InquirySpace Teacher Guides:
Spring Experiments and Model

1) Activities Covered

Hands-on experiment with sensors

- Spring & Mass
- Spring & Amplitude

Simulation-based experiment

- Spring & Mass Model

2) Summary

The goal of this trio of activities is to explore the effect of various physical features of a spring-mass system on the period (time for one cycle). They may be run independently, but doing all three together, if time allows, will result in a deeper understanding of the material. By running all three, students can explore several features of the spring-mass system and are given the opportunity to compare the model to the real experiment, which will shed light on both versions.

We recommend that the hands-on experiments be done first to give the students a concrete sense of the physical situation. These two experiments focus on easy-to-adjust variables: 1) mass and 2) amplitude. The time-series data is cyclical and relatively easy to collect. The simulation-based experiment allows the student to quickly explore additional variables that are harder to manipulate in the lab: spring constant, gravity, and damping.

3) Learning Goals

In the hands-on experiments, students will:

- Use a motion sensor to collect a distance-time graph of an oscillating spring-mass system, and send it to the CODAP table.
- Measure period and amplitude of a wave from a position-time graph.
- Make multiple runs with different masses and amplitudes.
- Construct graphs to study the results.
- Use the scaling, hide/show, connecting-lines and movable-line features to study the graphs.
- Recognize and select the portion of the collected data that is relevant.
- Draw conclusions about relationships based on the graphs.
- Recognize that mass is proportional to period (but not linearly).
- Recognize that period is independent of amplitude.
- Theorize from physics principles why these two relationships are true.

In the simulation-based experiment, students will:

- Set and run a model, collect data for various values of the parameters, and send it to the CODAP table.
- Explore the variable spring constant, gravity, and damping.
- Arrange the data and graphs to see the effect of one parameter at a time.
- Explore additional parameters (gravity and spring constant).

- Recognize that gravity does *not* affect period, and spring constant is inversely related to period (but not linearly).
- Theorize from physics principles why these two relationships are true.

4) Teacher Preparation

The most important step in preparing to run InquirySpace activities with students is to run the "Teacher Version" of each activity. These are available on the InquirySpace Portal.

http://inquiryspace.portal.concord.org

Teacher versions are essentially duplicates of the student versions with the addition of tips for successful classroom use. These tips are written in red within each activity. By running the activities yourself, you will become familiar with many important elements of the activity including the:

- flow of the activity between Lab and Experiment Tabs,
- physical set up of the hands-on experiments,
- use and limitations of sensors,
- functionality within the CODAP environment,
- questions that students will be asked to answer, and
- approximate amount of time needed to complete it.

5) Materials

Break students into groups of three. Each group will need the following:

An account on the InquirySpace Portal. For help on registration and class set up, please see the Portal and Quick Start Guide.

Hands-on experiment (per group):

