Impulse

Directions and Suggestions for Teacher

Purpose:

This lab is designed to show students the connection between force, time and change in momentum. Students will be able to change the time over which a force is applied and then see how that affects the change in momentum of the object. Once they have their graphs they will use the graph(s) to create a mathematical model and then use the model to make predictions.

Virtual Part:

(https://www.thephysicsaviary.com/Physics/Programs/Labs/ImpulseWithPredictionLab/)

This lab doesn't really translate well to any time of live activity and thus you should plan on doing this during a single forty minute period or have students work on this at home and then discuss it with them in class the next day.

Measuring Time of Fire:

The time of fire is simply the amount of time the force is being applied to the astronaut. That is, how long the fire extinguisher is being fired. There will be an analog meter that will show this time to the students. Make sure the firing stops before the astronaut moves through the photogates that start at the 70-meter line.

Determining Speed:

Students will wait until the astronaut has passed through both gates and then they will record the gate time. Diving the distance between the gates (10 m) by the time will give them the speed of the astronaut after the firing has been completed.

Determining Momentum:

Once they have the speed of the astronaut, they can multiply by the mass of the astronaut to determine the momentum. Since the astronaut started at rest, the momentum after firing is the same as the change in momentum of the astronaut.

Working Through the Lab:

Although there are technically an infinite number of different firing times that are possible in the virtual program, students need not do all levels. I would not suggest less than 5 levels as it is a good practice to collect more data to have greater confidence in your results. The program will randomize the astronaut's mass and the force created by the fire extinguisher, so all students will get different results. Students should not refresh the website while working or it will generate new values and thus make all the old data irrelevant. Below is a sample of what potential data might look like.

Data:

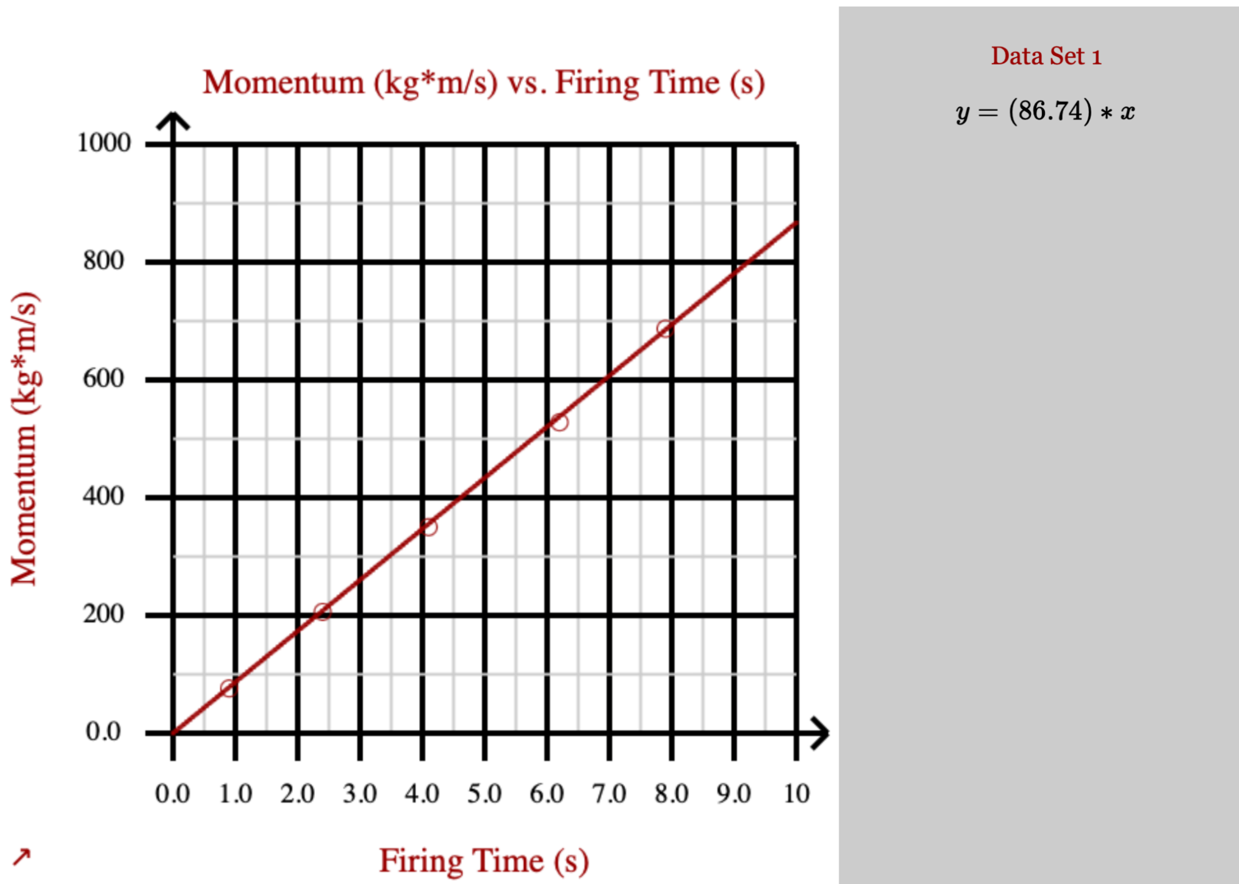
Firing Time (s)	Gate Time (s)	Speed (m/s)	Momentum (kg*m/s)
0.90	8.143	1.23	76.4
2.4	3.016	3.32	206
4.1	1.779	5.62	350
6.2	1.179	8.48	528
7.9	0.905	11.05	687

