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 on the floor. You will propose equations of motion to describe their position, velocity, and acceleration as functions of time.

Supplies

Spring activity: spring, hanging masses, index card, clamping support, motion sensor apparatus
Drop activity: clamping support, tape timer, ticker tape, hanging weight, tape measure, pad
Everyday activity: motion sensor apparatus, box, pie pan or coffee filter, human sprinter

Measurements

For each system, describe or sketch the apparatus. Also record how you took measurements.

System 1. Spring mass

1. Hang a mass from the spring.
2. Make the mass oscillate 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. Lift the mass and release so that it oscillates up and down.
4. 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 timer. The Tape Timer strikes the metal plate at a frequency of 40 hertz, making a mark on the paper at regular intervals of 1/40 sec.

Procedure

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 on the marking side of 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 weight, allowing the tape to run freely.
7. Turn off the timer. Remove the tape from the timer and fasten it to the table with masking 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—no computer does 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 dots and mark that dot as Position 0. (The first several dots are unreliable—do you see why?) Measure the distance x from Position 0 to each dot for up to 15 dots, if you have that many. (The last few dots on the tape are also unreliable—again, do you see why?) Record these values.

t (s)	x (cm)	Δx (cm)	v (cm/s)

2. Calculate the distance Δx between successive dots by subtracting the position of one dot from the next. Then, find the average speed v during each interval by using the relation $v = \Delta x/\Delta t$. 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 number in the Δx column by 40 to find speed in cm/s. A spreadsheet is a good way to automate this.

System 3: Everyday Stuff

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, 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.

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. Save your data into a file that you can access outside of lab.

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, save your data to a file that you can access outside of lab.

Analysis

For each system, you should have records 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 position-time relations 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 time intervals of a single trial, such as beginning, middle, and end. Overlay graphs of your proposed formulas on the graphs with your data to compare them.

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. Because you took the data with your lab group, everyone in a group may submit the same "Experimental" and "Observations and Data" sections. Your "Abstract," "Purpose," "Analysis and Discussion," and "Conclusions" sections should be your own.

1. Abstract

Identify the moving systems you studied, and what you did with the motion data.

2. Purpose

Why might we want to model the motion of objects mathematically?

3. Theory

There are defined relationships between position, velocity, and acceleration. What are they? (You may use the Theory section from Lab 1 here, because it's the same physics.)

We haven't yet explored in class any theoretical expectations for functional dependence of position, velocity, or acceleration with time. Nor have we explored why specific systems move in the way that they do. Consequently, you don't need to speculate here.

4. Experimental

Report how you set up the different situations and measurements, and how you took measurements. Identify any commercial products used by make and model. Give enough detail for another student to be able to repeat your experiments.

5. Observations and Data

Your raw data should be in your data table and in computer files. In this section, you communicate the data in the most concise, accessible, and understandable format possible. For this lab, graphs are probably the best way to do that.

6. Analysis and Discussion

The point of this experiment is to develop satisfactory mathematical descriptions of the different motions you observed. Discuss how that went for each of them. Here are some questions you can consider.

- What functions did you use to model the position, velocity, or acceleration for the different moving objects?
- Why did you choose those models?
- How well do the models describe the motion?
- How can you evaluate how well the models fit reality?
- 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, and judge how well they match.