DEVICE	Monkey in a Tree Demo
TOPIC	Projectile Motion/Mechanics

THEORETICAL BACKGROUND

Projectile motion is a special case of kinematics, i.e. the phenomenon is an examination of an object moving in two directions; simultaneous motion in the vertical and horizontal directions. The projectile never accelerates in the horizontal direction (acceleration = acceleration due to gravity = zero). Furthermore the projectile must move in the horizontal direction with a constant velocity. In accordance with one dimensional kinematics the position of the projectile after time t in the horizontal direction is

$$x - x_0 = v_{0x} t \Rightarrow x - x_0 = v_0 t \cos\theta_0.$$

Now consider the vertical motion of the projectile. The vertical motion of the projectile maintains a constant value of acceleration directed downward (acceleration = acceleration due to gravity = constant). One dimensional kinematics as applied here, models the projectile's vertical motion subject to constant acceleration. Here the acceleration due to gravity directs the projectile downward. Therefore its position in the vertical direction after time t becomes

$$y - y_0 = v_{0y} t - \frac{1}{2} g t^2 \Rightarrow y - y_0 = v_0 t \sin\theta_0 - \frac{1}{2} g t^2$$

and the vertical velocity becomes

$$v_{0y} = v_0 \sin\theta_0 - g t$$
$$v_{0y}^2 = (v_0 \sin\theta_0)^2 - 2g(y - y_0).$$

The horizontal range or the horizontal distance traveled by the projectile is $x - x_0 = R$.

The range is determined once the projectile returns to its launch height, $y - y_0 = 0$. The range reaches a maximum value when $\theta_0 = 45°$. It is also worth noting that as the projectile reaches its peak along the arc of its trajectory, its velocity in the vertical direction tends to zero. The maximum height of the projectile is then determined by equating y_0 and v_0 to zero and solving for y. The trajectory of the projectile is determined by eliminating the time t from the results found for the horizontal and vertical motion of the projectile. With some substitution procedures the path of the projectile is given as

$$y = (\tan\theta_0)x - \left(\frac{g}{2v_0^2 \cos\theta_0}\right)x^2$$

This equation has the form of a *parabola* $y = ax \pm bx^2$. All projectiles follow the path of a parabola.
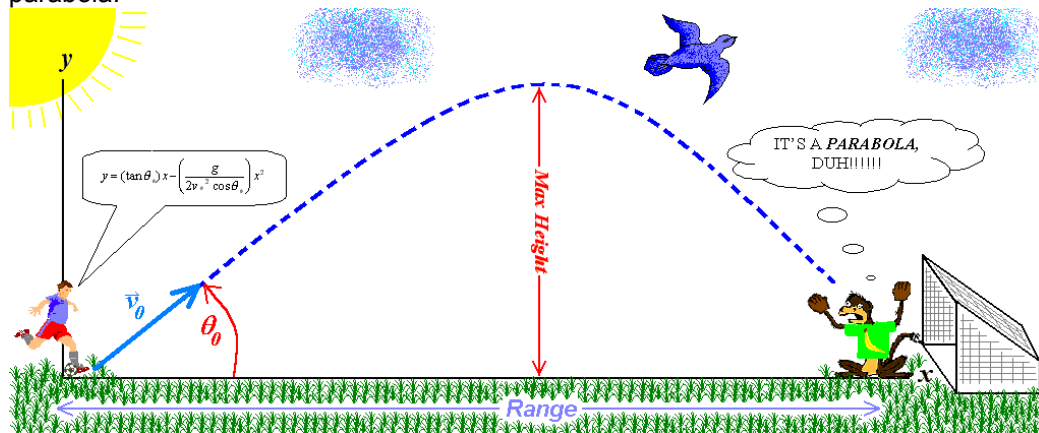
DESCRIPTION

The demonstration models two applications of kinematics: projectile motion and free-fall. The relative link between projectile motion and free fall is constant acceleration due to gravity. The vertical motion of a projectile along a trajectory is the same vertical motion of an object in free fall. The monkey (an empty milk jug with a $2\frac{1}{2}"$ hole cut out of its center) free-falls from a magnet mounted on a crossbar. Under the condition of constant acceleration, the ball travels a vertical distance equal to that of the monkey's fall from the crossbar. The monkey is hit by the ball at a point where his free fall path intersects the trajectory of the ball.
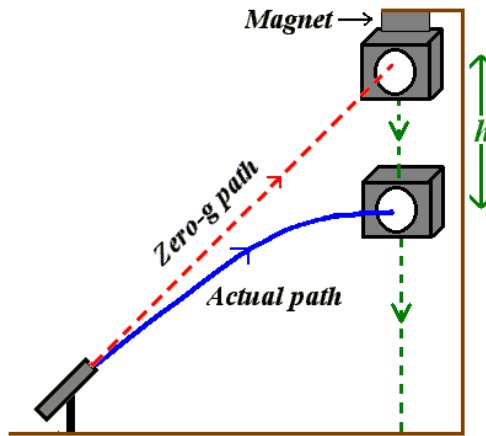
PROCEDURE

1. Align the barrel of the launcher with the target (monkey) using the crosshairs on the barrel. (The zero-g path reflects the motion of the ball if it were not subject to the force of gravity. This path provides a line of sight for the launcher.)
2. A photogate should be attached to the barrel. The monkey is hooked onto the crossbar by a drop box device containing a magnet. The photogate and magnet lead to a control box. The control box is configured so that as the ball passes over the photogate sensor the ball and monkey simultaneously begin to fall to the ground.
3. Cock the ball into the launcher.
4. Shoot the monkey when ready. For best results the launcher should be approximately 1.5 meters from the monkey. **Caution!!!** Never look directly down the barrel…we wouldn't want you to shoot your eye out!!!

SUGGESTIONS