

# LAB 17

## Lab Handout

### Lab 17. Impulse and Momentum: How Does Changing the Magnitude and Duration of a Force Acting on an Object Affect the Momentum of That Object?

#### Introduction

Forces are responsible for all changes in motion and momentum. Regardless of how quickly a force is applied, it can still change the motion of an object. Consider what happens when someone hits a ball with a bat. The time that the bat and ball are in contact is very short, but the force from this collision is strong enough to significantly change the motion of a ball. The force that results from a bat hitting a ball can even be strong enough to change the shape of the ball (see Figure L17.1) or the bat (see Figure L17.2).

**FIGURE L17.1**

A ball deforming from the force that results from the collision of the bat and the ball



**FIGURE L17.2**

The bat breaking from the force that results from the collision of the bat and the ball



*Momentum* is defined as the mass of an object multiplied by its velocity. Momentum is a vector quantity because it has both a magnitude and a direction. As a result, the momentum of an object can be positive or negative, depending on the direction an object is moving. Force is also a vector quantity because forces have both a magnitude and a direction. When an unbalanced force acts on an object, the momentum of that object will change. In other words, an unbalanced force will change the momentum of an object.

### *How Does Changing the Magnitude and Duration of a Force Acting on an Object Affect the Momentum of That Object?*

The amount of time that an unbalanced force acts on an object is also important to consider when examining the change in momentum of an object. Sometimes the amount of time a force is applied to an object is very short, such as when a bat hits a ball, and other times it is applied over long periods, such as when the thrusters attached to a satellite are fired for several minutes to launch that satellite into orbit. The term *impulse* is used to describe the product of the magnitude and the duration of a force that acts on an object. In this investigation you will have an opportunity to examine how the nature of an impulse can change the momentum of a cart moving in one dimension. Your goal is to create a conceptual model that you can use to explain how the magnitude and duration of a force affects the change in momentum of a cart.

### Your Task

Use what you know about momentum, impulse, the movement of matter within a system, and scale, proportional relationships, and quantity to develop a conceptual model that will enable you to explain how the momentum of an object will change in response to an impulse. To develop this conceptual model, you will need to design and carry out two different experiments to determine how (a) the magnitude of a force affects the momentum of an object and (b) the duration of a force affects the momentum of an object. Once you have developed your model, you will need to test it to determine if allows you to make accurate predictions about the change of momentum of an object over time in response to different types of impulse.

The guiding question of this investigation is, *How does changing the magnitude and the duration of a force acting on an object affect the momentum of that object?*

### Materials

You may use any of the following materials during your investigation (some items may not be available):

- Safety glasses or goggles (required)
- Dynamics cart with fan attachment
- Dynamics track
- Motion detector/sensor and interface
- Video camera
- Computer or tablet with data collection and analysis software and/or video analysis software
- Electronic or triple beam balance
- Stopwatch
- Meterstick or ruler

### Safety Precautions

Follow all normal lab safety rules. In addition, take the following safety precautions:

1. Wear sanitized safety glasses or goggles during lab setup, hands-on activity, and takedown.

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2. Keep fingers and toes out of the way of the moving objects.
3. Wash hands with soap and water after completing the lab.

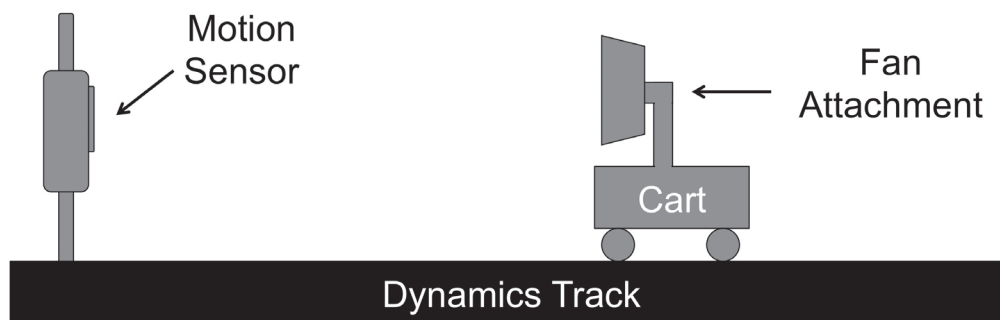
Investigation Proposal Required?  Yes  No

## Getting Started

The first step in developing your conceptual model is to design and carry out two experiments. In the first experiment, you will need to determine how changing the magnitude of a force will affect the momentum of a cart. In the second experiment, you will need to determine how changing the duration of the force affects the momentum of a cart. Figure L17.3 illustrates how you can use the available equipment to study the momentum of cart moving in one dimension. Before you can design your experiments, however, you must determine what type of data you need to collect, how you will collect it, and how you will analyze it.

