Lab Handout

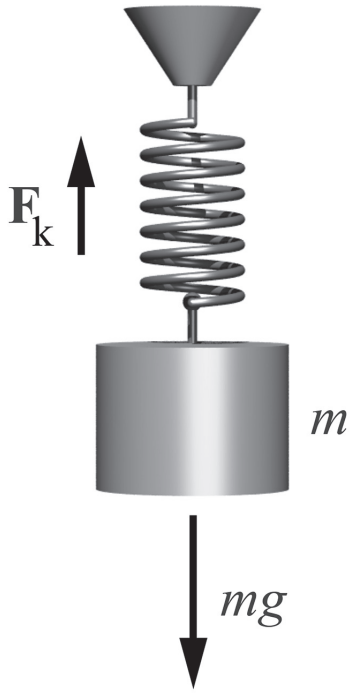
Lab 14. Simple Harmonic Motion and Springs: What Is the Mathematical Model of the Simple Harmonic Motion of a Mass Hanging From a Spring?

Introduction

A basic but important kind of motion is called simple harmonic motion. Simple harmonic motion is a type of periodic or oscillatory motion. An example of simple harmonic motion is the way a mass moves up and down when it is attached to a spring (see Figure L14.1). When the mass attached to a spring is not moving, the mass is said to be at equilibrium. When the mass is moved from the equilibrium position (such as when a person pulls down on the spring), a force from the spring ($\mathbf{F}_k$) acts on the mass to restore it to the equilibrium position. This force is called the restoring force. The further the mass is moved from the equilibrium position, the greater the restoring force becomes. In fact, the magnitude of the restoring force is directly proportional to the distance the mass is moved away from the equilibrium position (the displacement) and acts in the direction opposite to the direction of displacement.

We can explain the underlying cause of simple harmonic motion using Newton's second law of motion. Newton's second law of motion indicates that an object will accelerate when acted on by an unbalanced force. Thus, when an oscillator (in this case a mass attached to a spring) is disturbed from equilibrium, it accelerates in the general direction of the equilibrium position. When the mass reaches the equilibrium position, it has a non-zero velocity and the sum of the forces acting on it is zero. The mass will therefore move through the equilibrium position, at which point the restoring force increases until the mass reaches a maximum displacement from the equilibrium position. At the maximum displacement position, the restoring force is also at a maximum, while the velocity is equal to zero (0 m/s). This process repeats over time, which results in periodic or oscillatory motion.

FIGURE L14.1
A mass on a spring



In this investigation you will have an opportunity to examine the simple harmonic motion of a mass hanging on a spring. Your goal is to create a mathematical model that you can use to describe the vertical position of the mass in terms of time. Therefore, you will need to investigate the effect of different masses, release points, and types of springs during your investigation. It is important to note that your model will ignore dampening, the effect of slowing the mass-spring system down to a stop by frictional forces.

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Your Task

Use what you know about simple harmonic motion, patterns, and stability and change in systems to develop a function that will allow you to model the motion of a mass hanging from a spring. To develop a mathematical model, you will need to design and carry out several experiments to determine how (a) different masses, (b) different release points, and (c) different spring types affect the motion of a mass hanging from a spring. Once you have developed your model, you will need to test it to determine if allows you to make accurate predictions about the vertical position of the mass in terms of time.

The guiding question of this investigation is, ***What is the mathematical model of the simple harmonic motion of a mass hanging from a spring?***

Materials

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

- Safety glasses or goggles (required)
- Support stand
- Suspension hook clamp
- Hanging mass set
- Springs (variety)
- Motion detector/sensor
- Interface for motion detector/sensor
- Computer, tablet, or graphing calculator with data collection and 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. Wash hands with soap and water after completing the lab.

Investigation Proposal Required? ☐ Yes ☐ No

Getting Started

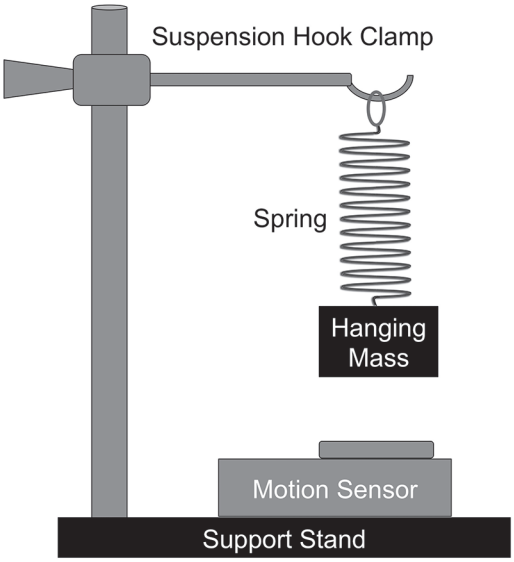
The first step in developing your mathematical model is to design and carry out three experiments. In the first experiment, you will need to determine how changing the mass affects the motion of a mass-spring system. You will then need to determine how changing the release point of the mass affects the motion of the mass-spring system. Finally, you will need to determine how changing the type of spring affects the motion of the mass-spring system. Figure L14.2 illustrates how you can use the available equipment to study the motion of a mass-spring system in each experiment. 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.

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

- What are the boundaries and components of the mass-spring system you are studying?
- Which factor(s) might control the rate of change in the mass-spring system?
- How could you keep track of changes in this system quantitatively?
- Under what conditions is the system stable, and under what conditions does it change?
- How will you measure the vertical position of the mass over time?
- What will be the independent variables and the dependent variables for each experiment?

FIGURE L14.2

One way to examine the motion of the mass-spring system using the available equipment



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

- What other factors will you need to control during each experiment?
- What scale or scales should you use when you take your measurements?
- 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:

- How much of your data is useful, given that you want to ignore dampening?
- What type of calculations will you need to make?
- What types of patterns might you look for as you analyze your data?
- What type of table or graph could you create to help make sense of your data?
- What types of equations can you use to describe motion that is periodic or harmonic?

Once you have determined how different masses, release points, and spring types affect the motion of a mass-spring system, your group will need to develop a mathematical model. The model must allow you to make accurate predictions about the vertical position of the mass in terms of time.

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The last step in this investigation will be to test your model. To accomplish this goal, you can add different hanging masses (amounts that you did not test) to the end of one of the springs or try different release points (ones that you did not test) to determine whether your mathematical model helps you make accurate predictions. 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 it is a valid and acceptable model of the simple harmonic motion of a mass hanging from a spring.

Connections to the Nature of Scientific Knowledge and Scientific Inquiry

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

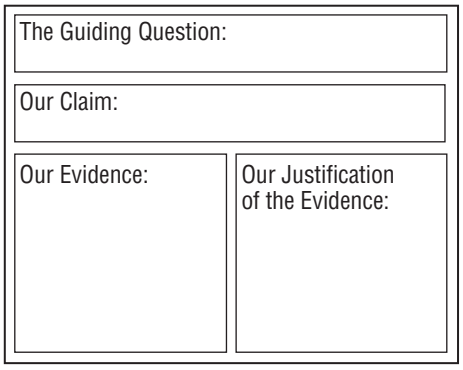
- how scientists use different methods to answer different types of questions, and
- the role of imagination and creativity in science.

Initial Argument

Once your group has finished collecting and analyzing your data, your group will need to develop an initial argument. Your argument must 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 L14.3.

FIGURE L14.3

Argument presentation on a whiteboard



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:

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 you 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!