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Impulse-Momentum Theorem Lab

AP Physics C – Mechanics

http://www.thephysicsaviary.com/Physics/Programs/Labs/ImpulseLab/

Objective: I can form an expression relating impulse to the change in velocity of an object by calculating the change in momentum of an object given a function of the net force acting on an object over time.

Background: The impulse of an object describes how much an object is being "pushed" or "pulled" and for how long. For a constant net force, the impulse is given to be $\boldsymbol{J} = \boldsymbol{F}\Delta t$. Note that because the force has direction, so too will the impulse. The impulse points in the same direction as the net force acting on the object. For a non-constant net force, the impulse then $\boldsymbol{J} = \int F(t)dt$.

Outer Space is as close to a natural vacuum as we can get. To that end, noting that the acceleration due to gravity is not substantial if you are far away from a celestial body, we can minimize the number of forces acting on an object, giving us a nice situation for investigating impulse and velocity of an object. You will use the simulation in the link above for this lab.

Procedure

Collect data for the force and time that the force is acting for several trials. You will want the force to stop acting on Wally BEFORE he reaches the photogates! You will also need to measure/calculate the velocity of the astronaut. Keep the mass of the astronaut constant for the entire experiment.

Use "Activate" to activate the extinguisher, and "Stop" to stop it. "Reset" resets the experiment (what a surprise!).

Fill out the data table below using *constant* forces. You should have 5 trials. Keep the time that the force acts on Wally constant across all trials. Fill out the 1st row with your variables and units of things you measured and calculated.

Trial	Force (N)	Force Time (s)	Time between photogates (s)	Photogate distance (m)	Calculated Velocity (m/s)
1	115	2.348	2.592	10	3.8580
2	175	2.365	1.691	10	5.9137
3	200	2.32	1.509	10	6.6269
4	85	2.334	3.528	10	2.8345
5	50	2.32	6.034	10	1.6573

Mass of Wally = 70 kg.

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Plot the measured velocity vs. the force. Linearize the graph and relate the slope to your other values written down. Include the graph (or graphs, if needed), trendline, and analysis below.

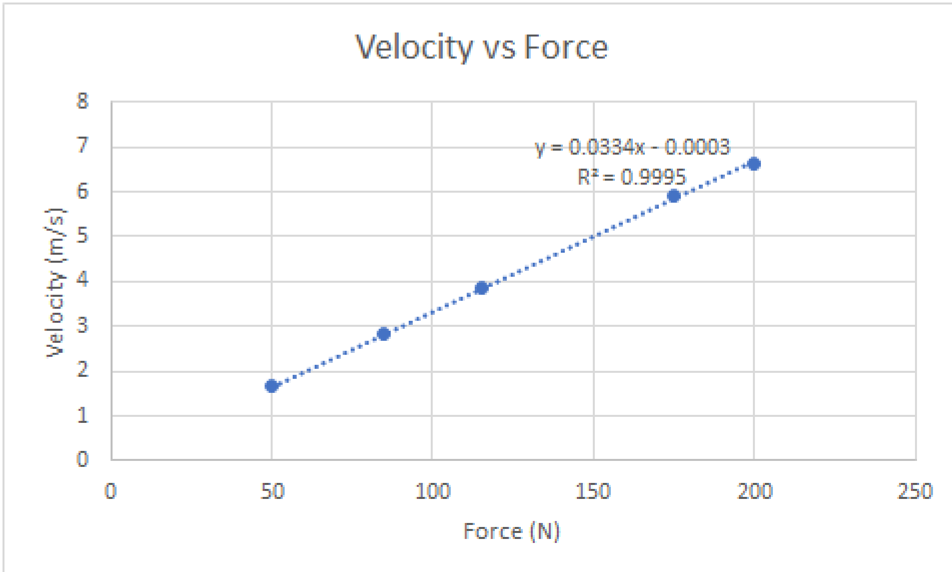

Figure 1: Graph of velocity of Wally as a function of the force

The data necessary to calculate the velocity of Wally was the distance traveled between photogates and the time between photogates. Overall, the graph of the velocity as a function of the force applied to Wally is a linear relationship. The slope of the graph comes out to be 0.0334, which is around the same as the time that the force was applied divided by the mass of Wally. This result agrees with the theoretical expectation, since from Newton's second law, we can find the impulse momentum theorem, which states that $F \cdot \Delta t = m \cdot v$, so $v = \frac{\Delta t}{m} \cdot F$. From our collected data, this slope comes out to be close to 0.0334, suggesting that our data is correct.

A possible source of error in this experiment is that since the force must be manually stopped, it was nearly impossible to stop the force at the same time between trials. This led to different amounts of time that things were run, which affects the calculated velocity. Another potential source of error could be that the numbers in the data collected are only accurate to four significant figures, which could lead to rounding errors in the process. To minimize such errors, we can conduct more trials. When compared to a real-world situation, one assumption made in this experiment was that Wally was not under the influence of any forces other than the fire extinguisher, making our results have less error than if the same lab was conducted in the real world.

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Post Lab Questions:

1. How does the velocity relate to the force? Does this match your expectations? Why or why not?
   The slope was equal to mass over force time. Yes, it does relate to the expectation. The impulse momentum theorem says that $F \cdot \Delta t = m \cdot v$, so $v = \frac{\Delta t}{m} \cdot F$
2. Name 2 sources of error in this laboratory from the simulation/measurements alone.

   First, you had to manually stop the force after a specific time, so it was hard to stop it at the exact time every time. This led to different amounts of time that things were run.

   Another source of error is that the numbers are only accurate to four significant figures, which could lead to things like rounding errors in the process.

3. Name 1 assumption that we made about Wally that is not true in the real world! Would this cause significant error?
   We assumed that Wally was not under the influence of any forces other than the fire extinguisher, which isn’t true because, even in space, things like gravity exist which could pull Wally in different directions. This likely would cause significant error unless Wally is very far away from any planets and was not under the influence of any other forces.
4. Newton’s 3rd law says that every force has an equal and opposite force. What is the equal and opposite force to the one used in the experiment?
   As the fire extinguisher pushes gas out to the right, the force used to push that gas is exerted back on the fire extinguisher, which is connected to Wally. This force pushes Wally to the left with the same magnitude and acts as the main force for this experiment.
5. Consider your results from this lab as well as your answer for Question 4. Which of Newton’s Three Laws, if any, are important for understanding the relation between velocity and force that you found (Hint: using your data, can you rearrange your trendline equation and graph to represent one or more of Newton’s Three Laws?)?

   Newton's second law states that $F = ma$. We can rewrite this as $F = m \cdot \frac{v}{\Delta t}$. If we multiply both sides by Δt, we get $F \cdot \Delta t = mv$. This is the impulse momentum theorem mentioned in question 1, and is the important relation between velocity and force, as the mass is held constant.