3?
   - o upward to the right
   - o to the right
   - o straight down
   - o downward to the right

7. An object moves in a circular path at a constant speed. What is the direction of the net force acting on the object?
   - The net force points in the direction opposite to the motion of the object.
   - The net force points in the same direction as the motion of the object.
   - The net force is directed away from the center of the circular path.
   - The net force is directed toward the center of the circular path.
   - The net force is zero because the object is moving with a constant speed.

8. A small piece of ceramic flies off the rim of a circular potter's wheel that is spinning fast. In which direction will the ceramic piece travel the moment it leaves the wheel?
   - Along a straight tangent to the circular rim at the point where the ceramic left the wheel
   - Along a curved path in parallel to the wheel's rim and in the same direction of motion as the rim.
   - Towards the center of the wheel
   - On a spiral path with increasing radius
   - Along a curved path parallel to the wheel's rim and in the opposite direction of motion as the rim.

9. Six artificial satellites circle a space station at constant speed. The mass m of each satellite, distance L from the space station, and the speed v of each satellite are listed below. The satellites fire rockets that provide the force needed to maintain a circular orbit around the space station. The gravitational force is negligible.



a. Rank each satellite based on its period. $T_3 = 196.34$ $T_4 = 1570.8$

$m = 200$ kg $L = 5000$ m $v = 160$ m/s	$m = 100$ kg $L = 2500$ m $v = 160$ m/s	$m = 400$ kg $L = 2500$ m $v = 80$ m/s	$m = 800$ kg $L = 10000$ m $v = 40$ m/s	$m = 200$ kg $L = 5000$ m $v = 120$ m/s	$m = 300$ kg $L = 10000$ m $v = 80$ m/s

$T_1 = 196.34$ $T_2 = 98$ $T = \frac{2\pi}{w}$ $V = wr$ $w = \frac{v}{r}$ $T_5 = 261.8$ $T_6 = 785.4$

$T = \frac{2\pi}{v/r}$ $T = \frac{2\pi r}{v}$

$\boxed{T_4 > T_6 > T_5 > T_1 = T_3 > T_2}$

b. Rank each satellite based on its acceleration. $a_c = \frac{v^2}{r}$

$m = 200$ kg $L = 5000$ m $v = 160$ m/s	$m = 100$ kg $L = 2500$ m $v = 160$ m/s	$m = 400$ kg $L = 2500$ m $v = 80$ m/s	$m = 800$ kg $L = 10000$ m $v = 40$ m/s	$m = 200$ kg $L = 5000$ m $v = 120$ m/s	$m = 300$ kg $L = 10000$ m $v = 80$ m/s

$a_{c1} = 5.12$ $a_{c2} = 10.24$ $a_{c3} = 2.56$ $a_{c4} = 0.16$ $a_{c5} = 2.88$ $a_{c6} = 0.64$

$a_{c2} > a_{c1} > a_{c5} > a_{c3} > a_{c6} > a_{c4}$

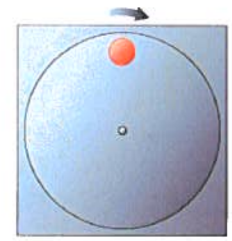
c. Rank each satellite based on the net force acting on it.

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

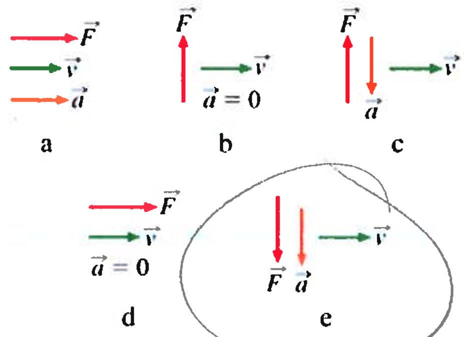
$F_{c1} = 576$ $F_{c2} = 92$ $F_{c3} = 1024$ $F_{c4} = 128$ $F_{c5} = 1024$ $F_{c6} = 1024$.

$F_{c3} = F_{c5} = F_{c6} > F_{c1} > F_{c2} > F_{c4}$

10. A small metal cylinder rests on a circular turntable that is rotating at a constant rate, as illustrated in the diagram.



a. Which of the following sets of vectors best describes the velocity, acceleration, and net force acting on the cylinder at the point indicated in the diagram?



b. Let R be the distance between the cylinder and the center of the turntable. Now assume that the cylinder is moved to a new location R/2 from the center of the turntable. Which of the following statements accurately describe the motion of the cylinder at the new location?

