TITLE: Horizontal vs. Vertical Motion

PURPOSE: To investigate the independence of horizontal and vertical components of motion.

INTRODUCTION

Imagine yourself in outer space. If you tossed a rock in outer space it would just keep going – forever, as illustrated in Figure A. Because the rock was going at a constant speed, (since there is no net force horizontally,) it would cover the same amount of distance in each second. The equation for distance traveled when motion is uniform is \( d_x = v_x t \). This is simply a rearrangement of the equation for speed, \( v_x = \frac{d_x}{t} \).

Back on Earth; what happens when you drop a rock? It falls to the ground and the distance it covers in each second increases, because gravity is constantly increasing its speed, as illustrated in Figure B. (This is because there is a net force in the vertical direction.) The equation for the vertical height, \( d_y \), fallen after any time, \( t \), is \( d_y = \frac{1}{2} gt^2 \). Therefore, if you know the height from which an object falls, you can calculate its time in the air by rearranging the equation to solve for time: \( t = \sqrt{\frac{2d_y}{g}} \).

What happens if you toss the rock sideways on Earth? The curved motion that results (see Figure C) can be described as the combinations of two motions: one vertical, and the other horizontal. The vertical motion undergoes the acceleration due to gravity, while the horizontal motion does not. The secret to analyzing projectile motion is to keep the two motions separate. One that treats the horizontal motion according to \( d_x = v_x t \); and the second that treats the vertical motion according to \( d_y = \frac{1}{2} gt^2 \).

Your goal in this lab is to be able to predict where a steel ball will land when launched horizontally from a certain height. The final test of your measurements and calculations will be to position an empty cup so that the ball lands in it the first time! Extra credit will be awarded to all who accomplish this goal.

PROCEDURE

1. Assemble the ramp so that the end of the track is at the edge of the table. Tape this end of the track in place. Stand the brick up on end and place it under the wooden board that the other end of the track is attached to. Make sure that the track forms a smooth curve, and that it is definitely traveling horizontally before the end.

2. Measure the height from the edge of the horizontal track to the floor. Record this in the data section.
3. Use your meterstick and masking tape to make a line on the floor that is directly beneath the edge of the table (and end of the ramp), so that you have a mark to start your measurements from.

4. Place the golf ball at the top of the ramp and allow it to roll down the ramp and onto the floor. Record how far the golf ball traveled horizontally from the end of the ramp in the data table. Repeat for a total of five trials. Calculate the average horizontal distance.

**DATA**

Height ____________

<table>
<thead>
<tr>
<th>TRIAL</th>
<th>HORIZONTAL DISTANCE</th>
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<tbody>
<tr>
<td>1</td>
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<td>2</td>
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<td>3</td>
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<td>4</td>
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<tr>
<td>5</td>
<td></td>
</tr>
<tr>
<td>AVERAGE</td>
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**CALCULATIONS & QUESTIONS**

1. Calculate the time that the steel ball was in the air.

2. Calculate the horizontal velocity of the steel ball.

3. Using the equations given in the introduction, and your experience and results from this lab; derive a single formula that will allow you to find the horizontal distance traveled (range) by the steel ball if you are only given the height of the end of the ramp.
4. How long would the ball be in the air if we had used a heavier steel ball? Explain your answer.

5. How long would the golf ball be in the air if we had used a ramp where the inclined part was twice as long? Explain your answer.

6. A tennis ball is shot horizontally from a cannon at a height of 5.0m. If the ball has a range of 110m, calculate the horizontal velocity of the tennis ball.

7. The teacher will give you a new height for the end of your ramp. Given what you did in Ques. 3, calculate the range that the steel ball will now have. DO NOT talk to any other lab groups about your answer. When you have your answer, take it to the teacher so they can record it.

8. When it is your groups turn you will place an empty cup at your calculated distance from the end of the new ramp to see if the steel ball hits your prediction.