Name: ____ **Hour:** _________

CIRCUS PHYSICS ACTIVITY GUIDE

Centripetal Acceleration

Trick riders may just ride in circles, but that doesn't mean they aren't accelerating. Moving in a circle requires steady changes in direction. This is a form of acceleration directed inward, with a magnitude that depends on the velocity of the horse and rider and the radius of the circle. This is the same acceleration that we feel when going around bends in a car, and that holds us in our seat on the rollercoaster. This unit uses trick riding to show students the basics of circular motion.

Watch the Video: Centripetal Acceleration

http://www.pbs.org/opb/circus/classroom/circus-physics/centripetal-acceleration/

In the video, watch as trick riders jump on and off a horse at galloping speed! Along the way, you'll learn about circular motion and why circus rings are as large as they are.

Questions to Consider While Watching the Video

1. What force does the horse exert?

2. What forces are acting on the horse?

3. How does the size the ring affect the speed at which the horse can gallop?

4. What kinds of acceleration do you see?

Questions after the video

Demonstration opportunity: There are many ways to show centripetal acceleration in action.
You can spin a penny on the bent end of a coat hanger, or spin a bucket full of water over your head. What's the point? There has to be some sort of acceleration that counters gravity, so what is it? Where does it come from? Ultimately, it's the tension in your arm holding the bucket or coat hanger. This is always directed toward the center of the circle, the object wants to go in a straight line, but it can't because it's being continually pulled off course.

1. Why does circular motion fit the definition of acceleration?

2. How does centripetal acceleration feel in real life?

3. Why do you lean when riding in a car going around a bend?

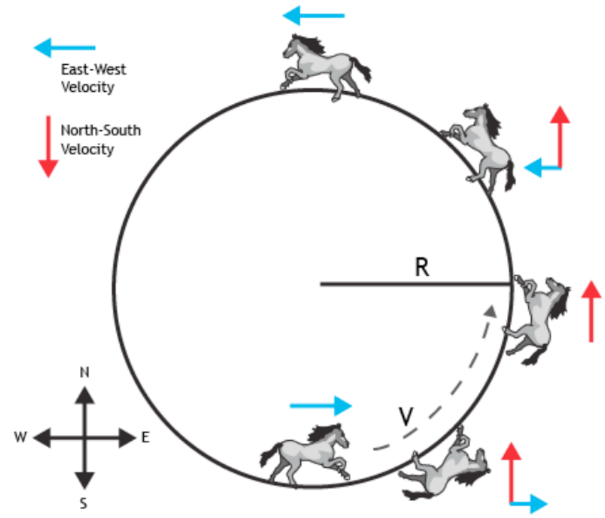
4. What happens for smaller radii and/or larger velocities?

Connections to Everyday Life

Most students will be familiar with centripetal acceleration from driving—going around turns.
The faster you take a turn, the more you lean. Taking a tighter turn has the same effect.
There are also numerous examples from the amusement park, rollercoaster, gravitron, etc.
One less obvious one might be the spin cycle on a washing machine. The water, unconstrained, goes flying off in straight lines. If you could accelerate in your car fast enough, for long enough, you could spin-dry your laundry in your trunk. Indy-style car racing is another one— why do cars change tires so much? The constant turning wears down rubber.

Digging Deeper

Here is a top-down view of the trickrider's horse as it runs around a ring. R is the ring's radius, V is the horse's velocity around the ring. The blue arrow is the component of the horse's velocity in the East-West direction, the x-direction. The red arrow is the component in the North-South, or y-direction.



As the horse runs around the ring, its velocity is always Directed around the circle. As the horse turns, however, its x and y component velocities change. Changing velocity is also known as acceleration.

A = change in v / change in t

But now we have a conundrum, if the horse is accelerating, Why doesn't it seem to be speeding up?

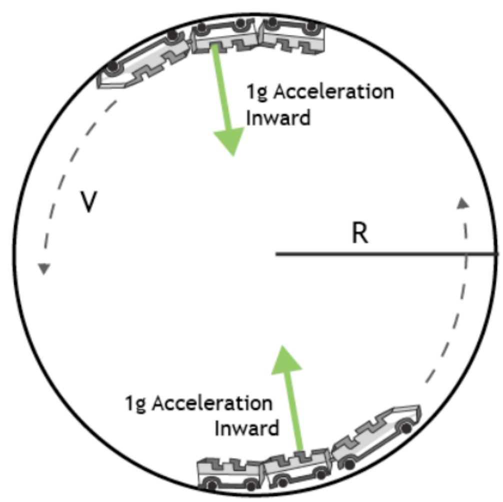
Notice that the horse's velocity arrow at the bottom of the ring is completely directed East (blue), with no North-South component (red). As the horse runs counter-clockwise, its East velocity decreases, while the North velocity increases. When the horse reaches the due East position, its velocity is entirely North, with no East-West component. The red arrow then decreases as the blue arrow increases again, this time headed West.

No matter where the horse is, one of its velocity components is decreasing, always being pulled back to zero in its respective direction. For this reason, we say the acceleration is directed toward the center of the circle. This is commonly known as *centripetal acceleration*. We can find the magnitude of this acceleration with a simple formula:

$A = V^2/R$

Recall from the second unit (Unit 2: Newton's Laws of Motion) that a net acceleration implies a net force.

This acceleration is caused by whatever is keeping the object moving in a circle. In the horse's case, it's caused by hooves pushing against the ground. In the case of a rollercoaster, it's caused by the tracks.



As you go through a horizontal rollercoaster loop, the tracks push against the car, and by extension your bottom, to keep you going in a circle. Your body pushes back, according to Newton's 1st and 3rd Laws (Unit 2: Newton's Laws of Motion). The force of your body pushing back is what keeps you in your seat. The acceleration required to pull this off must be equal to or greater than gravity. We call this a "g". A 1 g turn is then a turn in which you feel an amount of centripetal acceleration equal to the acceleration due to gravity.

Your Turn

Use the concepts and formulas from this unit to figure out the following:

How fast must a roller coaster go through a 25 meter-radius horizontal loop in order to maintain constant centripetal acceleration of 1 g?

Show Your Work: