Teach #	Target Audience/recommended course(s) General, Honors, AP, and IB Physics
Teach Date: Length of lesson: __60-90 minutes_________	Title of Lesson: What were you thinking?

Main Idea of the Lesson:

Using Interdisciplinary Studies, the students will observe and enact the concept of propulsion through hands-on activities and analyze the forces acting on an object in motion, both vertically and horizontally.

Next Generation Science Standards for the Lesson:

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.

HS-PS2-2. Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system.

Florida State Standards

SC.912.P.12.2. Analyze the motion of an object in terms of its position, velocity and acceleration as functions of time.

SC.912.P.12.3. Interpret and apply Newton's three laws of motion.

Engagement:

Estimated Time: 3-5 minutes__________

Description of Activity:

What the teacher does:	What the student does:	Possible questions to ask students—*think like a student and consider possible student responses*
1. Show a video clip of a dragster and rocket. Jet Dragster Video: located right under the photos www.fit.edu/stem-poster Orion Launch from Cape Canaveral Air Force Station: https://youtu.be/UEuOpxOrA_0 2. Ask the class probing questions and write their responses on the board.	Observe the video, and then propose answers to the teacher's questions.	What forces are acting on the dragster? What forces are acting on the rocket? How are these forces the same and/or different? *Note: Do not give the students the answers to these questions at this point (wait until the explain section). Simply record their ideas/explanations on the board for further discussion.*

Resources Needed: Internet Access, AV projector, White-board (Chalk-board)

Safety Considerations:

N/A

Exploration:

Estimated Time: 15-30 minutes__________

Overview of Activity:

What the teacher does:

1. Place the students in groups of 3-4 students.
2. Instruct the students that they will be making a balloon "dragster" and guide the students in how to make the initial set-up to complete the experiment.
3. You may want to demonstrate the set-up of the experiment for the students.
4. If time permits, allow the students to make additional modifications to the "dragster", predicting the potential outcome of these modifications, and hypothesizing why the changes in their data occurred.

Each group of students will need:

1-Balloon (long-straight balloons work the best)
1- straw
1- marker
12 feet of string, sewing thread*, or fishing line* (enough for a 10 foot race track)
* = lowest amount of friction
1 yard stick or tape measure
A few pieces of masking or scotch tape
1- stopwatch or timer on cell phone
Various masses (AAA batteries, or dimes work well). The mass should only be a few grams, if it is too heavy it will not travel the full distance.
(Optional: clothespin to pinch balloon opening)

What the student does:

Follow the teacher's guidance to set-up initial experiment.

Part A:

1. Obtain the materials for the experiment.
2. Tie one end of the string to a chair, desk or other support.
3. Insert the other end of the string through the straw.
4. Have one group member pull the string tight horizontally with the ground, and mark the starting and finishing points on the string using the marker and tape measure. The balloon racetrack should be 10 feet in length, leaving room for the balloon dragster and to hold the string.
5. Blow up the balloon to a desired length or circumference and pinch the end. Record this measurement. All trials should use the same length/circumference of the balloon.
6. Have a group member hold the string tight and level. Tape the balloon to the straw with the open end facing your partner and the balloon horizontal to the ground.
7. Position the front of the balloon at the starting line.
8. Be prepared to time the balloon's travel from the starting line to the finish line.
9. The group member pinching the balloon should call out, "Ready, Set, Go" releasing the balloon as the other group member times its travel from start to finish.
10. Record the time it takes the balloon to travel from the start to finish.
11. Blow up the balloon to the same length/circumference as in step 5.
12. Repeat steps 6-10 two more times.

* Please note that "start" is defined when the balloon is released, and "finish" is defined when the balloon runs out of air.

Part B:

13. Record the mass of your "cargo" the balloon dragster will be carrying (Note: if the mass is too large the balloon will not travel the entire distance).
14. Tape the mass (cargo) to the straw.
15. Blow up the balloon to the same length/circumference as in step 5.
16. Repeat Steps 6-11 for three trials. Record the data in the table.

Possible questions to ask students—*think like a student and consider possible student responses*

What is causing the balloon to move across the string?

Why did the balloon stop moving?

How does increasing or decreasing the length/diameter of the balloon effect its travel across the string?

How does changing the mass the balloon is carrying effect its travel across the string?

What forces are acting on the system?

What can be determined with the data we are collecting (eg. velocity, acceleration, momentum, force, thrust)

Explanation: **Estimated Time: 15 minutes**________________

Overview of Activity:

