Research Experiences for Teachers (RET) – 2014
LESSON PLAN

MODULE TOPIC: Kinematics
Sub-Topic: Free Fall and the effects of Gravity
Allied Topic: Using statistics to understand data

OBJECTIVE(S): 1) Understanding the kinematics equations 2) Understanding basic Excel and Statistical analysis

STANDARD(S) & INDICATOR(S):

HS-PS2-1. Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.
CCSS.MATH.CONTENT.HSA.CED.A.1
Create equations and inequalities in one variable and use them to solve problems. Include equations arising from linear and quadratic functions, and simple rational and exponential functions.

MATERIALS:
2 different sized "Hoppers", Meter Stick

LIST OF HANDOUTS (attach original copies of each handout - teacher & student edition)
Hopper Lab (see Attached)

BACKGROUND INFORMATION:
Students will have learned the basic Kinematics equations. Application here will be for understanding applications of Free Fall and the relationship to Gravity.

CLASSROOM ACTIVITY DESCRIPTION (LABORATORY/EXERCISES/PROBLEMS) including detailed procedures:
Using a yard stick, student teams will measure the height attained by 2 different sized "Hopper" toys. Problem solving will include finding a way to measure more than one meter and discovering that gravity is the force that causes the acceleration in Free Fall.

SAMPLE QUESTIONS TO ELICIT CLASS DISCUSSION:
"Devise a method to measure the height for the large hopper; 5 point bonus for the team that gets it."
"Describe the forces that are acting on the Hoppers?"

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HOMEWORK ACTIVITY/EXERCISES/PROBLEMS:
See Attached Worksheet

PARAMETERS TO EVALUATE STUDENT WORK PRODUCTS:

1. **Students will chart data properly.**
2. **Students will understand the concept of using the mean for the equations.**
3. **Students will complete all calculations using the correct Kinematics equations.**
4. **Students will conceptualize that gravity is a constant and acts proportionally to all objects based on their mass.**
5. **Students will use Excel to perform calculations for each trial and the mean of the data and compare the results.**

REFERENCES:

1. **PSI Presentation.**
2. **Excel Help**

ACKNOWLEDGEMENT

This material is based upon work supported by the National Science Foundation under Grant No. 1301071

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Hopper Lab (Guided LT)

PSI Physics

Name:_____________________________________

Problem: The goal of this lab is to determine:

1. the time (t) a hopper is in the air and
2. the initial velocity (v_0) of the hopper.

Materials:

- One large hopper
- One small hopper
- Meter stick

Procedure: Gather your data using the following procedure:

1. Invert the hopper and place it on your lab top.
2. Using a ruler, determine the maximum height the hopper reaches.
3. Repeat this process 5 times for each of your two hoppers.
4. Fill in the chart with your data.

Data:

	Large Hopper Height, Δx	Small Hopper Height, Δx
Trial 1		
Trial 2		
Trial 3		
Trial 4		
Trial 5		
Average Height		

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Equations:

$$v = v_o + at$$
$$x = x_o + v_o t + \frac{1}{2}at^2$$
$$v^2 = v_o^2 + 2a(x - x_o)$$
$$g = -9.8\frac{m}{s^2}$$

Analysis:

1. What is the speed of a hopper when it reaches the highest point of its trajectory?

2. Using the equations above, calculate the initial velocity of each hopper using the average height.

   a. Large hopper b. Small Hopper

3. Find the time each hopper was moving up in the air using the average height.

   a. Large hopper b. Small Hopper

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Interpretation and Application Questions:

1. What is the velocity of the large hopper at the instant before it hits the table? Prove your answer using one of the given kinematics equations (*).

2. A coin was flipped in the air and reached a maximum height of 1.5 meters. What was the initial velocity? How long was the coin in the air? Ignore air resistance.

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Hopper Lab (Teacher Notes)
LT Lab
PSI Physics

Hoppers are plastic toys that pop up or “hop” when inverted and placed on a sturdy surface. Students can measure the peak height of the hopper and use the kinematics equations to determine the initial velocity and the time in the air. They are available from party stores and online volume discounters, like Oriental Trading Company.

Materials:

- One large hopper per group
- One small hopper per group
- One meter stick per group

Timing: (This is a **one period** lab)

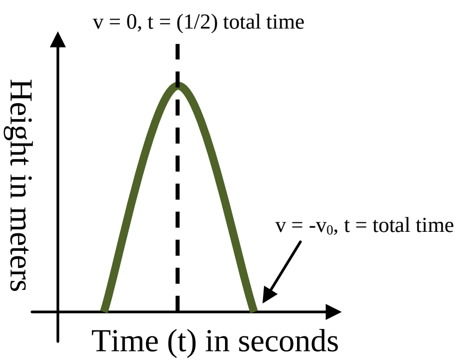
- 5-10 minutes to show and explain the hopper lab presentation
- 10 minutes to collect and record the data
- 15 minutes to analyze data
- 5-10 minutes for class discussion and conclusion

Purpose:

To familiarize students with the practical use of kinematics equations. Given only the height of the hopper, they should be able to determine the maximum height of the hopper and the amount of time that it was in the air.

Anticipated and Sample Results:

During this lab, you can expect the large hopper to jump an average height of 1.4m ± 0.2m, and the small hopper to jump an average height of 0.8m ± 0.3m.



