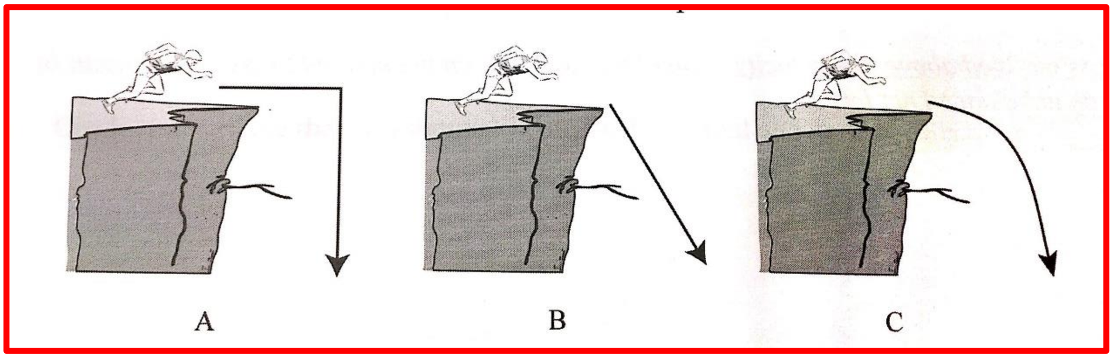
**AP Physics Lab #3: Horizontal Projectile Motion** (Big Idea 3)

**3.A.1.3:** The student is able to analyze experimental data describing the motion of an object and is able to express the results of the analysis using narrative, mathematical, and graphical representations.

*If a ball were to roll off a table, exactly where would it land? This is the primary question explored in this lab. According to Newton's First Law of Motion, all objects will move in a straight line at a constant speed unless acted upon by an unbalanced net force. If a force is present, the object will accelerate. In this activity, a ball will be launched horizontally off the edge of a table. According to Newton, the ball will travel in the horizontal direction at a constant speed. The motion in the vertical direction, however, will be different. Since the ball is under the influence of gravity, it should accelerate in the vertical direction.*

**Horizontal Projectile Motion Pre-Lab:**

**P1**. The following sketches show three possible paths of the character running off a cliff. Explain why the first two sketches ( A and B) are not possible and outline why the third sketch (C) is in fact an accvurate depiction.




*When analyzing the motion of an object traveling in two dimensions the analysis is simplified by viewing and calculating the horizontal motion separately from the vertical motion. Keep in mind the horizontal velocity of the object is independent of its vertical velocity. Furthermore, the horizontal displacement of the object has no effect on the vertical displacement. The horizontal time, however, is equal to the vertical time since horizontal and vertical motion takes place at the same time.*

**P2**. Sketch the position time graphs for a ball that is traveling horizontally off a cliff in both the x and y directions. Define the starting point (the cliff) as x=0 and y=0. You will have two sketches here.

**P3**. As outlined above, the velocity of an object will remain unchanged unless acted upon by an unbalanced force. Considering the four kinematic equations for uniformly accelerated motion, derive an equation that best summarizes the motion of the ball in the horizontal direction.

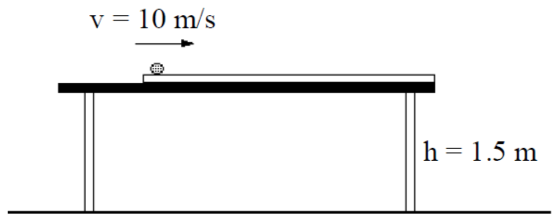
**P4**. Before leaving the table, the ball is not moving in the vertical direction. So the initial velocity of the ball in the vertical is direction is zero. As outlined earlier, the ball is under the influence of gravity, so it will accelerate in the vertcial direction as it falls to the ground. Considering the four kinematic equations for uniformly accelerated motion, state the formula that best summarizes the motion of the ball in the vertical direction.

**P5**. Based on your answers to P3 and P4, list the variables that affect the motion of an object in the horizontal and vertical directions. Which variable is common to both directions?

**P6**. In this activity, you will use your understanding of two-dimensional kinematics to predict the landing position of a ball rolled down a ramp set on the edge of a table. What factors could decrease the accuracy of your prediction? Explain what you can do to avoid these sources of error or how you can account for these factors.

*An object that travels at a constant speed will cover the same distance during sequential identical time intervals. An accelerating object, however, will increase/decrease its distance traveled over equal intervals of time. In the case of two-dimensional projectile motion, the object accelerates in the vertical direction, but travels at a constnt speed in the horizontal direction. The constant rate of displacement (i.e., velocity) compared to the changing rate of displacement (i.e., acceleration0 becomes apparent when studying sequential frames of a video of a moving object. Sequential frames of video can be "frozen" by viewing one frame after another.*

**P7**. A horizontally launched projectile's initial vertical velocity is zero. Solve the following problems with this information. Given the following situation of a marble in motion on a rail with negligible friction as shown to the right.




a. Once the ball leaves the table, calculate how long it will take for the ball to hit the floor.

b. Determine the impact velocity (magnitude and direction) of the marble right before it hits the floor

c. How far will the ball travel horizontally before hitting the floor?

