Name _____ Date _____ Period _____

Juggling and Independence of Motion

CONCEPTUAL PHYSICS: UNIT 2

BACKGROUND: Most jugglers depend on their instincts to tell them how to throw. In many cases, these instincts are nothing more than an intuitive understanding of the physical constants of the universe, such as the force of gravity on Earth. The physics of juggling involves the concepts of parabolic arcs, speed, velocity, acceleration, independence of motion, and air resistance, but gravity is the most important force.

Gravity is the engine of a juggler's art -- it both enables the act and makes it challenging for the juggler. Gravity limits what jugglers can do, putting strict time limits on each toss and catch. At the same time, the constant rate of acceleration of gravity makes each toss during a juggling session a predictable and dependable component. The skilled juggler must have has a good feeling for that rate of acceleration of gravity, which is 9.8 meters per second squared. For each second an object falls, its speed increases by 9.8 meters per second. Because an object that spends a longer time falling ends up going faster, objects that are tossed higher will be falling faster when they must be caught. This means that the only way a juggler can slow down his or her pattern -- by tossing the prop higher -- can cause errors. At the same time, objects tossed only a short distance into the air will perhaps not give the juggler enough time to free a hand and make the catch.

The constant downward force that gravity exerts is also what makes juggling an inherently continuous spectacle: You don't really marvel at watching a person toss and catch something once, even if it's a knife or a flaming torch. The appeal of juggling is that it places a constant and continuous stress and pressure on the juggler.

Three-ball juggling is the simplest form of the art; some jugglers have claimed that they juggled up to 14 props. Different patterns are needed for odd or even numbers of props. In one-handed juggling, two main patterns are used: the fountain pattern, where the toss and catch are in a circular motion, and the column pattern, where each ball is thrown and caught at the same place.

QUESTIONS:

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. How does air resistance change things?

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4. Assuming the ball stayed in the air for 1 second, calculate the height the balls would reach on Earth, the Moon, and Jupiter. *(The acceleration due to gravity on Earth is 9.8 m/s², the Moon: 1.6 m/s², Jupiter: 26 m/s².)* **Show all of your work**

a. Earth-

b. Moon-

c. Jupiter-

6. What would you have to do in order to juggle the balls to the same height on the Earth, Moon, and Jupiter? **Explain**