What the teacher does:	What the student does:	Possible questions to ask students – *think like a student and consider possible student responses*
Depending on the level and capabilities of your students the calculations and covered concepts can be modified accordingly. 1. Have the students' average the time it took the balloon to travel in part A and B. 2. Have a member from each group record the time and distance from part A and B on the board for discussion. 3. Have Newton's three laws of motion written on the board. Discuss the first and third laws with the students and have them explain these in terms of their observations in the experiment. 4. Discuss Newton's second law (F=m*a), and ask the students how they could determine the overall force from the data they collected? Then introduce the formulas d = vot + ½ at2, which reduces to a = (2d)/(t2) (d = distance =10 feet, t = time, a = acceleration, vo = initial velocity = 0) 5. Add the following columns to the board: mass (under the mass column add m1 = balloon, tape and straw, m2 = balloon, tape, straw and dime) and acceleration (under the acceleration column a1 = 2d/(t1)2 first trial with no added mass, a2 = 2d/(t2)2 second trial with added mass, etc. Have the students discuss and calculate the average acceleration with and without the added mass and add it to the board. They should notice different accelerations for the trials with and without the added mass caused by the change in time. 6. Have the students calculate the force of their balloon dragster for each of the trials with and without the additional mass. They should notice the force stayed relatively constant (if they kept the balloons the same diameter). Have the students discuss these results and explain them in terms of force, acceleration, and time. The force is provided by propulsion, resulting from gas leaving the balloon. *Additional topics can be discussed such as momentum, thrust, etc.	1. Average their times in Part A and B, and share this information on the board for the class. 2. Discuss Newton's first and third laws of motion. 3. Discuss Newton's second law and have the students determine the average acceleration of the balloon for parts A and B. 4. The students will determine the sum force in parts A and B, and discuss	How is Newton's first law of motion demonstrated in this experiment? If the balloon dragster were allowed to continue across the string, would its velocity remain the same? What is acting on the dragster to cause its velocity to decrease? How is Newton's third law of motion demonstrated in this experiment? What forces are acting on the balloon dragster in order for the motion to occur? What is the difference between speed and velocity? Can we determine the acceleration of the balloon dragster using the data we collected in today's experiment? Is the acceleration the same in part A and B? Why? Is the sum force exerted in part A the same as part B?

Elaboration: **Estimated Time: 20 minutes**__________

Overview of Activity:

What the teacher does:	What the student does:	Possible questions to ask students *– think like a student and consider possible student responses*
*Students often do not understand the difference in the amount of force required for an object to move vertically versus horizontally and the forces that cause this difference. *Additionally the principle of the conservation of linear momentum can also be introduced during this portion of the lesson. It may be best introduced using an analogy, such as "why does a rifle recoil when fired?" Now imagine if a bunch of tiny bullets were fired (gas molecules). Discuss with the students that the sum force exerted by the balloon in the exploration portion of the lesson was the same if the length/circumference of the balloon remained the same. Have the students predict what will occur if the "race track" goes from horizontal to vertical. This section could be completed as a teacher demonstration depending on the constraints of the classroom. 1. Place the students in groups of 3-4 students. 2. Instruct the students that they will be making a balloon "rocket" and guide the students in how to make the initial set-up to complete the experiment. 3. You may want to demonstrate the set-up of the experiment for the students. Have a separate string attached to the ceiling, prior to students entering the lab. 4. If time permits, allow the students to make additional modifications to the "rocket", predicting the potential outcome of these modifications, and hypothesizing why the changes in their data occurred. Each group of students will need: The same materials as used in parts A and B (exploration portion) of the lesson. The only difference is the "racetrack" will be vertical, and the string will need to be attached to the ceiling. *It is recommended to use a new balloon for this part of the lesson	Follow the teacher's guidance to set-up initial experiment. Part C: 1. Obtain the materials for the experiment. 2. Your teacher should have a string attached to the ceiling running down to the floor for each group. 3. Insert the loose end of the string (on the floor) through the straw. 4. Have one group member pull the string tight vertically (careful not to pull too hard), and mark the starting and finishing points on the string using the marker and tape measure. The balloon racetrack should be about 6-8 feet in length, leaving room for the balloon rocket and to hold the string tight. 5. Blow up the balloon to the same length/circumference as you did in the earlier portion of the lesson. All trials should use the same length/circumference of the balloon. 6. Have a group member hold the string tight and level. Tape the balloon to the straw with the open end facing the floor and the balloon vertical to the ground. 7. Position the front of the balloon at the starting line. 8. Be prepared to time the balloon's travel from the starting line to the finish line. 9. The group member pinching the balloon should call out, "Ready, Set, Go" releasing the balloon as the other group member times its travel from start to finish. 10. Record the time it takes the balloon to travel from the start to finish. 11. Blow up the balloon to the same length/circumference as in step 5. 12. Repeat steps 6-10 two more times and record your observations in the data table. Part D: 13. Record the mass of your "cargo" the balloon rocket will be carrying. It should be the same mass as used in the previous part of the lab (Part B). 14. Tape the mass (cargo) to the straw. 15. Blow up the balloon to the same length/circumference as in step 5. 16. Repeat Steps 6-11 for three trials	Will the force and acceleration of the balloon "rocket" be the same as they were for the balloon "dragster"? When you attached the mass to the balloon "rocket" was it able to cross the finish line? What caused the balloon to shoot upwards?

Evaluation:

Estimated Time: 10 min________

Description of Activity:

What the teacher does:	What the student does:	Possible questions to ask students – *think like a student and consider possible student responses*
1. Discuss the results of the parts C and D of the lesson (Elaboration portion). 2. Discuss with the students the change in sum force. "What's wrong with our calculations?" 3. Graphing and Interpretation: Provide the students the sample data, either hard copy or digital file. 4. For homework or as a class activity have the students graph the provided data, examining distance vs. time, velocity vs. time, and acceleration vs. time.	1. Average the time for each of the trials in parts A and B. 2. Calculate the acceleration of the balloon "rocket" with and without the mass. 3. Calculate the sum force of the balloon "rocket" for each part. 4. Graph a) distance vs. time, b) velocity vs. time, and c) acceleration vs. time using the provided data.	Why did it take longer to travel the same distance? What caused the difference in the velocity and acceleration of our rocket? Why was the sum force different in parts C and D? What are we forgetting to calculate in our formula? What relationships exist in each of the three graphs? What do the different points in each of the graphs explain?