LAB 2. MODELING HOW THINGS MOVE

Introduction

You will record the motion of objects in different circumstances. The systems of study include a dropping mass, a mass hanging from a spring, a sprinting classmate, a falling coffee filter, and an object sliding across a level surface. You will propose equations of motion to describe their position, velocity, and acceleration as functions of time.

Supplies

Drop Station: clamping support, tape timer, ticker tape, hanging weight, pad
Spring Station: spring, hanging mass, clamping support, motion sensor setup
Everyday station: motion sensor setup, box, pie pan or coffee filter

Measurements

For each system, Record the setup of the apparatus in your lab notebook. Also record how you took measurements.

System 1. Spring mass

1. Hang a mass from the spring.
2. Make the mass oscillate up and down at the end of the spring. Figure out the best way to make it do that.
2. Point the motion sensor under the spring facing upward.
3. Start the motion sensor. Make graphs of position, velocity and acceleration. Save your data into a file that you can access outside of lab. It is even better if you can save the graphs as well, but you may need to re-create the graphs from the data. You may do this as a Google file, or as a file that you email to yourself, or that you save to a USB drive.

System 2. Drop

In this activity, you will drop a weight hanging from a paper tape so that it falls freely and draws the tape between a metal plate and a circle of carbon paper on the Pasco tape timer. The timer strikes the metal plate at a frequency of 40 hertz, making a mark on the paper at regular intervals of 1/40 sec.

1. Set a pad under the tape timer to catch the falling weight.
2. Cut a piece of paper tape long enough to reach from the timer to the floor, with about 50 cm excess.
3. Thread one end of the tape through the slots on the timer, from top to bottom. Make sure that the tape runs between the metal bar and the circle of carbon paper.
4. Fold over the lower end of the paper and hook the weight through both layers. (This keeps the paper from tearing.)
5. Hold the rest of the tape above the timer so that the mass hangs just below the bottom of the timer. Turn on the timer to 40 Hz. Let it run for a few seconds to get up to speed.

6. Drop the tape, allowing the weight to fall and land freely.
7. Turn off the timer. Remove the tape from the timer and fasten it to the table with tape.
8. Repeat this procedure for a second trial. (You may run additional trials if you think something went wrong or if you want to get another look at how the system operates.)

Data Processing

With this apparatus, you must convert distances to numerical data yourself—Capstone is not here to do it for you. Here is how to determine positions and velocities of the falling weight throughout its drop.

1. Choose a starting point a few centimeters past the first group of dots and mark that dot as Position 0. (The first several dots are unreliable—do you see why?) Measure the *total* distance from Position 0 to each successive dot for up to 15 dots. (The last few dots on the tape are also unreliable—again, do you see why?) Record these values in your notebook.
2. Calculate the distance Δd between successive dots by subtracting the position of the previous dot. Then, convert to average speed during the interval by using the relation $v = \Delta d/\Delta t$. Since the timer was set on 40 Hz, it was making 40 dots per second, so the time between successive dots is 1/40 s or 0.025 s. Numerically, this means you should multiply the Δd value by 40. A spreadsheet is a good way to automate this.
3. Make a plot or plots of total distance vs. time from your calculations. You can make the plot on graph paper, or using a spreadsheet. If you plot data from different trials on the same graph, use different plot symbols and colors for them. Scale your graph to use at least half of each axis. Include a legend on your graph to tell which is which. Provide the units in the axis labels. Title your graph.
4. Make a plot or plots of the velocity vs. time from your calculations. Include a legend with your graph to tell which is which. Provide the units in the axis labels. Scale your graph to use at least half of each axis. Title your graph.

System 3: Sprinter

1. Set up the motion detector to follow a person.
2. Take data of a person sprinting from rest, toward or away from the detector.
3. Create the position-time graph, velocity-time graph, and acceleration-time graph. Save your data into a file that you can access outside of lab. You may do this as a Google file, or as a file that you email to yourself, or that you save to a USB drive.
4. Make a few more trials to see the diversity of shapes and patterns of the graphs.

System 4: Sliding box

1. Set up the detector to follow a box.
2. Start data collection.
3. Push the box toward the detector and let it slide along the floor to a stop in front of the detector.
4. Create the position-time graph, velocity-time graph, and acceleration-time graph. Save your data into a file that you can access outside of lab. You may do this as a Google file, or as a file that you email to yourself, or that you save to a USB drive.

System 5: Drifting fall

1. Place the motion sensor on the floor with its transducer facing up. Hold a coffee filter or pie pan high in the air directly above it.
2. Start data collection and drop the object, so that it falls onto the detector. Stop data collection.
3. Or try it the other way around. Clamp the motion sensor to a stand so that the transceiver faces down. Hold a coffee filter or pie pan under it and release it, allowing it to drop to the floor.
4. When you have a data set you like, export the position-time, velocity-time, and acceleration-time data to a file.

Analysis

For all of your trials, you should have measurements of position, velocity, and perhaps acceleration at sequential times. These naturally lend themselves to graphs of the quantities as a function of time. What functional forms do the graphs appear to take? Propose mathematical formulas to model the position, velocity, and acceleration values as functions of time. You may use different, similar, or identical formulas for the different runs. You may also use different formulas for different segments of a single trial, such as beginning, middle, and end.

How well do your models describe the observations? If your models do not match the observations exactly, consider what might be causing the difference. Possibilities include that he model is not actually related to the system, that the measurements are faulty, or that significant factors omitted from the model affect the system or the measurements.

Your Lab Report

Communicate your measurements and findings in a concise lab report.

1. Abstract

Identify the systems you studied, what you looked for, and what you did.

2. Purpose

What is the point of modeling the motion of objects mathematically?

3. Theory

There are theoretical relationships between position, velocity, and acceleration. What are they?

We haven't yet explored in class any theoretical expectations for functional dependence of position, velocity, or acceleration with time, so you don't need to speculate here.

4. Experimental

Describe how you set up the different situations and measurements, and how you took measurements.

5. Observations and Data

Your raw data should be in your lab notebook and in files created by Capstone. Here you communicate the data in the most concise, accessible, and understandable format possible. For this experiment, that format is as graphs.

6. Analysis and Discussion

What functions did you use to model the position, velocity, and acceleration for the different moving objects? Why did you choose them? How well do the models describe the motion? Are differences between the models and the data failures of the models, failures of the measurements, or something else? If some of the motions are described by their models better than others, why might that be?

7. Conclusion

Identify the models you matched to the different motions.