The following graph depicts the time that the hopper is in the air versus the height of the hopper. By the end of the labs, students should be able to explain and recreate this graph.

h	v_0	t_{total}
0.8 m	3.96 m/s	0.81 s
1.1 m	4.64 m/s	0.95 s
1.4 m	5.24 m/s	1.07 s
1.7 m	7.77 m/s	1.59 s

The following chart depicts sample data that should be expected during the experiment.

Presentation and Handout Materials

Smart Notebook class presentation and lab handouts for this lab are available through teacher access to the PSI Algebra-based Physics website in the Kinematics Unit.

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This lab may be either guided or discovery. For the guided lab, use the entire Smart Notebook and provide the lab handout. For discovery labs, use the Smart Notebook only and omit the procedures section.

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Stomp Rocket Laboratory

Name___________________________________ Period________ Date __________

Problem:

The goal of this experiment is to calculate the initial velocity and peak height of a rocket launched vertically, using the kinematics equations learned in class.

Procedure:

1. Go outside and set up the rocket launcher and rocket. Try to have the rocket aiming perfectly straight up.

2. Do a couple of practice launches.

3. When you are ready, you should time the entire flight of the rocket for each person in your group, up to three people.

4. As one student launches the rocket, another student will time the flight with the stopwatch. Remember you need the time from when the rocket is launched to when the rocket returns to the ground.

5. Write down each person's name and their total flight time in the data table on the next page.

Calculations:

Using the kinematics equations for constant acceleration, FIRST perform the following calculations for YOUR launch. Then repeat the calculations for the other two launches. Lastly, add your results to the data table.

<u>Equations:</u>

$g = -9.8\ m/s^2$

$v = v_o + at$

$x = x_o + v_o t + ½ at^2$

$v^2 = v_o^2 + 2a(x-x_o)$

1. **The apex is the peak of the rocket's flight.** Calculate the time it takes the rocket to reach its apex, which is equal to ½ the total flight time. Enter this information in the data table.

2. Make a mini-sketch of the path of the rocket launch and landing.
   - Label the ground level "x_o" and the highest point "x."
   - Next to the x's, write the corresponding symbols for initial and final velocity.
   - What section(s) of your sketch do you think would be represented by t and ½ t? Label t and ½ t.

3. What is the velocity of the rocket at the instant it reaches its apex?

   ____

4. What is the acceleration of the rocket during its flight?

   ____

5. For **your launch**, fill in any values you have for the following variables. Indicate unknowns with a (?).

v_o	
v	
x_o	
x	
a	
$t_{\text{highest point}}$	

6. Taking into account the variables for which you have data, select an equation that could be used to determine the <u>initial launch velocity</u> of the rocket. Write the equation below.

7. Use the equation you chose in #6 to calculate the initial velocity of your launch only.
   - Be sure to recopy the equation and rewrite all the variables you have data for, solve for the initial velocity showing all work. Fill in the initial velocity for your launch in the data table.

8. Now, again taking into account the variables which you now do have data for, what equations could be used to determine the maximum height achieved by the rocket?

9. Use either of the equation you chose in #8 to calculate the maximum height of your rocket. Show ALL work and steps as you did in #7. Enter this information in the data table.

10. Now repeat the above steps for the other two launches in each case, solving for initial velocity (v_o) and maximum height (x).
    - Be sure to use each of the two possible equations for maximum height in order to gain familiarity with each of them. Enter this information in the data table.

Data:

Name	Total Time (seconds)	Time to Apex (seconds)	Initial Velocity (m/s)	Maximum Height (m)

Conclusions:

1. What was the rocket's velocity at the apex of its flight?

2. What is the rocket's speed just before it hits the ground equivalent to?

3. Rank your three launches in terms of lowest to highest initial velocity and lowest to highest maximum height.

(Lowest v_o) ________________ ________________ ________________ (Highest v_o)

(Lowest apex) ________________ __________________ ________________ (Highest apex)

4. What is the relationship between the initial velocity and the apex of the rocket?

5. Explain how you could use this method to calculate the height of fireworks?

ACKNOWLEDGEMENT

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Stomp Rocket Lab (Teacher Notes)
PSI Physics

Objective:
The purpose of this lab is to further familiarize students with kinematics equations. By measuring the time the rocket is in the air, students can determine the initial velocity of the hopper, as well as its maximum height.

Background:
Stomp Rockets are plastic projectiles that are launched when a bladder of air is hit or stomped with a foot. Typically the launch angle can be changed, but should be left at 90^{o} (completely vertical) for this lab. Using stopwatches, students can measure the total amount of time that the rocket is in the air. They can then use the kinematics equations to determine the initial velocity and peak height of the rocket.

Materials:
- One Stomp Rocket Set per group
- Stopwatch

Timing:
The stomp rocket lab is a two period lab. Approximate timing is as follows:
- 5 -10 minutes to show and explain the lab presentation
- time to go outside and return - school dependent
- 10 minutes to collect and record data
- 10-15 minutes to analyze data
- 10-15 minutes for class discussion and conclusion

Anticipated and Sample Results:
From the lightest to heaviest stomps, the rocket can be expected to be in the air from 3.0 ± 0.5 seconds. However, the lightest taps may lead the rocket to be in the air as short as 1.8 seconds.

Sample Answers

Total Time (s)	Time to Apex (s)	Initial Velocity (m/s)	Max Height (m)
2.5 seconds	1.25 seconds	12.25 m/s	7.66 meters
3.0 seconds	1.5 seconds	14.7	11.03 meters
3.5 seconds	1.75 seconds	17.15 m/s	15.01 meters

Presentation and Handout Materials

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