If the table were 3.0 m high (so we have doubled the height), and sphere was traveling with the same velocity of 10 m/s while on the table determine each of the following:

d. Determine how much longer it will take the ball to fall to the floor.

e. What effect did doubling the height have on the horizontal range of the marble? What other factors affect the range of the sphere?

**Horizontal Projectile Motion Lab:**

**Materials**: projectile launching ramp, C-clamp or spring clamp, golf ball, calipers, photogate timer, LabQuest 2 interface, Logger Pro (optional), meter stick, cup.

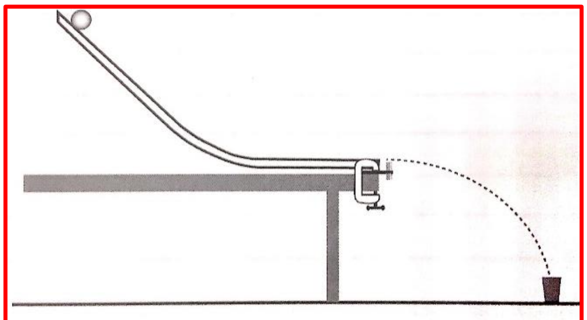


Figure 1

In this activity you will predict the landing position of a ball launched off the edge of a table. You could simply roll the ball off the table, but it will be nearly impossible for you to roll the ball with a consistent velocity from trial to trial. Instead, you will take advantage of the fact that a ball rolled from the top of a ramp will always leave the ramp with the same speed. The ramp you will use is curved such that the bottom of the ramp is horizontal, allowing the ball to be launched horizontally, as shown in figure 1. A photogate will be positioned at the end of the ramp and used to measure the instantaneous velocity at that location. The photogate works by projecting an infrared beam from one arm of the sensor to the other arm. When the beam is blocked the sensor stops sending a signal, which illuminates an LED on the top of the gate as well as triggering the LabQuest to display a blocked message in the meter display (see figure 2 on the next page). You will be using the "gate timing" mode in this lab. Gate timing begins when the photogate is first blocked. The timing will continue until the gate is unblocked. The duration of the interruption is thus timed. If the length of the object is entered in the "length of object field", the speed is calculated. Speed calculation in gate mode relies upon knowing the length of the object going through the gate. For some objects, (e.g. note cards), this is not a problem, but other objects might be more challenging. For example, if you rolled a marble through the gate, you would need to know the diameter or secant of the ball that went through the beam. You will use the calipers to accurately measure the diameter of the golf ball. The general set-up is shown in figure 3.

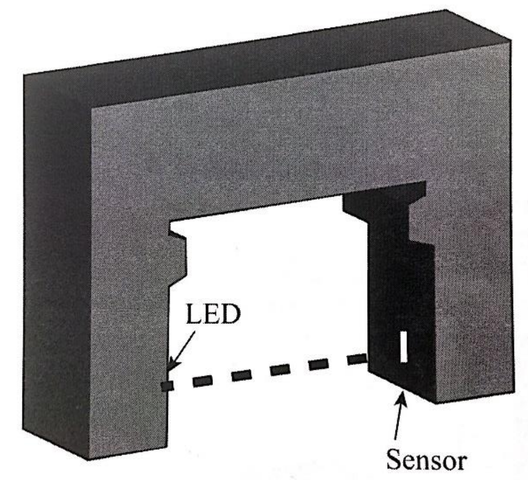



**Figure 2**

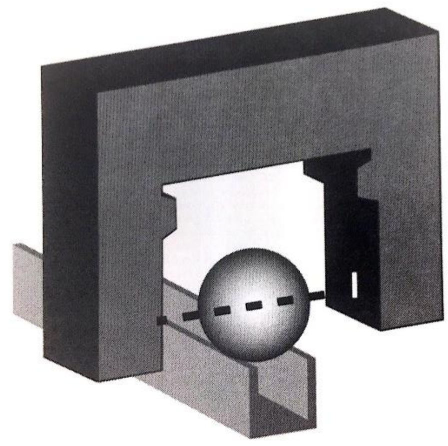


**Figure 3**

**Q1**. Record the diameter of the ball. Take multiple measurements and ensure your data are accurate. This will be entered into the "length of object field".

*In this lab you will be predicting the landing position of the ball. To do so, you must first measure the launch velocity of the ball. DO NOT allow the ball to hit the ground, as this will obviously influence your prediction. Use a large tub or plastic beaker to catch the ball the instant it leaves the ramp. Repeat this numerous times to obtain an accurate initial velocity in the x-direction. DO NOT allow the ball to hit the floor during these trials.*

**Q2**. Create a table to organize your data. Collect data and show any calculations.

**Q3**. Prepare another data table that summarizes all the variables that affect the motion of an object in the horizontal and vertical directions (see P5).

**Q4**. Given these variables and the experimentally determined launch velocity, calculate the landing position of the golf ball.

**Q5**. Now that you have made predictions based on the mathematics, it is time to launch the ball. Place a cup in the position on the floor that you predicted. Collect data by completing numerous trials. Did the ball land into the cup on your first attempt? Write an explanation as to why the launch was not successful, and what changes in calculations or positioning you would make to ensure success next time.

Please self-assess your lab report using the rubric/checklist.