Circular Motion Activities

Read these lessons:

Uniform Circular Motion and Centripetal Acceleration

Uniform Circular Motion and Centripetal Forces

Open the following simulations and answer the questions. Show all work and formulas used.

Ferris Wheel

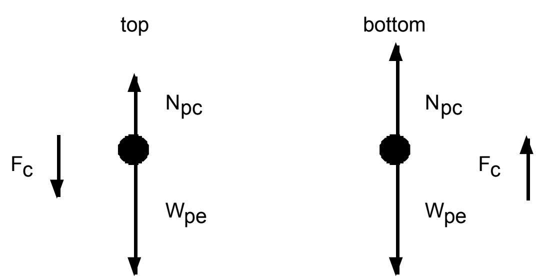
1. Press the PLAY button to watch the animation. Use a stopwatch to measure the period (the time to go around once). Click MEASUREMENTS to find the radius.

T = 14.8 s
r = 9.00 m

2. Calculate the linear (tangential) velocity, centripetal acceleration, and centripetal force on a 65 kg rider

v = 3.8 m/s	**$v = 2r/T = 2(9.00\text{m})/14.8$ s**
a_c = 1.6 m/s^2	**$a_c = v^2/r = (3.8\text{ m/s})^2/9.00\text{m}$**
F_c = 105 N	**$F_c = ma_c = (65\text{ kg})(1.6\text{ m/s}^2)$**

3. Draw freebody (force) diagrams for the person at the top and the bottom of the ferris wheel.



4. How does the centripetal force compare to the normal force and weight of the person at the top? At the bottom?

Top $F_c = W_{pe} - N_{pc}$ **Bottom** $F_c = N_{pc} - W_{pe}$

5. Where does the person feel the heaviest? Explain, referring to the freebody diagrams above. **Bottom (see below)**

Top $N_{pc} = W_{pe} - F_c$ **Bottom** $N_{pc} = W_{pe} + F_c$

The Anti-Gravity Machine

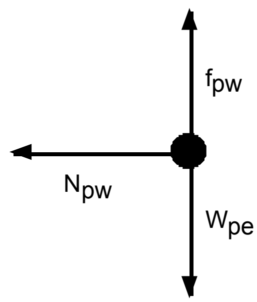
1. Press the PLAY button to watch the animation. Use a stopwatch to measure the period (the time to go around once). Click MEASUREMENTS to find the radius.

T = 3.8 s
r = 7.0 m

2. Calculate the linear (tangential) velocity, centripetal acceleration, and centripetal force on a 55 kg rider

$v = 11.6$ m/s **$v = 2r/T = 2(7.0\text{m})/3.8$ s**
$a_c = 19.1$ m/s^2 **$a_c = v^2/r = (11.6\text{ m/s})^2/7.0\text{m}$**
$F_c = 1053$ N **$F_c = ma_c = (55\text{ kg})(19.1\text{ m/s}^2)$**

3. Draw a freebody (force) diagram for the person.



4. What provides the centripetal force to keep the person moving in the circle?

N_{pw} – normal force on person by wall

5. Find the minimum coefficient of friction that will keep the person from sliding down the wall.

$f = N$ where $f_{pw} = W_{pe} = (55\text{ kg})(9.8\text{ m/s}^2) = 539$ N and $N_{pw} = F_c = 1053$ N
$= f/n = 539\text{ N} / 1053\text{ N} = 0.51$

Roller Coaster

1. Read through how to estimate the coaster's velocity. Run the movie and take the measurements needed to find the coaster's velocity at the highest point on the loop. A more accurate method of timing than using a stopwatch is to advance the movie frame by frame (there are 30 frames per second). Show your measurements and work below:

$v_{top} = 10$ m/s **$t = 42$ frames/30 fps = 1.4 s $x = (7\text{ cars})(2.0\text{ m/car}) = 14$ m**
$v = x / t = 14\text{m}/1.4\text{ s} = 10.$ m/s

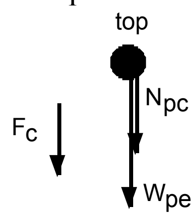
2. Click Loop's dimensions and then MEASUREMENTS to find the radius at the top of the loop.

r = 7.0 m

3. Calculate the centripetal acceleration and the centripetal force on a 70 kg rider at the top of the loop.

$a_c = 14.3\ m/s^2$ **$a_c = v^2/r = (10\ m/s)^2/7.0m$**
$F_c = 1000\ N$ **$F_c = ma_c = (70\ kg)(14.3\ m/s^2)$**

4. Draw a freebody (force) diagram for a person at the top of the loop.



5. At the minimum velocity that will keep the person in the car without relying on the seat belt, the normal force is equal to zero. What then, would the centripetal force and centripetal acceleration equal for this minimum velocity? Also find the minimum velocity. Refer to your freebody diagram above.