Graphing Data:

(https://www.thephysicsaviary.com/Physics/Programs/Tools/Graphing/)

Once students have finished collecting data, they should graph it and find a relationship between the variables. The firing time (s) is the independent variable and should be placed on the x-axis and the momentum of the astronaut (kg*m/s) should be on the y-axis. This graph should come out to be a proportional graph.

I prefer always having the students transfer their graph onto their lab sheet by hand.



Equation:

For this graph students get a proportional relationship between the variables. This indicates to them that a larger firing time will correspond to a larger change in momentum. Doubling the firing time will result in a doubling of the final momentum of the astronaut, which again, is the same as the change in momentum of the astronaut.

The equation for a proportional relationship is given below.

$$y = (\text{slope})(x)$$

We want to continue to emphasize to them the idea that each of these letters has real physical significance. Looking at the axes, they should see that the y is the change in momentum of the astronaut in kg*m/s and the x is the firing time in seconds. So the equation becomes:

$$\Delta p = (\text{slope})(t)$$

We then want students to think about the significance of the slope. We can prompt them what could have changed about the situation that would have given us different results. Hopefully students will realize that the strength of the fire extinguisher is the thing we could have changed that would have given us different momentums even if we had fired the extinguisher for exactly the same amount of time. The slope turns out to be equal to the force generated by the extinguisher and the final equation is

$$\Delta p = F \bullet t$$

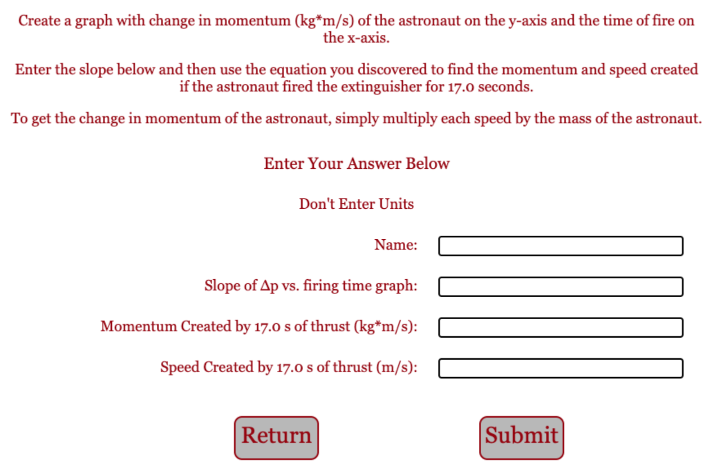
Where F•t is called impulse

$$\Delta p = \text{Impulse}$$

Checking their work:

Once the students have reached the point where they have graphed and created an equation, they will then be able to check their work. They should simply hit “Finished” on the program to be brought to a form they can fill out to see if they did everything correctly. Remind students that they all will be getting different answers and that they shouldn’t worry if their answers differ from those of their classmates.

They will be entering their slopes for their proportional graphs. They will then use their equation to make predictions for information for which they didn’t collect data. Once they have predicted the momentum for the randomly generated firing time, they divide that by the mass of the astronaut to get the speed of the astronaut through the gates.


