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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.

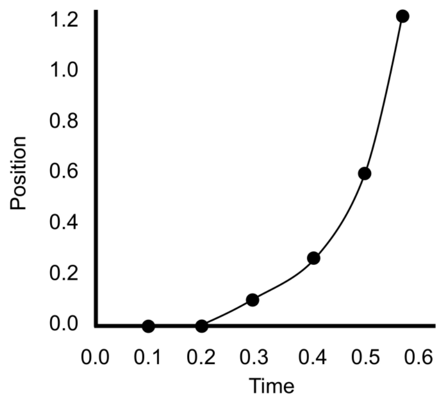
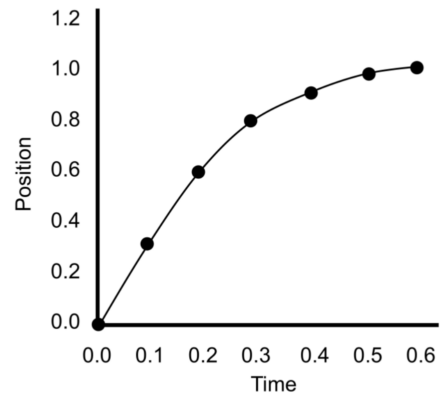


FIGURE L1.2

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.

Lab Handout

Lab 13. Simple Harmonic Motion and Pendulums: What Variables Affect the Period of a Pendulum?

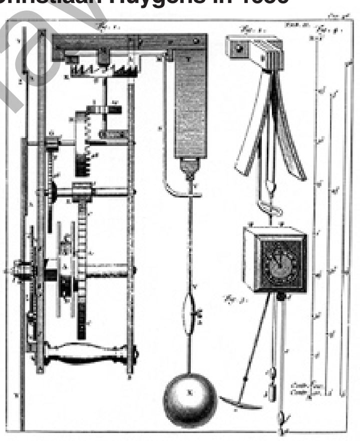
Introduction

A pendulum, which is a mass swinging at the end of a rope, has a wide range of uses in our daily lives. One of the most frequent uses of a pendulum is in a clock. Christiaan Huygens built the first pendulum clock in 1656 (see Figure L13.1 and version available at *www.nsta.org/adi-physics1*), and his use of a pendulum to keep accurate time was considered a breakthrough in clock design. Pendulums can also be found as parts of amusement park rides, in religious ceremonies, and in tools that help musicians keep a beat. Most school-age children are also familiar with pendulums, because playground swings are just a pendulum with a person at one end.

Pendulums are part of a class of objects that undergo simple harmonic motion; such objects are called oscillators. Harmonic oscillators are objects that move about a point called the equilibrium position (see Figure L13.2). When a pendulum is not moving, the bob will rest (or hang motionless) at the equilibrium position. When an outside force moves the bob from its equilibrium position, a restoring force causes the object to move back toward its equilibrium position. This process is then repeated multiple times as the bob swings back and forth. This motion is referred to as *simple,* because after the initial force to move the bob from equilibrium, the only forces acting on the bob are the restoring force and the tension in the string. Other types of harmonic motion are called *damped,* when friction slows down the motion, or *driven,* when an outside force is repeatedly exerted on the oscillator. There

FIGURE L13.1

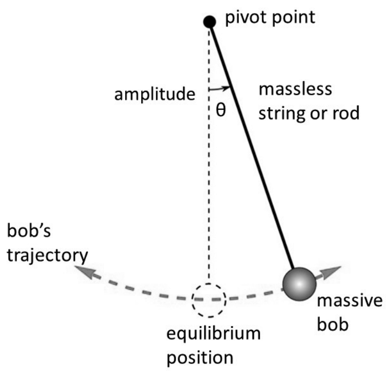
The original pendulum clock built by Christiaan Huygens in 1656



Note: This image is best viewed on the book's Extras page at *www.nsta.org/adi-physics1*.

FIGURE L13.2

The components of a pendulum



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are many ways to describe the motion of a bob. The most frequent is the period (*T*), which is how long it takes a bob to make one full swing back and forth.

For most pendulums, the period does not change from one swing to the next. This makes the pendulum a particularly useful tool for timekeeping, such as in the pendulum clock shown in Figure L13.1. Early physicists recognized this and investigated the pendulum to understand what variables influence its period. This would allow them to more effectively use pendulums in clocks, as well as in other devices.

Your Task

Use what you know about simple harmonic motion, causal relationships, the relationship between structure and function in nature, and the importance of patterns to design and carry out a series of experiments to determine which variables do and which variables do not change the period of the pendulum.

The guiding question of this investigation is, ***What variables affect the period of a pendulum?***

Materials

You may use any of the following materials during your investigation:

Consumables
- Tape
- String

Equipment
- Safety glasses or goggles (required)
- Electronic or triple beam balance
- Washers
- Paper clips
- Protractor
- Ruler
- Meterstick
- Stopwatch
- Scissors

To use a photogate system, you will need to have a sensor interface and a computer, tablet, or graphing calculator with data collection and analysis software. To use video analysis, you will need to have a video camera and a computer or tablet with video analysis software.

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. Use caution when working with scissors. They are sharp and can cut or puncture skin.