$F_c = 686\ N$ **$N_{pc} = 0$ so $F_c = W_{pe} = (70\ kg)(9.8\ m/s^2)$**

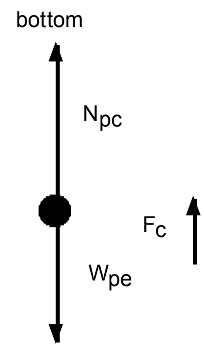
$a_c = 9.8\ m/s^2$
$v_{min} = 8.3\ m/s$ **$a_c = v^2/r$ so $v = SQRT(a_c r) = SQRT[(9.8\ m/s^2)(7.0m)]$**

How does your v_{min} compare to v_{top} in question #1? **slower**

6. Use conservation of energy ($KE_{bottom} = PE_{top} + KE_{top}$) to find the minimum velocity with which the train must go into the loop so the person doesn't fall out of the train at the top. How does this compare to the 60 mph top speed I found for this coaster online?

v_{min} = 27.4 m/s **$\frac{1}{2}mv_{bot}^2 = \frac{1}{2}mv_{top}^2 + mgh$**
masses cancel so v_{bot} =SQRT[(8.3 m/s)^2 + 2(9.8m/s^2)(35m))]
v_{min} = 61.3 mi/h **27.4 m/s (3.28 ft / 1 m) (1 mi / 5280 ft) (3600 s / 1 h)**

7. Calculate the centripetal acceleration at the bottom of the loop. (radius = 35m – 7m) How many g's does the rider feel?



a_c = 26.8 m/s^2 $a_c = v^2/r$ = (27.4 m/s)^2/28.0m

g's = 3.7 **$N_{pc} = W_{pe} + F_c$ in terms of acc. 26.8 m/s^2 + 9.8m/s^2 = 36.6 m/s^2**
g's =36.6 m/s^2/9.8m/s^2

Scrambler

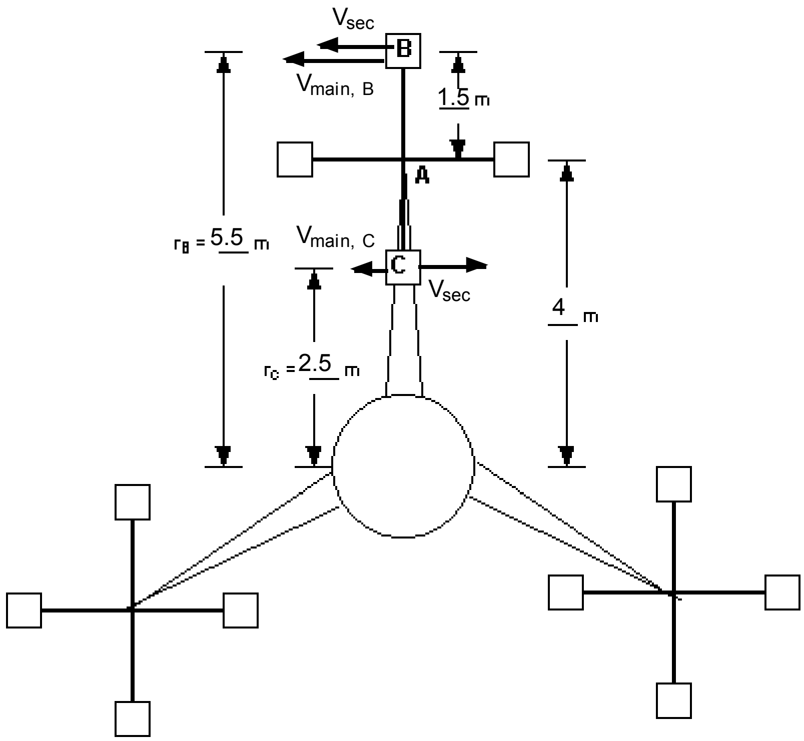
1. Click MEASUREMENTS to find the length of the minor arm (radius of the secondary sweep) and the major arm (radius of the main sweep).

length $_{minor}$ = 1.5 m
length $_{major}$ = 4.0 m

2. Press the PLAY button to watch the animation. Use a stopwatch to measure the period just due to the spin of the minor arm around point A (Hint – start the stopwatch when a blue car passes a major arm and stop it when it passes that arm again.). Calculate the linear (tangential) velocity around point A due to the secondary sweep.

T_{sec} = 3.5 s
v_{sec} = 2.7 m/s **v = 2r/T = 2(1.5 m)/3.5 s**

3. Use a stopwatch to measure the period due to the spin around the center due to the main arm. (Hint – start the stopwatch when a major arm points to the top of the screen and stop it when it points to the top of the screen again.)
T_{main} = 6.9 s



4. How far from the center of the ride is a person at point B? Calculate the linear (tangential) velocity due to the main sweep at point B.

r_B = 5.5 m **4.0 m + 1.5 m = 5.5 m**

$v_{main, B}$ = 5.0m/s **v = 2r/T = 2(5.5 m)/6.9 s**

5. How far from the center of the ride is a person at point C? Calculate the linear (tangential) velocity due to the main sweep at point C.

r_C = 2.5 m **4.0 m - 1.5 m = 2.5 m**

$v_{main, C}$ = 2.3 m/s **v = 2r/T = 2(2.5 m)/6.9 s**

6. Draw arrows on the diagram above to show the directions of the velocities of both the main sweep and secondary sweeps at point B and point C.

7. Find the velocity of a person at points B (outermost point) and C (innermost point) due to the combined motion of the main and secondary sweeps.

v_B = + 7.7 m/s **$v_{main, B} + v_{sec}$ = 5.0m/s + 2.7 m/s**

v_C = - 0.4 m/s **$v_{main, c} - v_{sec}$ = 2.3 s - 2.7 m/s**

10. Find the centripetal acceleration and centripetal force on a 72 kg person at points B and C.

$a_{c,B} = 10.8\ m/s^2$ **$a_c = v^2/r = (7.7\ m/s)^2/5.5m$**

$F_{c,B} = 776\ N$ **$F_c = ma_c = (72\ kg)(10.8\ m/s^2)$**

$a_{c,C} = 0.064\ m/s^2$ **$a_c = v^2/r = (-0.4\ m/s)^2/2.5m$**

$F_{c,C} = 4.6\ N$ **$F_c = ma_c = (72\ kg)(0.064\ m/s^2)$**