Grade Level: 11	**Subject/Topic: IB DP Physics/ Topic 2.1 Motion**
Lesson Title: Projectile Motion	**Duration: 90 minutes**

Prior Knowledge
A basic understanding of distance, time, velocity and acceleration. Ability to calculate the average velocity of an object traveling a certain distance over a period of time. Familiarity with acceleration due to gravity.

Essential Idea: Motion may be described and analysed by the use of graphs and equations.

Nature of science:
Observations: The ideas of motion are fundamental to many areas of physics, providing a link to the consideration of forces and their implication.

Lesson Overview
In this lesson, students will experiment and use simulation to evaluate projectile motion and the variables that affect how projectiles move.

Content
By the end of this lesson, students will be able to:

- Describe the trajectory of an object in projectile motion
- Determine how far the projectile will travel based on initial conditions
- Contrast the motion of a projectile without air resistance to motion with air resistance.

Educational Standards

Common Core State Standards - Math
Statement Notation CCSS.Math.Content.HSN-Q.A

Description High School — Number and Quantity

Reason quantitatively and use units to solve problems.

Statement Notation CCSS.Math.Content.HSA-REI.B.3

Alt. Statement Notation A.REI.3

Description High School — Algebra

Reasoning with Equations and Inequalities

Solve equations and inequalities in one variable

Solve linear equations and inequalities in one variable, including equations with coefficients represented by letters.

Statement Notation CCSS.Math.Content.HSA-CED.A.4

Alt. Statement Notation A.CED.4

Description High School — Algebra

Creating Equations

Create equations that describe numbers or relationships

Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations.

Materials

10 Pencil/Pen
10 Laptops (with pre-installed Logger Pro software)
5 Vernier computer interface
5 Vernier Projectile Launcher
10 goggles
5 levels
5 plumb bobs
5 small cardboard boxes
5 meter stick or metric measuring tape
5 waxed paper
5 tapes
5 steel balls
5 Time of Flight Pad (optional, but available)
5 Independence of Motion Accessory (optional, but available)

Instructional Resource

Projectile Motion Simulation. (n.d.). Retrieved from https://phet.colorado.edu/sims/projectile-motion/projectile-motion_en.html

Safety

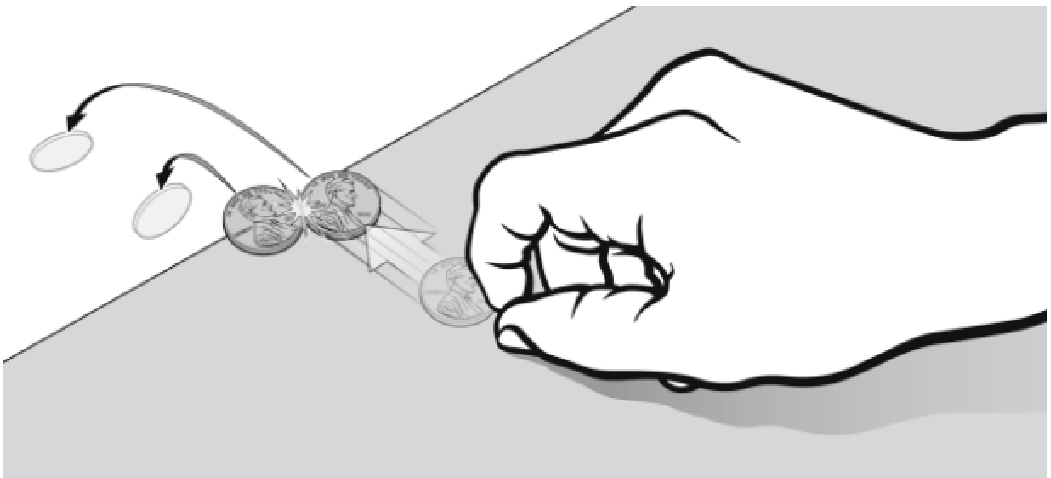
Safety glasses will be worn during the experiment with the steel ball. Before starting the simulation, students will be reminded of the school's technology and safe browsing policy.

Contextual Background

This is a small class that has 4 male students and 1female student. Most students are highly proficient in English. There are no exceptional or special needs students in this class.

Engage (10 minutes)
Level of Inquiry (Discovery Learning)

The teacher will balance one penny on the edge of a table. Place his index finger on a second penny, then flick the second penny so that it travels off the table, while the first penny is gently nudged off the edge.



Then the teacher will ask students to work in pairs to make **predictions** about the following:

- Which penny will land first, the penny moving horizontally, or the one that simply drops off the table. Explain.
- What will happen if you increase the speed of the second penny? Predict.
- What if you increase the height from which the pennies are dropped? What will happen? Predict.

