LAB 1

Lab Handout

Lab 1. Acceleration and Velocity: How Does the Direction of Acceleration Affect the Velocity of an Object?

Introduction

The ability to describe motion is the basis of much of physics. To explain why objects move the way they do, we must first be able to describe how an object moves. *Velocity* and *acceleration* are terms often used to describe motion. These two terms, however, have different meanings in science. The rate of change in an object's position is called its velocity. An object's velocity describes how fast it travels and its direction of motion. The rate of change of velocity is called acceleration. Like position, velocity and acceleration are vector quantities with a magnitude (i.e., how much) and a direction (i.e., which way). Choosing a frame of reference when you study an object's motion is up to you. Your reference frame will specify which direction is the positive direction and which one is negative.

Graphs that show a change in position of an object over time (called a position vs. time graph) and the change in velocity of an object over time (called a velocity vs. time graph) can help us describe the motion of an object. On these types of graphs, the rate of change for the object of interest corresponds to the slope of the line. For example, the slope of the line on a position vs. time graph at a specific time is the velocity of an object at that time, because velocity is the rate of change of an object's position with respect to time. For a graph with a curved line, such as those shown in Figures L1.1 and L1.2, the slope of the line at a given point in time on the graph is defined as the slope of the tangent line to the curve at that specific point.

Not all rates of change remain constant, however. For example, it is possible for an object to increase or decrease in velocity. We can also represent this change on a motion graph. If the slope of the tangent line gets steeper or gets less steep downward as time increases, this is called a "concave up" graph (see Figure L1.1). A concave up position versus time graph indicates that an object's velocity is increasing over time. When

FIGURE L1.1

A concave up position vs. time graph indicates that the velocity of an object is increasing.

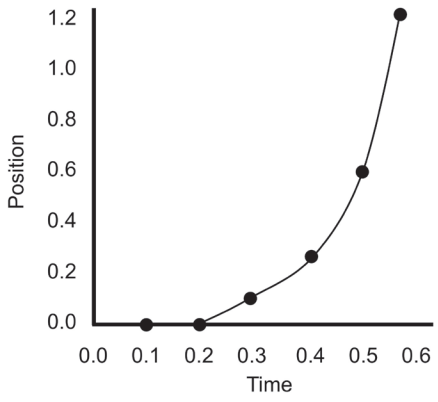
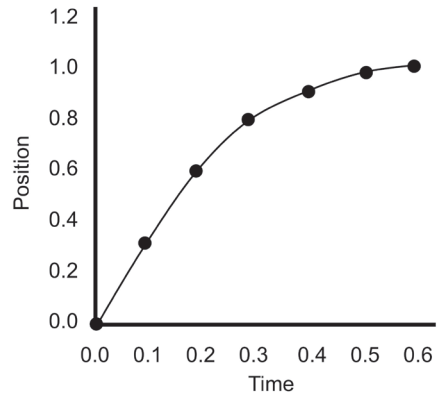


FIGURE L1.2

A concave down position vs. time graph indicates that the velocity of an object is decreasing.



the slopes of the tangent lines decrease, in contrast, it is called a "concave down" graph. A concave down position versus time graph can either be getting less steep upward or becoming more steep downward (see Figure L1.2). Either way, a concave down position versus time graph indicates that the velocity of the object is decreasing over time.

Physicists use the term acceleration to describe any change in the velocity of an object. The acceleration of an object can be either positive or negative. The direction of that acceleration, however, is important because it may cause an object's velocity to change differently. In this investigation you will have an opportunity to explore the motion of a cart on a track in order to explain how the movement of that cart changes when it accelerates in different directions.

Your Task

You will observe the motion of a cart and then use what you know about vectors and graphs, patterns, and scale, proportion, and quantity to determine a mathematical relationship between velocity and acceleration.

The guiding question of this investigation is, ***How does the direction of acceleration affect the velocity of an object?***

Materials

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

- Safety glasses or goggles (required)
- Cart with fan attachment
- Track for cart
- Video camera
- Motion detector/sensor and interface
- Computer or tablet with data collection and analysis software and/or video analysis software
- Meterstick

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.
2. Keep fingers and toes out of the way of moving objects.
3. Do not place fingers into the fan.
4. Keep hair, clothing, and jewelry away from the cart while the fan attachment is switched on.
5. Wash hands with soap and water after completing the lab.

