Name: _____ Date: _____

CH 6 CIRCUS PHYSICS ACTIVITY: PROJECTILE MOTION

Jugglers know that if you throw a ball, a bean bag, or a pin into the air, it will follow a curved path. This curve is what naturally happens when an object can move in two dimensions—horizontal and vertical—at the same time. As the ball moves horizontally, gravity pulls down.
Physicists call this *projectile motion*. This unit helps students understand why any projectile, no matter if thrown, shot, or launched, will follow a curved path while in the air.

Questions While Watching the Video

1. What determines how high a juggling pin goes?

2. What determines how far it travels horizontally while in the air?

3. How does the change in the pin's vertical velocity compare to the change in horizontal velocity?

Watch the Video: Projectile Motion

http://www.pbs.org/opb/circus/classroom/projectile-motion/

Questions After the Video

1. What determines how many objects a person can juggle?

2. As you throw a ball higher, why is it harder to have it come back down in the same place?

3. Does the spinning of the juggler's pin affect how long it's in the air?

4. How does air resistance change things?

5. Would juggling be the same on the Moon ($g = 1.6\ m/s^2$)? How about Jupiter ($26\ m/s^2$)?

Your Turn

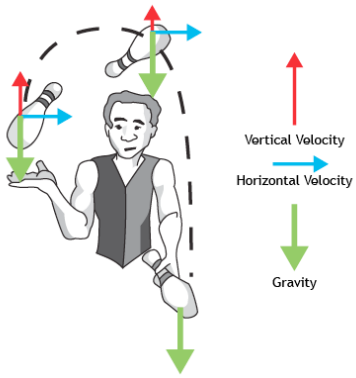
A ball rolls with a speed of 2.0 m/s across a level table that is 1.0 m above the floor. Upon reaching the edge of the table, it follows a parabolic path to the floor. How far along the floor is the landing spot from the table?

	Givens	Unknown	Equation	Substitute into equation	Answer with Units
Vertical					
Horizontal					

Digging Deeper_____

Before we jump in, let's agree on two things:

1. Velocity is how much you change your position per change in time.
2. Acceleration is how much you change your velocity per change in time.



In the diagram of the juggler, notice how the pin's horizontal velocity remains constant while the pin is in the air. The vertical velocity gets smaller as the pin nears the top of its curve. This is because the acceleration due to gravity is always downward. The changing vertical velocity, due to the force of gravity, is what causes the curve. Without the force of gravity the pin would travel in a straight line.

As the pin goes up, its vertical velocity slows down. By how much? For every second the pin stays in the air, its velocity goes down by 9.8 meters per second the acceleration due to gravity. This means that if you tossed a pin into the air with an initial vertical velocity of 9.8 meters per second, it would take exactly one second for its vertical velocity to equal zero. This happens when the ball is at the very peak of its path. After two seconds, the pin's vertical velocity will again be 9.8 meters per second, but this time in the downward direction. If nothing stops the pin, after three seconds, it will be falling at 19.6 m/s, after four, 29.4 m/s, and so on.

Horizontally, there is no gravity, so there's nothing to slow down the pin's horizontal velocity. After one second, its horizontal velocity is exactly the same as it was when you tossed it…assuming there's no air friction.

Note: Gravity only affects the vertical velocity, not the horizontal.

So, what determines how high the pin will go? Gravity has to play a role. So does the initial vertical velocity—how hard you throw it. The final ingredient is the time the pin takes to reach the top of its arc. We can combine these to come up with a formula that tells you how high a pin will go:

$D_y = V_i \times \text{time} + (1/2) \times \text{gravity} \times \text{time}^2$

So if we throw a pin with an initial velocity of 9.8 meters per second, we know it will take one second to reach the top of its arc. Its height at the top will be:

$D_y = (9.8 \text{ m/s}) \times (1 \text{ s}) + (1/2) \times (-9.8 \text{ m/s/s}) \times (1 \text{ s})^2$

$D_y = 4.9 \text{ m}$

Note that gravity is negative because it is acting in opposite direction to the initial velocity.

Defining Projectiles

A projectile is an object upon which the only force acting is gravity. There are a variety of examples of projectiles. An object dropped from rest is a projectile (provided that the influence of air resistance is negligible). An object that is thrown vertically upward is also a projectile (provided that the influence of air resistance is negligible). And an object which is thrown upward at an angle to the horizontal is also a projectile (provided that the influence of air resistance is negligible). A projectile is any object that once *projected* or dropped continues in motion by its own inertia and is influenced only by the downward force of gravity.