- o The speed of the cylinder has decreased. $v = \omega r$
- o The speed of the cylinder has increased.
- o The magnitude of the acceleration of the cylinder has decreased. $a = \frac{v^2}{r}$ $v = \frac{2\pi r}{T}$
- o The magnitude of the acceleration of the cylinder has increased.
- o The speed and the acceleration of the cylinder have not changed. $a = \left(\frac{2\pi}{T}\right)^2 R$

11. If the speed of an object in circular motion is doubled, what should be the new radius if the radial acceleration is to remain unchanged?

$a_c = \frac{v^2}{r}$

$a_c = \frac{4v^2}{4r}$

- o The new radius should be one-fourth the original radius.
- o The new radius should be √2 times the original radius
- o The new radius should be two times the original radius
- o The new radius should be four times the original radius
- o The new radius should be one-half the original radius

12. You see a penny sitting on a turntable rotating with constant speed. How many forces are acting on the penny?

- o The friction force of the turntable on the penny pointing inward towards the center.
- o The downward force of the earth on the penny, the upward force of the turntable on the penny, and the inward friction force of the turntable on the penny
- o The centripetal force
- o The downward force of the earth on the penny.
- o The downward force of the earth on the penny and the upward force of the turntable on the penny.

13. Video Tutor

None of the above

14. Rank the net force acting on each satellite from their rockets.

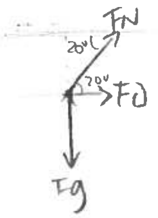
$F_c = \frac{mv^2}{r}$ $v = \frac{2\pi r}{T}$ $F_c = \frac{m\left(\frac{2\pi r}{T}\right)^2}{r}$

$m = 200$ kg $L = 5000$ m	$m = 100$ kg $L = 10,000$ m	$m = 100$ kg $L = 2500$ m	$m = 400$ kg $L = 2500$ m	$m = 800$ kg $L = 5000$ m	$m = 300$ kg $L = 7500$ m
1,000,000	1,000,000	250,000	1000000	4,000,000	2,250,000

$\boxed{F_c = \frac{4\pi^2}{T^2} mr}$

15. A car of mass M = 1500 kg traveling at 55.0 km/hour enters a banked turn covered with ice. The road is banked at an angle θ, and there is no friction between the road and the car's tires as shown in (Figure 1). Use g = 9.80 m/s2 throughout this problem.

a. What is the radius r of the turn if θ = 20 ° (assuming the car continues in uniform circular motion around the turn)?
Solve using only variables, then substitute relevant values.



$F_g = mg$

$F_c = \Sigma F = \frac{mv^2}{r}$

	X	Y
F_g	—	mg
F_c	$F_N \sin\theta$	—
ΣF	$\frac{mv^2}{r}$	$F_N \cos\theta$

$$\frac{F_N \sin\theta}{F_N \cos\theta} = \frac{mv^2}{rmg}$$

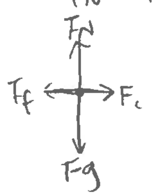
$$\tan\theta = \frac{v^2}{rg}$$

$$r = \frac{v^2}{g \tan\theta} \qquad r = \frac{(15.278\ m/s)^2}{9.8 \tan 20°}$$

$$\boxed{r \approx 65.4}$$

b. Now, suppose that the curve is level (θ=0) and that the ice has melted, so that there is a coefficient of static friction μ between the road and the car's tires as shown in (Figure 2). What is μmin, the minimum value of the coefficient of static friction between the tires and the road required to prevent the car from slipping? Assume that the car's speed is still 55.0 km/hour and that the radius of the curve is 65.4 m.
Solve using only variables, then substitute relevant values.

$F_N = F_g = mg$ $\qquad f_s = \mu_s F_N$



$f_s = \mu_s mg$

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

$$F_c = F_f$$

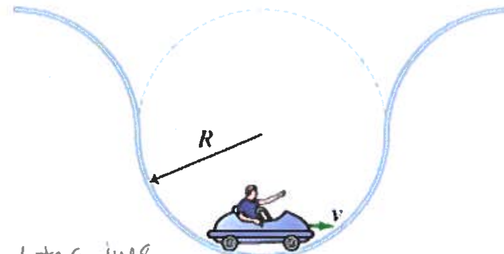
$$\mu_s \cancel{m} g = \frac{\cancel{m} v^2}{rg}$$

$$\mu_s = \frac{v^2}{rg}$$

$$\mu_s = \frac{(15.278)^2}{(65.4)(9.8)}$$

$$\boxed{\mu_s = 0.364}$$

16. A roller-coaster track has six semicircular "dips" with different radii of curvature. The same roller-coaster cart rides through each dip at a different speed.



a. For the different values given for the radius of curvature R and speed v, rank the magnitude of the force of the roller-coaster track on the cart at the bottom of each dip. **Solve using only variables, then substitute relevant values.**

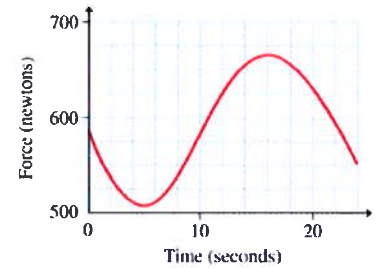
$F_c = \frac{mv^2}{r}$. m stays the same. $\frac{v^2}{r}$ determines the magnitude.

$R = 60$ m, $v = 16$ m/s	$R = 30$ m, $v = 4$ m/s	$R = 15$ m, $v = 8$ m/s	$R = 45$ m, $v = 4$ m/s	$R = 30$ m, $v = 16$ m/s	$R = 15$ m, $v = 12$ m/s
$x_1 = 4.267$	$x_2 = 0.533$	$x_3 = 4.267$	$x_4 = 0.356$	$x_5 = 8.533$	$x_6 = 9.6$

$x = \frac{v^2}{r}$

$x_6 > x_5 > x_1 = x_3 > x_2 > x_4$

17. A woman rides on a Ferris wheel of radius 16m that maintains the same speed throughout its motion. To better understand physics, she takes along a digital bathroom scale (with memory) and sits on it. When she gets off the ride, she uploads the scale readings to a computer and creates a graph of scale reading versus time. (Figure 1) Note that the graph has a minimum value of 510N and a maximum value of 666 N. The acceleration due to gravity, g=9.80 m/s^2.



a. What is the woman's mass?
Solve using only variables, then substitute relevant values.

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

$F = mg - F_{N top}$

$\frac{mv^2}{r} = mg - F_{N top}$.

$F_{N top} = mg - \frac{mv^2}{r}$

$F = F_{N bottom} - mg$

$\frac{mv^2}{r} = F_{N bottom} - mg$

$F_{N bottom} = \frac{mv^2}{r} + mg$

$F_{N top} + F_{N bottom} = mg - \cancel{\frac{mv^2}{r}} + mg + \cancel{\frac{mv^2}{r}}$

$2mg = F_{N top} + F_{N bottom}$

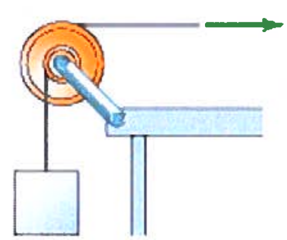
$m = \frac{F_{N top} + F_{N bottom}}{2g}$

$m = \frac{666 + 510}{2(9.8)}$

$\boxed{m = 60 kg}$

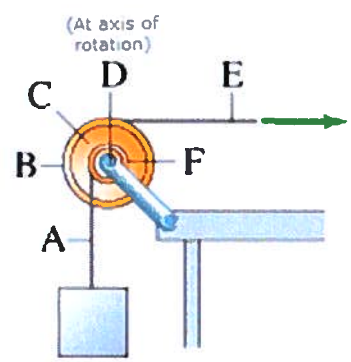
18. The pulley in (Figure 1) represents different pulleys that are attached with outer radius and inner radius indicated in the table. The horizontal rope is pulled to the right at a constant linear speed that is the same in each case, and none of the two separate ropes slips in its contact with the pulley.

a. Rank these throws based on the maximum height reached by the ball.



