Unit 2 – Module 2

SHOOT FOR YOUR GRADE ACTIVITY – calculating the range for projectile motion

RATIONALE

Students should be able to calculate the range of a horizontal projectile from a fixed height, given enough information to determine the height and initial velocity. The students at this point should understand that the x and y motion of a projectile are independent. The horizontal displacement is determined to be constant velocity multiplied by the time of flight (which in this case of the horizontal projectile from a fixed height is the same time as the vertical time of flight). The vertical displacement is determined by accelerating objects due to gravity. In this case, the object has no initial vertical component and is in freefall. The displacement is determined by the formula dy = ½ g t2. Students should be able to realize that if they are able to determine the initial horizontal velocity from a fixed height, that they have enough information to calculate the range, or horizontal displacement of the projectile.

This activity is presented to be performed in groups of 4. The teacher should attempt to balance the groups so that there is a representative range of abilities within each group. The goal is that each group has an adequate chance to draw on their prior knowledge of projectiles both conceptually and mathematically to be successful at this lab, “Shoot for your Grade!” The lab can be modified for different class skill levels by providing greater opportunity for the students to determine what information is required to solve the task based on the skill level of the class. This lab provides an intense experience for students because they recognize that their ability to accurately solve the task will significantly affect their grade. This provides poignancy to this lab that draws out the students’ highest motivation. It is also an opportunity for healthy competition to present itself within the classroom. Students have a strong desire to be successful. In order to reward effort and to ensure good problem solving skills, a large portion of the grade for the lab is based on the group’s demonstration of their problem solving and calculations. Depending on the appropriate skill level of the class, the proportion of the grade that makes up the success level of the calculated range can be determined by the teacher. The students who do not hit the target or who desire a higher grade for the performance part of the lab are required to redo the problem solving and calculation portion of the lab, and must explain the sources of all of their error. The teacher can decide how to incorporate these “retrials” into the group’s grade. Much of the learning is created by the intensity of a “real” life challenge. Lack of initial success should be utilized to encourage greater engagement with the task and the requisite explanation of sources of error and correct solution of the problem.

PRIOR KNOWLEDGE AND SKILLS

* knowledge of motion equations
* ability to manipulate variables to calculate using multiple equations
* understanding that concerning projectiles, horizontal motion and vertical motion can be treated independently
* concerning projectiles, horizontal motion is constant velocity and vertical motion is acceleration
* the time involved for the horizontal and vertical components of motion is the same for a horizontal projectile from a given height
* for a horizontal projectile the height determines the time that the projectile is in the air because there is no initial vertical component of velocity and the vertical component can be treated as free-fall
* the formula for the vertical displacement of free-falling objects with zero initial velocity is dy = ½ g t2
* the formula for the horizontal displacement (the range) of an object is dx = vxt

CE’s AND PE’s

15. Know that the horizontal component of motion of a projectile has constant velocity

16. Know that the vertical component of motion of a projectile is accelerating

* Since this is projectile motion, the acceleration is due to gravity

17. Know the physics conventions for projectile motion problems (no air resistance, uniform gravitational field, flat, level, infinite plane)

18. Know the value of the acceleration and velocity for a projectile at critical points in a projectile’s trajectory, including launch, peak, and impact (no calculations)

* The horizontal component of the velocity does not change, it is constant
* The vertical component of the velocity changes

*19. Combine the aspects of constant velocity in the x direction and accelerated motion in the y direction to solve simple projectile problems when initial vertical velocity is zero*

* *Though the components may be treated independently there is only one object which means that there is only a single time of flight*

PHYSICS CONVENTIONS

* no air resistance
* uniform gravitational field
* flat, level, infinite plane

STUDENT GROUPING

This activity is presented to be performed in groups of 4. The teacher should attempt to balance the groups so that there is a representative range of abilities within each group. The goal is that each group has an adequate chance to draw on their previous knowledge of projectiles both conceptually and mathematically to be successful at this lab. The groups should determine which person will perform each task in the lab. There need to be multiple time keepers (3 helps to average out error) and one student to catch the projectile as it leaves the table. Any of these students can perform the task of measuring the height of the table and the length that the projectile travels across the table.