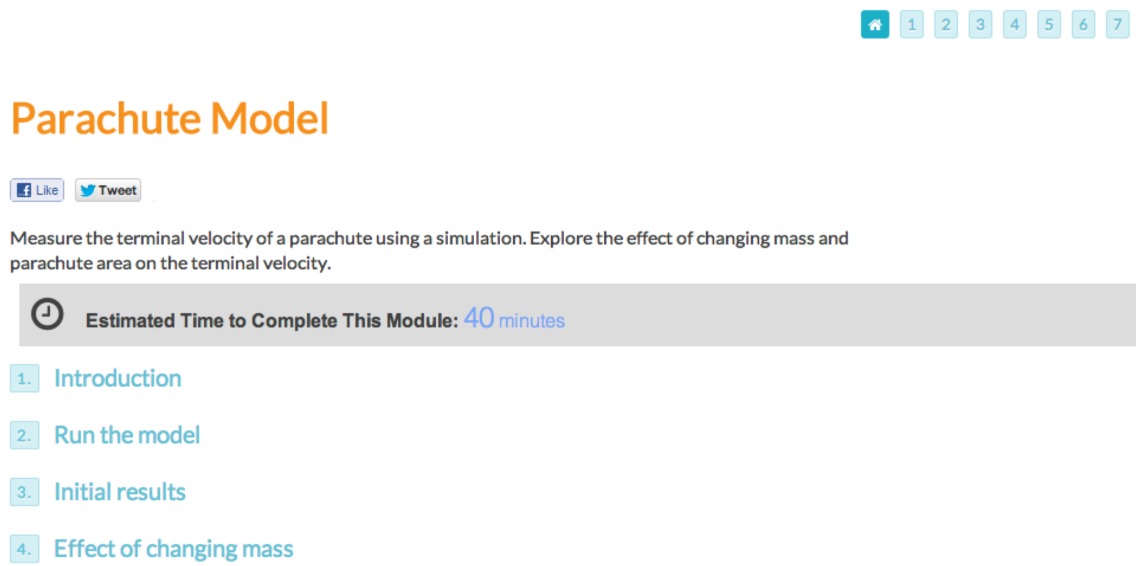
- Computer
- Internet connection
- Vernier motion sensor and LabQuest Mini
- Lab stand to hang spring-mass system
- Spring(s)
    - We recommend Jones Spring Company, part #174C. It is difficult to find a soft enough spring in a hardware store.
- (4) 60-gram (2-oz) masses
    - We recommend lead fishing weights, available online. Make sure students wash hands after use.
- Paper clips for connections between spring and cup
- Paper or plastic cups with paper clip handle
- String, if needed, to adjust height

Simulation-based experiment (per group):

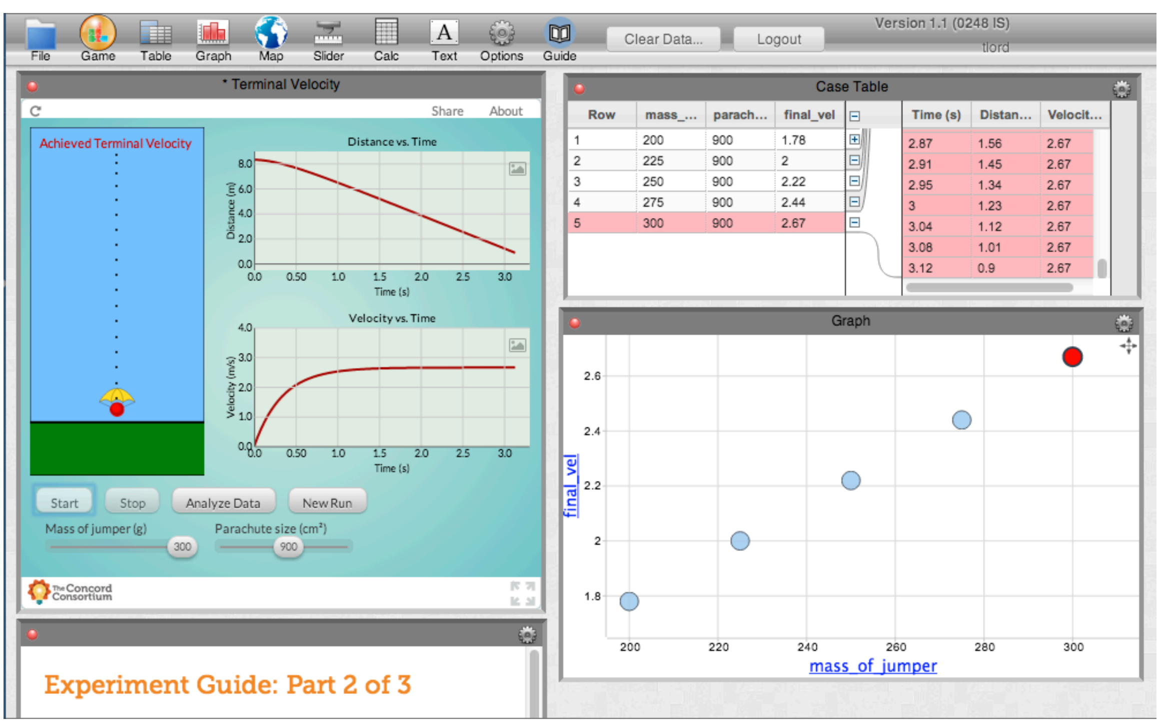
- Computer
- Internet connection

6) The Student Experience

When you run the Teacher Version of the activity, you will become more familiar with the flow of InquirySpace activities. The student version of each activity follows the same flow. When the student clicks the **Run** button under an activity in the InquirySpace Portal, the activity will open in a new tab. Students should follow the steps of the activity in sequence. Any answers to questions within the activity are automatically saved to their account.