Create a graph with change in momentum (kg*m/s) of the astronaut on the y-axis and the time of fire on the x-axis.

Enter the slope below and then use the equation you discovered to find the momentum and speed created if the astronaut fired the extinguisher for 17.0 seconds.

To get the change in momentum of the astronaut, simply multiply each speed by the mass of the astronaut.

Enter Your Answer Below

Don't Enter Units

Name:

Slope of Δp vs. firing time graph:

Momentum Created by 17.0 s of thrust (kg*m/s):

Speed Created by 17.0 s of thrust (m/s):

Return

Submit

I would normally offer a small amount of extra credit added to the lab grade if they get all their answers correct. I would have them show me their completion certificate so I could record that they earned the extra credit. If a student doesn’t get everything correct, you can have them redo the lab by refreshing their page if time permits.

Live Part:

Although I usually try to do a live part for every lab that I conduct, this one is not easy to do in a live setting. However, if you want to get the students actively involved in collecting data, we can have them calculate the momentum of different objects.

momentum = (mass)(velocity)

You can then get creative and have the students mass different objects and then time them moving through different distances to get their momentums. You can have them do almost anything at this point, but I give a few suggestions below.

1. **People:**
    a. Set up two traffic cones 10 meters apart and have the students time each other as they run through that distance.
    b. Allow the students a space ahead of the cones to accelerate to top speed before hitting the first cone.
    c. Most students can estimate their weight in pounds and then convert to kg.
    d. If you have access to a scale you can have the students optionally get their weight and then their mass.
2. **Toy Cars:**
    a. If you don't have time to go out and get the momentums of the students as they run, you can set up a start and finish line in the class room for toy cars to move through.
    b. Use a scale for students to get the mass of the cars.
    c. You can use whichever tools are most convenient for getting the time it takes the cars to move from start to finish lines.
3. **Pre Recorded Videos**
    a. If you have no time for live data collection, you can have pre-recorded videos or videos from YouTube that students can use to get the momentums of objects.
    b. You can use videos of track and field athletes or race cars. Students can look up the mass of the individual athlete or the type of car being shown in the video.

Conclusion:

I personally like to have students write out a conclusion by hand after they are done with the entire lab (live part and virtual part). Some things you can have students include in the conclusion.

1. **Restatement of the purpose.**
    a. This is a great way to open the conclusion
    b. It helps to reinforce the reason we were doing the lab.
2. **Brief Summary of the steps**
    a. I don't want too much here but I do want students to transition from the purpose to the results with a sentence or two summary of the steps.
    b. This part of the conclusion should paint with a very broad brush what type of data we were collecting and what remained constant when collecting data.
3. **Results**
    a. I want students to clearly state what type of relationship existed between the two variables we were examining.
    b. I want them to clearly explain what this means in simple to understand terms.
    c. Basically, they will be making sense of the equation they have discovered in the lab.
4. **Error**
    a. They should talk about their percentage of error from the lab (you can have them do this for the live part or the virtual part or both).
    b. They should brainstorm at least one possible source of that error and how it can be minimized if they redid the lab.
5. **Limitations to the model**
    a. Whenever possible I want them to think about when the mathematical model for the lab would break down and no longer apply.
    b. For instance, with this lab, the equation relating Δp to time will only hold true if we can keep the force constant for the entire time it is being applied to the object. There are many examples where the impulse on an object occurs with a time varying force and students at this level of mathematics are going to struggle with the math required to successfully predict the change in momentum. You can give them a preview of this idea so they are ready for it in future physics classes.

Going Further

If you have the time, you could challenge the students with the following types of things.

1. You could ask the students to try sketching out another line on their graph that shows how things would change if the fire extinguisher had generated a greater force. They should do this in a different color than the original line.

2. Having students calculate the momentums of some familiar objects will help them establish reference points for future calculations. Most students have no previous knowledge of momentum so making them complete a table like the one below might be helpful going forward. You can prefill some of the boxes or have students look up values online.

Object	Typical Mass (kg)	Typical Speed (mph)	Typical Speed (m/s)	Momentum (kg*m/s)
Fastball in MLB				
Bowling Ball from professional bowler				
NASCAR				
Top Olympic Sprinter				