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Investigation Proposal Required? ☐ Yes ☐ No

Getting Started

To answer the guiding question, you will need to design and carry out an experiment using a fan cart and a track. The cart can be placed on the track so it will only move in two directions (i.e., left or right). You can use the fan to apply a force to the cart so it will accelerate in different directions. You have two options for tracking the motion of the cart on the track. The first option is to use a motion detector/sensor attached to the end of the track. The motion detector/sensor will allow you to record the exact position of the cart on the track at a given point in time and how the position of the cart relative to the motion detector/sensor changes on the track over time. Figure L1.3 shows how you can set up the equipment for this investigation if you use a motion detector/sensor to track the motion of the cart. The second option for tracking the motion of a cart is to use video analysis software. In this case, you will need to use a video camera and a meterstick. Place the meterstick in front of the track and then video record the cart as it moves. You can then upload the video to a computer or tablet and use video analysis software to examine the motion of the cart. The meterstick is important because it will provide a reference point in the video so you can measure the cart's displacement over time. Figure L.1.4 shows how you can set up the equipment for this investigation if you decide to use video analysis software to track the motion of the cart.

FIGURE L1.3

How to examine the motion of a cart using a motion sensor

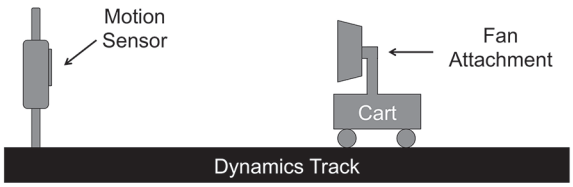
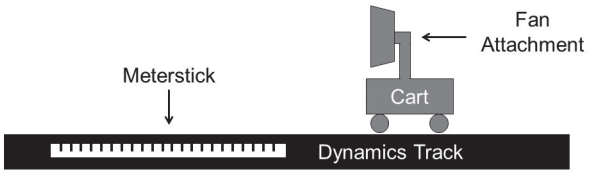


FIGURE L1.4

How to examine the motion of a cart using a video camera



Before you can begin to design an experiment using this equipment, however, you will need to determine what type of data you need to collect, how you will collect it, and how you will analyze it. 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?
- Which factor(s) might control the rate of change in this system?
- How could you keep track of changes in this system quantitatively?

- What information do you need to determine the cart's velocity and acceleration?
- What will be the reference frame?
- Are your variables vector quantities or scalar quantities?

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

- How will you change the direction of acceleration?
- What comparisons will you need to make?
- What measurement scale or scales should you use to collect data?
- How will you make sure that your data are of high quality (i.e., how will you reduce error)?
- For any vector quantities, which directions are positive and which directions are negative?

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

- How will you identify both the magnitude and direction of the vector quantities?
- What type of calculations will you need to make?
- How could you use mathematics to describe a change over time?
- How could you use mathematics to describe a relationship between variables?
- What types of patterns could you look for in your data?

Connections to the Nature of Scientific Knowledge and Scientific Inquiry

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

- the difference between observations and inferences in science, and
- the nature and role of experiments in science.

Initial Argument

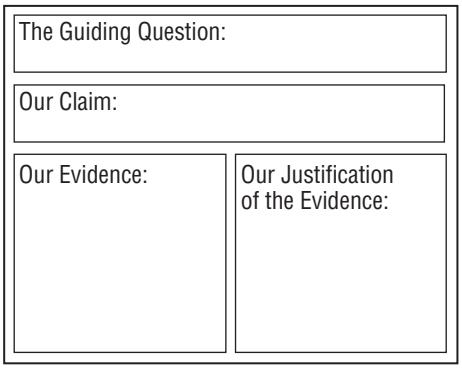
Once your group has finished collecting and analyzing your data, your group will need to develop an initial argument. Your initial argument needs to include a claim, evidence supporting your claim, and a justification of the evidence. The claim is your group's answer to the guiding question. The evidence 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 L1.5 (p. 46).

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.

FIGURE L1.5

Argument presentation on a whiteboard



Critiques about our initial argument and suggestions for improvement:

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!