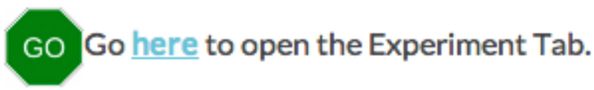


Each InquirySpace activity has two parts, the Lab Report (shown in the example screenshot above) and the Experiment Tab (shown in the example screenshot below).

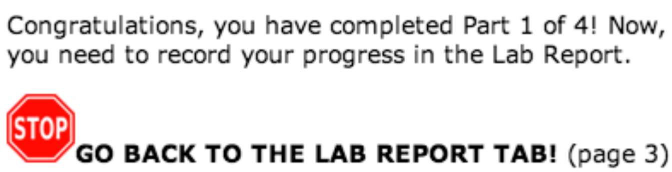


The Lab Report Tab is what is first launched via the Portal. The Lab Report for each activity gives background information and instructions for setting up experiments, asks questions, and saves answers. Eventually, the instructions within the Lab Report will ask students to collect and analyze data using the CODAP environment, which is referred to as the Experiment Tab. The Experiment Tab is where students will use sensors or run models to collect data, create graphs, and analyze data.

When it is time to use CODAP, students will see this sign in the Lab Report:



The CODAP environment will open in a new browser tab. CODAP is a separate piece of software with its own ability to save work. Work in the Experiment Tab is not yet shown in the Portal Reports (this feature is in development). As students work through the InquirySpace activity, they will move back and forth from the Experiment Tab to the Lab Report Tab. Remind students to read the instructions carefully and watch for Stop and Go signs! They will be directed to return to the Lab Report with messages like this:



7) Potential Trouble Spots

Hands-on Experiment

- The sensor will not read a distance less than about 20 cm. Students must adjust the ring stand height accordingly. When there are two or more masses, it will probably be necessary to hang the system over the side of a table and place the sensor on the floor.
- *Zeroing the sensor at the rest position* every time is very important! Otherwise the oscillation will not be around the zero line on the Y-axis, and it will be harder to compare runs or measure amplitude.
- Students may be too rough with the spring, pulling it down too far or tossing in the mass to get it going. They should place the mass(es) in the cup, then gently pull the cup down so its motion is smooth. A small amplitude will give just as good data as a large amplitude!

Content

- Depending on their background, students may have trouble understanding the period of a wave and how to measure it. Review this as needed.
- Students frequently confuse amplitude (displacement from the zero position) with the length of the spring. When they add masses and the cup's zero position becomes lower, they think the amplitude is greater. This confusion is addressed in the activity but may need additional discussion.
- Most students predict that amplitude affects period and are somewhat surprised to

discover that it does not. When they make a period vs. amplitude graph, it will be a horizontal line. This provides an excellent discussion topic.
- Explain that the spring constant is a measure of the stiffness of the spring. The more force it takes to stretch the spring a given distance, the greater the spring constant. The units are Newtons/meter.
- The model provides an opportunity to confirm the experimental findings and explore other variables that are harder to change in the lab, e.g. spring constant and gravity. You could assign different variables to different groups or have them explore several, depending on their sophistication and the time available. The results provide good material for a discussion of the physics.