Each group will collect their data separately (the initial velocity and consequently the range will be changed for each group!). Once all data has been collected, the group will work collectively on their calculation of the range of the projectile. However, each group member will submit their own copy of all tables of measurements, calculations, and conclusions.

MATERIALS

* Long lab table (preferably approx 2 meters long)
* A board to act as the Inclined Plane (preferably about 1 meter long with as smooth a transition to the table top as possible – so that the projectile does not bounce, though a small piece of paper taped to the bottom of the ramp and to the table will mitigate bounces)
* A steel ball preferably approximately 1” in diameter (the projectile)
* Meter sticks
* The “Shoot for you Grade” Target (A target on paper with a small hole at the center, with concentric circles, a bullseye. The first circle should be approx. 4 cm in diameter marked with an “A”, The second concentric circle should be about 8 cm marked “B”, the third concentric circle should be about 16cm marked “C”; the fourth circle should fit on your paper, marked “D” about 24cm; and outside that is marked “Sorry, E- Try Again”, The target should be colorfully marked if possible to encourage excitement at hitting the target, but should allow you to mark where the projectile hits (unless you prefer to place a sticker))
* Masking tape
* Space at end of table for projectile Range and for students to make measurements and for the teacher to position themselves to mark where the projectile lands

TIMELINE (about 100 minutes)

2-3 minutes – lecture, congratulating the class on getting to the point that they are ready to “Shoot for their Grade!” and reminding them of the basic facts about projectiles (if this is necessary). Explain that they will be in the assigned groups of 4, that each team member should have assigned jobs for the lab, and that everyone is responsible to have their own lab and calculations at the end.

10 minutes – Allow the teams to get into their groups. Explain how the lab will work. (The inclined plane is already set up on the lab table with about a meter of horizontal space from the end of the ramp to the edge of the table) The inclined plane is a “black box” literally or figuratively. (The inclined plane enables different initial placement of the projectile for each group, which the teacher marks by group, so that the initial velocity for each group is different but reproducible! Students do not need to be concerned with the incline plane and it could be concealed if this is possible, so that the students only know that each group has a different initial velocity and, consequently,

Range.) The students will have an opportunity to make all of the measurements that they need to determine the initial velocity and the vertical height of the table. Given this information and three practice trials each group will then calculate how far horizontally the projectile will travel in the air (the range of the projectile.) Holding up the target, the teacher indicates that the group will place the center of the target where they have calculated the projectile will land. Hitting the target in the bullseye will result in an “A” for the lab part of the lab and will be averaged with the write-up part of the lab, consisting of the data tables, measurements, calculations, and conclusion based on your results indicating all of the sources of error. If the target is missed all together, or if the students want to shoot for a better grade, the students will complete an entirely new sheet containing all of their new calculations and a new conclusion indicating where their sources of error were, specifically. If time allows, the groups can have an opportunity to recalculate their initial velocity, if that is the source of the error.

Explain the Rules… Each group will have 3 trials to determine the initial velocity of their projectile. The group must make all necessary measurements. The teacher will release the projectile (marking on the inclined plane the location and the name of the group so that the velocity is repeatable). One group member will catch the projectile just after the projectile leaves the table… Don’t let the projectile hit the floor! (If the projectile hits the floor the students will know what the range is! Some negative consequence, such as a zero grade, may be needed to make sure the projectile does not hit the floor.) The other three group members will have stop watches and will determine the time that the projectile takes to cross the horizontal distance from the base of the ramp across the table.

**Information for the teacher**:

Try this activity on your own before the students do it.

The group should have measured this distance so that they can calculate the initial velocity using vx=dx/t with t being the average time of the three trials. The group should record all of their data including the height of the table so that they can calculate the time that the projectile is in the air, using dy = ½ g t2. Solving for t, and realizing that the horizontal time and the vertical time of flight are the same, the group should calculate dx = vxinitial t.

Upon completing their calculations, each group will have one opportunity to place the target. (The group should remember to set the center where they calculated the range to be… the teacher may direct them to consider that they measure the range from the point directly below where the projectile leaves the table.)

A student that is not in the group will be instructed on how to release the projectile from the correct spot for the present group. There must be consistency between this release and the group’s practice releases. The teacher then positions him/herself beside the target, preferable kneeling along the target, so that he/she can mark where the projectile hits the floor (hopefully on the target! – this can be done by directly marking the target or placing a sticker or using a sheet of carbon paper inverted and placed on top of the target to record the point of impact).