Next, the teacher will ask each student to conduct the experiment to see if their predictions were supported or refuted before engaging them in a brief whole class discussion.

Checkpoint: Students can describe what they just observed.

Explore (Interactive demonstration) (20 minutes)

For this interactive demonstration the teacher will begin the activity by manipulating (demonstrating) how the projectile motion launcher works and how to use it with Logger Pro to collect data.

Vernier Projectile Launcher

The teacher will ask students to wear their goggles before taking them outdoors where Vernier Projectile launchers have been set up for them on tables. The teacher will then ask a guiding question “What is the relationship between the launch angle and the range of the steel ball?” After eliciting responses (predictions), the teacher will choose some launch angles and execute the demonstration while encouraging students to document their observations. The teacher will then solicit further explanations from the students and help them reach conclusions based on the evidence collected.

Students will then be asked to work in small groups of no more than 3 students to make predictions about the following :

- What is the relationship between the landing point of the steel ball and launch speed?
- What is the relationship between the landing point of the steel ball and the launch speed and the launch angle?

After making their predictions, students will be asked to carry out their tests using the experimental set-up and analyze the data that has been collected to discuss the differences between their predicted and actual results.

After the collection of data the teacher will guide students to reflect on their preconceptions, and then confront and resolve any that are identified. The goal during this process will be to model appropriate scientific procedures, and thereby helps students learn implicitly about inquiry processes.

Observe and **Explain (**Some aspect of an inquiry lesson**) (15 minutes)**

Investigation Skills: analyze data to formulate reasonable explanations, use models to represent aspects of the natural world, use appropriate tools to collect, record and analyze information, including computers, identify limitations of models

To further develop the students' proficiency in the process of scientific experimentation an activity will be given which requires the use of a simulation. Students will be asked to visit the following website: https://phet.colorado.edu/en/simulation/projectile-motion

The teacher will then instruct the students to explore how air resistance affects the flight time of a projectile. After students have explored, the teacher explains that the drag coefficient is a measurement of the effect of air resistance on the projectile.

Questions to guide students' learning and thinking	Questions to gather information about students' understanding and learning
• Are the flight times the same or different when air resistance is activated? • Are the times longer or shorter than before when air resistance was deactivated (not on)? • The tank shell has a drag coefficient of 0.05, what effect did air resistance have on its flight time? Try it out! • Would the blue line (no air resistance) exist in real life? Why?	• When air resistance is activated, are the forces on a projectile balanced or unbalanced? What evidence do you have? • Based on your experience, how would you define air resistance? drag coefficient? • If the flight times were the same with the tank shell, what can we conclude about the limitations of our model (the PhET simulation)? • Why do you think it is important for a tank shell to have a low drag

	coefficient?

Teacher defines a projectile as, “an object in the air acted on by the force of gravity” and projectile motion as, “how a projectile moves.”

Elaborate (15 minutes)

Note: The equations listed below are considered the fundamental equations of motion. The combination of these four equations can solve any projectile motion problem, given the correct number of initial conditions.

1. $v_f = v_o + at$
2. $x_f = x_o + v_o t + \frac{1}{2}at^2$
3. $v_f^2 = v_o^2 + 2a(x_f - x_o)$
4. $x_f = x_o + \frac{1}{2}(v_f + v_o)t$

Content Focus: Teacher will explain the mathematical concepts behind projectile motion by engaging in a brief lecture on the equations. By the end of this activity students should be able to accurately defend why certain equations should be used to solve problems related to projectile motion. In addition, students will be asked to explain step by step how to use the equation(s) selected to solve for the value desired. Both students' conceptual understanding and algebraic skills will be important in solving these problems.

Evaluate (20 minutes)

Result of the simulation activity and the completion of the worksheet linked here serves as the evaluation for learning.

Proactive Classroom Management Planning
Students will be familiar with projectile motion lab-set, use of Logger Pro and lab safety procedures.

Closure (10 minutes)
Teacher conducts a ‘cold call’ where he chooses students' names from a hat. This activity serves to summarize the key points of the lesson.

References

IB DP Physics Subject Guide. (2016). Retrieved September 27, 2021, from https://resources.ibo.org/data/d_4_physi_gui_1402_5_e.pdf

McQuerry, G. (2021, April 8). Physics. Retrieved September 27, 2021, from http://sites.isdschools.org/hs_science_remote_learning_resources/useruploads/physics/Wednesday, April 8_Gardner, McQuerry_Physics.pdf

O'Shea, K. (2018, June 30). Model Building. Retrieved from https://kellyoshea.blog/model-building/

Science Resources. (2016, December 12). Retrieved from https://andrewmanningphysicsandengineering.wordpress.com/2016/05/13/science-resources/