**FIGURE L17.3**

One way to study the change in momentum of an object



To determine *what type of data you need to collect*, think about the following questions:

- What are the boundaries and components of the system you are studying?
- How do components of the system under study interact?
- How will you track the movement of matter within this system?
- How could you keep track of changes in this system quantitatively?
- What factors affects the momentum of an object?
- How will you determine the velocity of each object?
- What will be the independent variable and the dependent variable for each experiment?

### *How Does Changing the Magnitude and Duration of a Force Acting on an Object Affect the Momentum of That Object?*

To determine *how you will collect the data*, think about the following questions:

- What other factors will you need to control or measure during each experiment?
- Which quantities are vectors, and which quantities are scalars?
- For any vector quantities, which directions are positive and which directions are negative?
- What scale or scales should you use when you take your measurements?
- What equipment will you need to collect the measurements you need?
- How will you make sure that your data are of high quality (i.e., how will you reduce error)?
- How will you keep track of and organize the data you collect?

To determine *how you will analyze the data*, think about the following questions:

- What type of calculations will you need to do?
- What types of patterns might you look for as you analyze your data?
- Are there any proportional relationships you can identify?
- What types of comparisons will be useful to make?
- What type of table or graph could you create to help make sense of your data?

Once you have determined how the magnitude of a force and the duration of a force affect the momentum of a cart in one dimension, your group will need to develop a conceptual model. Your model must include the various forces acting on the cart and allow you to make accurate predictions about how the momentum of cart changes over time in response to different forces.

The last step in this investigation will be to test your model. To accomplish this goal, you can apply different impulses (ones that you did not test) to the cart to determine if your model enables you to make accurate predictions about how the momentum of the cart changes over time. If you are able to use your model to make accurate predictions, then you will be able to generate the evidence you need to convince others that your model is a valid and acceptable. The fan attached to the cart you will use in this investigation may have a limited number of different speeds, so it will be important to reserve at least one speed setting for this step of your investigation.

### **Connections to the Nature of Scientific Knowledge and Scientific Inquiry**

As you work through your investigation, you may want to consider

- the difference between laws and theories in science, and
- the difference between data and evidence in science.

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## Initial Argument

Once your group has finished collecting and analyzing your data, your group will need to develop an initial argument. Your initial argument needs to include a claim, evidence to support your claim, and a justification of the evidence. The *claim* is your group's answer to the guiding question. The *evidence* is an analysis and interpretation of your data. Finally, the *justification* of the evidence is why your group thinks the evidence matters. The justification of the evidence is important because scientists can use different kinds of evidence to support their claims. Your group will create your initial argument on a whiteboard. Your whiteboard should include all the information shown in Figure L17.4.

**FIGURE L17.4**

**Argument presentation on a whiteboard**

The Guiding Question:	
Our Claim:	
Our Evidence:	Our Justification of the Evidence:

## Argumentation Session

The argumentation session allows all of the groups to share their arguments. One or two members of each group will stay at the lab station to share that group's argument, while the other members of the group go to the other lab stations to listen to and critique the other arguments. This is similar to what scientists do when they propose, support, evaluate, and refine new ideas during a poster session at a conference. If you are presenting your group's argument, your goal is to share your ideas and answer questions. You should also keep a record of the critiques and suggestions made by your classmates so you can use this feedback to make your initial argument stronger. You can keep track of specific critiques and suggestions for improvement that your classmates mention in the space below.

*Critiques about our initial argument and suggestions for improvement:*

### *How Does Changing the Magnitude and Duration of a Force Acting on an Object Affect the Momentum of That Object?*

If you are critiquing your classmates' arguments, your goal is to look for mistakes in their arguments and offer suggestions for improvement so these mistakes can be fixed. You should look for ways to make your initial argument stronger by looking for things that the other groups did well. You can keep track of interesting ideas that you see and hear during the argumentation in the space below. You can also use this space to keep track of any questions that you will need to discuss with your team.

*Interesting ideas from other groups or questions to take back to my group:*

Once the argumentation session is complete, you will have a chance to meet with your group and revise your initial argument. Your group might need to gather more data or design a way to test one or more alternative claims as part of this process. Remember, your goal at this stage of the investigation is to develop the best argument possible.

### **Report**

Once you have completed your research, you will need to prepare an *investigation report* that consists of three sections. Each section should provide an answer to the following questions:

1. What question were you trying to answer and why?
2. What did you do to answer your question and why?
3. What is your argument?

Your report should answer these questions in two pages or less. This report must be typed, and any diagrams, figures, or tables should be embedded into the document. Be sure to write in a persuasive style; you are trying to convince others that your claim is acceptable or valid!