CODAP

- There are two “levels” of graph in CODAP: the time-series graphs that are exported from the sensor collector (distance vs. time), and the values for each run that are measured using the time-series graphs (mass, period). Students get used to this but it is confusing at first.
- There are various ways in CODAP to hide/show and highlight the various runs so that that can be analyzed one at a time. This may take some practice and extra instruction.
- If the graph rescales so that the Y-axis range is small, this line may appear irregular at that finer scale, even though the period has changed very little.
- Collecting data is quick and easy in the simulation, so the harder task will be to group the runs so that the effect of each variable can be viewed separately. CODAP places all the runs in the same table and all the runs appear on every graph. However, There are various ways in CODAP to hide/show and highlight the various runs so that that can be analyzed one at a time. This may take some practice and extra instruction.
    - Runs (one or many) are made bold in the graphs when students highlight them in the table.
    - At the top of the graph is a “Show All - 1 2 3 4 …” menu for showing individual runs.
    - The non-highlighted runs can be hidden altogether using the “hide/show” choices under the graph’s gear menu.
    - If “run number” is dragged into the field of the graph (rather than the axes) and then treated as “categorical”, each run is a different color.

7) Discussion Topics

Students will need your help to make their work with InquirySpace activities a meaningful experience. Help them make sense of their observations by facilitating full class and/or small group discussions at the beginning of each class, at the end of each activity, and before the start of the next one. Often stopping a class in the middle of an activity for discussion is difficult because groups work at their own pace. However, bringing the class together between activities is an important role for teachers to play.

Mass vs. Period

- What is the period of a repeating motion? How do you measure it?
- What did you have to do to get clean runs without any spikes?
- Were you able to zero the distance sensor at the zero position?
- What period did you measure for one mass (60 g)? Compare answers from different groups. How close were they to each other?

- What problems did you overcome to measure the period?
- Did you keep all other factors the same? How?
- What relationship between mass and period did each group discover? What did their graphs of mass vs period look like?
- Is the relationship linear? How can you tell? (Note: period is proportional to the square root of the mass.)
- Why do you think this pattern exists? (Why would a greater mass result in a longer period?)

Amplitude vs. Period

- What is amplitude? How do you measure it?
- Can there be a longer (more stretched out) spring but still a very small period? [Make sure they understand that amplitude is measured from the zero point, not from the length of the spring.]
- Compare methods and results of different groups: how did you control and change the amplitude for different runs?
- Did you keep all other factors the same? How?
- What relationship between amplitude and period did each group discover? What did their graphs of amplitude vs period look like?
- Were you surprised by this result? (Most students think period increases with increasing amplitude.)
- Why do you think this pattern exists? (Why would increasing the amplitude not increase the period?)

Spring-mass Model

- Encourage different groups to try different variables, for example gravity and spring constant.
- Have each group report on the effect of their first chosen variable. What did the graph look like? What does it mean about the relationship? [Note: spring constant has an inverse relationship with the period. Surprisingly, changing gravity has no effect on the period!]
- What did you learn from the model, compared to what you learned from the physical experiment?

8) The Physics

Students could do all of these activities entirely as exercises in measurement and analysis of relationships using graphs, but they should at least try to develop an explanation based on what they have learned about forces and acceleration. Here are some questions that might elicit a good discussion of the physics behind the spring-mass system.

The nice thing about a spring-mass system is that force, acceleration, velocity, and distance are all sine waves, and they are related in a straightforward way coming directly from Newton's Second Law. They can easily be observed and physically felt.

- What are the forces on the mass at every position—at the zero position, above it, below it? Note: distinguish between the forces and the net force.
- Introduce the idea of a restoring force, which always aims toward the zero position. This

is a common feature of all oscillators.

- Draw a diagram of how the net force changes with displacement, including its direction.
- Given the picture of forces, how does the acceleration change with displacement, including its direction?
- Given that picture of acceleration, how does the velocity change with displacement?
- In summary, where in the cycle are the force, acceleration, velocity, and displacement either zero or maximum?
- Why does a greater mass increase the period? [The restoring force caused by the spring causes a smaller acceleration, because a = F/m. So the mass doesn't return to the zero position as quickly.]
- Why does a larger spring constant (stiffer spring) decrease the period? [The restoring force is greater; hence, the acceleration is greater as well.]
- Why doesn't the amplitude affect the period? [A greater amplitude results in a greater restoring force and hence a greater acceleration, which is balanced by a greater travel distance. The two effects cancel out.]
- Why doesn't changing gravity effect the period? [It doesn't change the restoring force, since it's always in one direction.]

9) NGSS Standards

HS-PS2-1. Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.