With some flourish the teacher asks if the group is sure, then says on the mark, get set, go. The student holding the projectile releases it and the teacher marks the spot where the projectile hits the floor. (Only the distance from the table matters as the projectile may “wander” to the side and this horizontal displacement should not be counted against the group… mark where the projectile hits, but count the grade based on the position perpendicular to the central axis!!! A modified bullseye that is more rectangular may be called for to alleviate some of the lateral error.)

30 minutes – approximately five minutes per group. Allow the students to perform their measurements and collect their data for three trials. Encourage the students, as needed to record all data, create tables, measure accurately and precisely, and to be clear on what they need to measure to complete the task.

(Ideally all groups can get their data in one period)

30 minutes – all the groups should be able to complete their calculations and “Shoot for their Grade!”

10 minutes – any groups that missed the target should have had time to redo their calculations and rewrite their conclusion. This is an opportunity for all groups that need to, to retry placing their target.

(This ends the second period, everyone should have completed the process of “Shooting for their Grade”)

For Homework, the students will complete their formalized lab, with all data charts, calculations, recalculations and thorough conclusions of their lab experience and results. Those groups that required a second trial shot are encouraged to be extra thorough in their write-up as that will potentially compensate for a less than desirable calculation. Explaining the sources of error is extremely important!

The third class – collect the lab reports with calculations

20 minutes – Class discussion about the lab. What was learned and what were the sources of error. How could we perform the lab more accurately? What equipment would make the lab more accurate?

Congratulate the class on completing, “Shoot for your Grade”!

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| **Stage of activity** | **What the students should do** | **Student mistakes** |
| Explanation of Activity | Ask questions to clarify what they need to measure and calculate to complete the task | Not asking questions  Misunderstanding concepts |
| Possible teacher responses:  The teacher needs to determine how much conceptual and mathematical information to provide, that is appropriate to the level of the class. Hopefully before this activity the conceptual basis of projectiles has been reviewed. However, if there are misconceptions, these should be clarified so that the task is clear. | | |
| Determining responsibilities of the group members | Determine all of the necessary duties for the lab and assign roles that can be performed successfully | Missing tasks  Assigning tasks inequitably |
| Possible teacher responses:  Encourage the groups to completely account for all tasks required to complete the lab. Ask guided questions of the lab groups that are not accounting for all the tasks. Indicate to the groups that do not have a balance of tasks that the grade for each member will be based on their participation in the group as well as on the final result and lab write-up. | | |
| Measuring necessary quantities, (ie Length and height of table) | Measure all quantities accurately and precisely | Students may not measure from the proper starting and ending point for the projectile  Students may not measure perpendicular for the height  Students must be precise to get a good result |
| Possible teacher responses:  Encourage students to consider what part of the projectile they need to measure in order to determine the horizontal initial velocity. Also indicate that accuracy is essential for good results and that height is a measurement of perpendicular distance from the floor. The students should be encouraged to measure as precisely as their measuring device will allow to ensure that their calculations will be correct for the range. Errors accumulate. | | |

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| Determining the time elapsed that the projectile is travelling at constant velocity | Students should measure the time that the projectile is travelling at constant velocity… this is the time that it is travelling horizontally across the table. | Students often measure the time including the time coming down the inclined plane, which introduces error  Students don’t always start when the projectile reaches the table or stop when it leaves the table and that this is the same distance that they measured |
| Possible teacher responses:  Make sure to question the students about what they are measuring and to guide them to understanding that they are attempting to calculate the constant velocity of the projectile. Ask them whether the projectile is going at constant velocity when it is travelling down the inclined plane. Ask them what distance they measured and whether this is the same time that they are measuring. Sometimes confusion occurs because there are TWO time quantities that students must keep track of: the time across the table and later the time in flight. | | |
| Number of trials necessary to calculate the average velocity of the projectile | Students should utilize as many stop watches as possible for each trial and complete three good trials recording ALL times. | The students might only designate one time keeper.  The students might not record all the times for all the trials. |
| Possible teacher responses:  Encourage the students to be as accurate and diligent in their scientific method as possible. Time is very difficult to measure accurately and the students should utilize as long of a distance over which the projectile is experiencing constant velocity as possible to determine the horizontal initial velocity as the projectile leaves the table. The students should be encouraged to record ALL times for ALL trials and to include them in their data table. Later if times are determined to be inaccurate they must be explained. | | |
| Calculating the range of the projectile | The groups work together but each student must complete their own calculation with ALL work shown | The students may not understand how to calculate the range  The students may not show all work and not complete their own calculation |
| Possible teacher responses:  The teacher will be working with the groups to get their data but must also be aware of the groups that are working on their calculations. The groups must be encouraged to get all their data while they are collecting projectile data and measurements so that they will be able to complete the task. Repeatedly encourage the groups that are working on their calculations to write up their own calculations and lab report. Hopefully the groups are balanced so that the groups have a balance of abilities and that they can help each other. Encourage the students to be clear about what they are attempting to calculate. Ask the students to consider what the variables of the formulas stand for. Tell the students to consider if their results are reasonable. Double check their calculations and check their units! | | |