$R_{outer} = 0.4$ m, $R_{inner} = 0.2$ m	$R_{outer} = 0.4$ m, $R_{inner} = 0.3$ m	$R_{outer} = 0.8$ m, $R_{inner} = 0.4$ m	$R_{outer} = 0.2$ m, $R_{inner} = 0.1$ m
$\frac{0.2}{0.4} v_0$ $\frac{1}{2} v_0$	$\frac{3}{4} v_0$	$\frac{1}{2} v_0$	$\frac{1}{2} v_0$
	$R_{outer} = 0.6$ m, $R_{inner} = 0.2$ m	$R_{outer} = 0.6$ m, $R_{inner} = 0.5$ m	
	$\frac{1}{3} v_0$	$\frac{5}{6} v_0$	

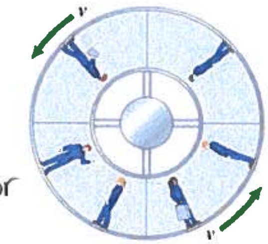
b. Rank the designated points on the basis of their linear or tangential speed.



$V = \omega r$

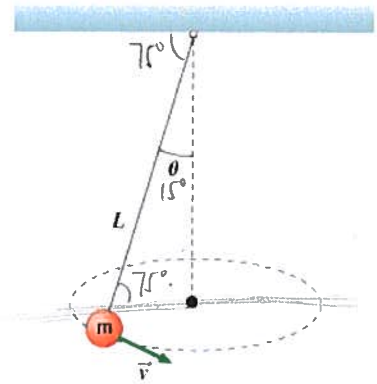
$B = E > C > F = A > D$

19. In the movies you often see space stations with "artificial gravity." They look like big doughnuts rotating around an axis perpendicular to the plane of the doughnut (Figure 1). People walking on the outer rim inside the turning space station feel the same gravitational effects as if they were on Earth.How does such a station work to simulate artificial gravity?

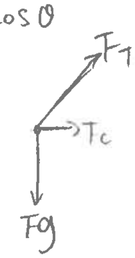


The "artificial gravity" is created by spinning the spacecraft or space station.
Because of this people experience an inward radial force exerted on them by the outer rim of the space station. This process simulates the effect of gravity.

20. (Figure 1)A bob of mass m = 0.300 kg is suspended from a fixed point with a massless string of length L = 20.0 cm . You will investigate the motion in which the string traces a conical surface with half-angle θ = 15.0 °.



$r = L\cos\theta$



a. What tangential speed v must the bob have so that it moves in a horizontal circle with the string making an angle 15.0 ° with the vertical

	x	y
Fg	—	mg
F_T	$F_T\cos\theta$	$F_T\sin\theta$
ΣF	$F_c = \frac{mv^2}{r}$	—

$mg = F_T \sin\theta$

$F_T = \frac{mg}{\sin\theta}$

$F_T\cos\theta = \frac{mv^2}{r}$

$\frac{mg}{\sin\theta}\cos\theta = \frac{mv^2}{L\cos\theta}$

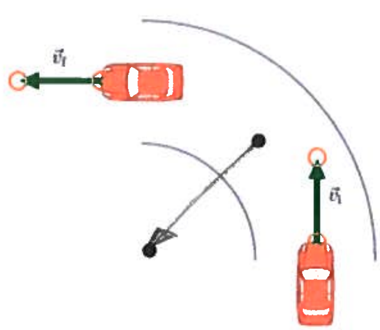
$v^2 = \frac{L\cos\theta g\cos\theta}{\sin\theta}$

$v = \sqrt{\frac{Lg\cos^2\theta}{\sin\theta}}$

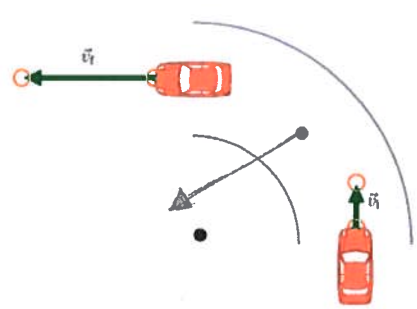
$v = \sqrt{\frac{(0.2)(9.8)\cos^2 75°}{\sin 75°}} = \boxed{0.367 \text{ m/s}}$

21. Find the direction of the acceleration vector for each of the three scenarios:

a. Find the direction of a car's acceleration at the marked point in the middle of the circular turn shown. The car is moving at constant speed.



b. Find the direction of a car's acceleration at the marked point in the middle of the circular turn shown. The car is speeding up.



c. Find the direction of a car's acceleration at the marked point in the middle of the circular turn shown. The car is slowing down.