Measuring "g" by using trajectory projectile motion: 5E learning cycle and low-cost materials

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Abstract

In some countries physics lessons are limited in many cases due to different constraints to lecturing and rote learning with in short supply use of teaching materials and other practical activities. These limitations can make physics abstract and difficult for students to understand. This paper presents one of activities, which can be done by using low-cost materials that can be found around schools or home. It might be useful for teachers to teach physics and make abstract physics more concrete.

Introduction

The purpose of this paper is to demonstrate how teachers can provide students an opportunity to measure "gravity" by observing and analyzing the trajectory of projectile motion in 2D. Another aim is to have students use the 5E learning cycle in this activity, which can be conducted with low-cost materials. In addition, it allows students to study the relationship between different factors such as air resistance and friction, which are in their cognitive competence. For example, students can explore and explain what kind of approximations they need to make. These approximations might be air resistance and friction. So, they can find out how these factors affect their results because they will get a different result from $g=9.8\ m/s^2$. Of course, there are other factors that affect the result such as measurement errors. Students will learn to plan and conduct scientific investigations through studying the motion of a ball or a marble to measure "g". This allows students to realize there is not just one fixed investigation method to follow while conducting investigations.

The activity was conducted in a PHYSWARE Collaborative workshop on low-cost and appropriate technologies that promote undergraduate level, hands-on physics education throughout the developing world. This paper records how the activity to measure g was set up and presented authors in the PHYSWARE workshop held in Italy in 2009. This workshop focused on mechanics teaching in physics topics. Although we developed various instructional materials as one is seen in this paper, created construction plans, and ideas for activities to help educators make effective use of both low cost and high technology equipment, only one, the trajectory projectile motion activity is discussed here.

This activity had also been run by Byansi in an undergraduate physics course. However, no formal research has been conducted to investigate students' conceptual understanding, views, and performance of "g" measurement. Based on his observations, students were actively engaged and showed curiosity because it was not a traditional way of conducting an activity to measure "g" such as dropping a ball. It was a more creative way of measuring g. Use of the 5E learning cycle model to conduct the activity distinguishes it from traditional cookbook lab experiments. The 5E learning cycle model is an instructional model that provides active learning experiences and promotes student inquiry and exploration as a process of learning science. Students construct new understanding and develop new skills.

Application of 5E Learning Cycle Model

1. **Engage:** Brainstorming by asking questions (open-ended questions to engage the students in the activity). For example, how can we measure "g"? and which physical quantities do you think can be used to measure "g" in the trajectory of projectile motion?

2. **Explore:** By using the following low-cost materials, students design an activity to measure "g". They will explore how to measure "g" and this activity will be conducted by guidance.

- A small ball or marble (as an object that to be released from the top of a stack of books or paper
- Meter rulers
- Paper or carbon paper (for marking the landing point of the released object)
- A table
- A stop-watch
- A wooden board (smooth surface) to make incline for releasing the ball-the system was used to launch the ball like a ball launcher.

Students should discuss the following questions with their group peers.

a) How do you think you could measure "g" with the trajectory of projectile motion in 2D?

b) How do you think the quantities that you will use might be related to each other?

c) Draw graph (s)

d) Briefly explain your reasoning behind the graph(s).

The following table and figure demonstrate a way of recording data and drawing of the set up for the activity.

Height (h=y) (cm)	X (cm)	Time(t) (s)

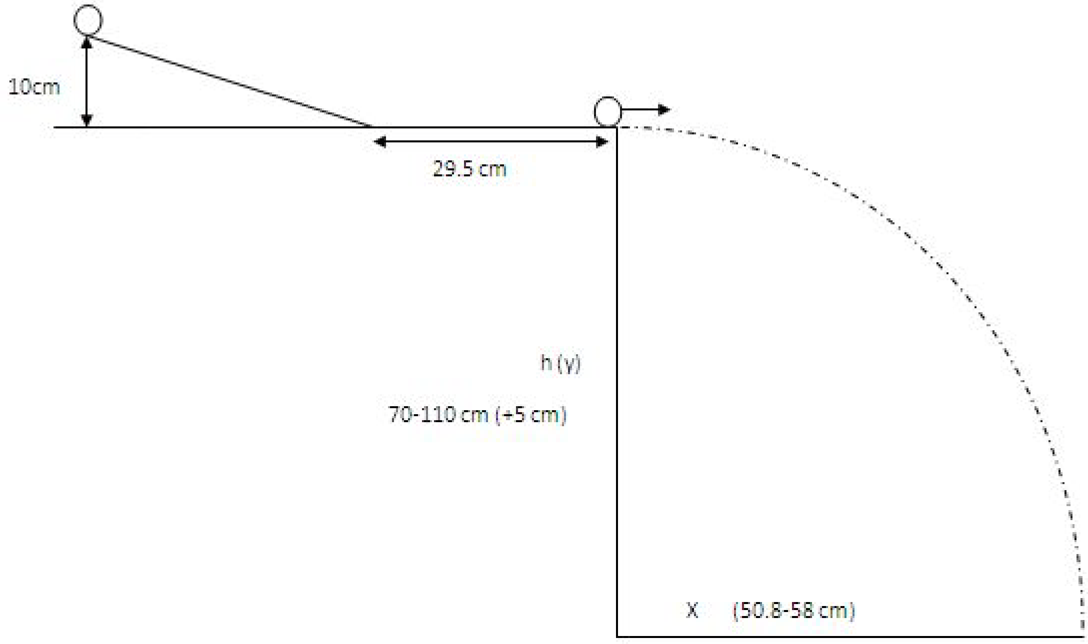

Figure 1: Drawing of the set up for measuring "g"

Figure 2: Pictures taken during the activity for measuring "g" by using trajectory projectile motion in PHYSWARE workshop in Italy, 2009.

Horizontal displacement: $x = vt \Rightarrow t = \frac{x}{v}$

Vertical displacement: $y = \frac{1}{2}gt^2, y = \frac{1}{2}g\left(\frac{x^2}{v^2}\right) = \frac{g}{2v^2}x^2 = \frac{g}{2v^2}x^2$

Slope $S = \frac{g}{2v^2} \Rightarrow g = 2v^2 S$

S: Slope from the y vs. x^2 graph

$g = 2(0.89)^2\, 0.0435 = 8.41 \text{m/s}^2$

3. Explain: Students' observations and methods that they use to measure "g" will be shared. For example,

- What kinds of approximations and simplifications did you make? Why?
- What difficulties did you encounter in conducting this activity?
- Is the value of gravity that you found close to the theoretical value of gravity? If not, what do you think the values you obtained were not the same or closer to the theoretical value of "g"? Please explain.

In this part, students will discuss all factors affecting the results such as air resistance, friction, time measurement error (a stop-watch was used), and distance measurement error.

4. Elaboration/Extension: Students are supposed to apply this concept in other contexts and extend their understanding and skills. This question can be asked. If you do this activity in another country to measure "g", will you get the same value?

5. Evaluation: Students assess their knowledge and skills. They can be asked to conduct another activity to measure "g" in a different way so the activity permits evaluation of student development. For example, students can think about another way to measure "g" and design an activity to conduct to be able to measure "g".

To teach physics, we do not need to purchase "high tech" equipment or specialty materials that are sold through physics supply catalogs. Physics activities or experiments do not need to be very costly in time and resources. Many different valuable activities like the one seen in this paper can be conducted using inexpensive materials such as balls, papers, meter sticks that can be bought from any store or can be provided from the home. The noteworthy thing about these activities students performed is that they are very easily duplicated with common, ordinary household items that can be probably found around schools or homes.