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| Shooting for the Grade | One student from the group should place the center of the target at the calculated distance from the point where the projectile leaves the table | The student does not place the target at the center of the bulls-eye  The student does not measure from the perpendicular distance below where the projectile leaves the table |
| Possible teacher responses:  Ask the students where they expect the projectile to land and whether they have placed the center of the target there. Also ask the students where they should measure the starting point from if they are not measuring from the perpendicular spot of the table. | | |
| Re-calculating if necessary | The group should take their measurements and do a new calculation sheet.  If the initial velocity is the problem then the group should repeat the three trials again | The students miss the target but do not want to redo the trial  The students suspect that their initial velocity is wrong but don’t know what to do  The students attempt to simply correct their calculations  The students attempt to calculate their answer based on “knowing the value of the first trial” |
| Possible teacher responses:  All groups that missed the target or that are not satisfied with their grade are required to completely redo their calculation. This should be turned-in in addition to their first trial. The students are strongly encouraged that science is about documentation and that re-calculating their results is a valuable and rewarded pursuit. If the students need more data then they should be encouraged to set up for three more trials, indicating where they made their mistake as a justification for be allowed to retry. The students need to be held accountable that they are working to solve the calculations based on THEIR DATA!!! Make sure that the students are not figuring out their error from merely adjusting their initial results based on where the first trial hit… THIS is CHEATING AND WILL RESULT IN AN E. Encourage the students that despite a bad initial trial that their efforts will be rewarded and that they must be very thorough in explaining their sources of error in their conclusion! | | |

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| Lab Write-Up | Each student should complete an independent and comprehensive lab write-up | Students try to turn in group lab  The students that did well on the first trial attempt to not complete lab-write up  The lab write-ups are not thorough and complete with all work, calculations, and data tables  The conclusions are absent or not thorough |
| Possible teacher responses:  Having built up the suspense of the “Shoot for your Grade” part of the lab, the teacher must now ensure the students that did not do well that they can get a decent grade by turning in a thorough lab report with explanatory conclusion which is completed independently. The students that did very well on the trial part of the lab must be reminded that a large part of the lab grade is the write-up. Everyone must be reminded that this is a Complete Lab-Write Up and that all the parts of the lab write-up must be present!!! | | |

MODIFICATION OF THE ACTIVITY

Instead of measuring the distance and time needed to calculate the constant velocity of the projectile, let the projectile hit the floor as if shooting for the grade. With measurement of the height and distance from the table, the initial horizontal velocity can be calculated. Then take the entire set up and move it to a different initial height for the actual “Shoot for your Grade” activity.

POST ACTIVITY DISCUSSION PROMPTS

Much of the discussion should happen while the activity is taking place, although the final twenty minutes can be utilized to summarize the experience and to attempt to make this semi-competitive experience positive for everyone.

Groups can be asked to present their results and explain how they came to their calculated value. The goal is that everyone understands how to complete the task now that they have completed the lab.

The students should have a discussion about how they went about solving the projectile problem. A discussion about misconceptions and errors that were made should be facilitated. The students should be asked why the trials were repeatable. What role does that inclined plane play in the lab? Why is it important that the table be horizontal? Could we solve the problem if the table was at an angle? If the next unit to be discussed is on Energy, then it is possible to utilize this lab as an introduction into potential and kinetic energy as indicated by the inclined plane.