PhET Tips for Teachers — Masses and Springs

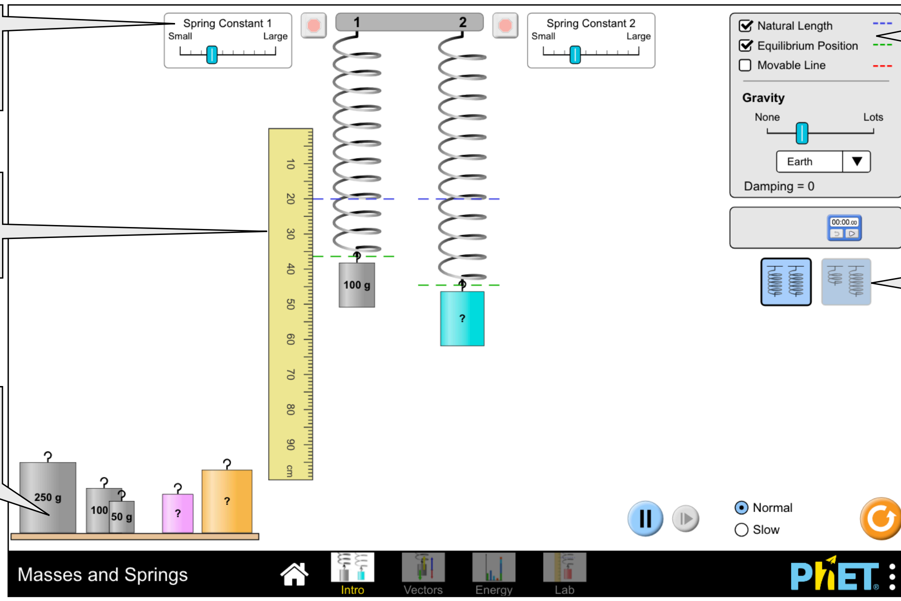
Intro Screen

Play with one or two mass-spring systems and discover which variables (such as mass, gravity, spring constant, spring length) affect the period.

ADJUST the spring constant

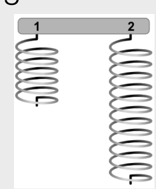
MEASURE the displacement

HANG masses from springs



VIEW natural length and equilibrium position

COMPARE springs with different natural lengths



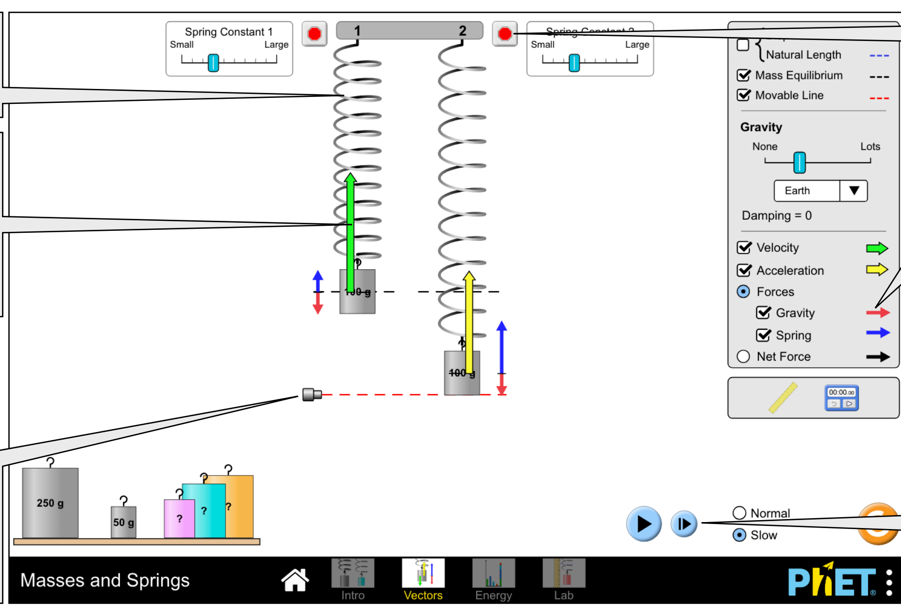
Vectors Screen

View the net force or component forces in the system, and explore how the velocity and acceleration change throughout the oscillation.

COMPARE two systems

OBSERVE the velocity and acceleration in real-time

SET reference point with Movable Line



STOP oscillation

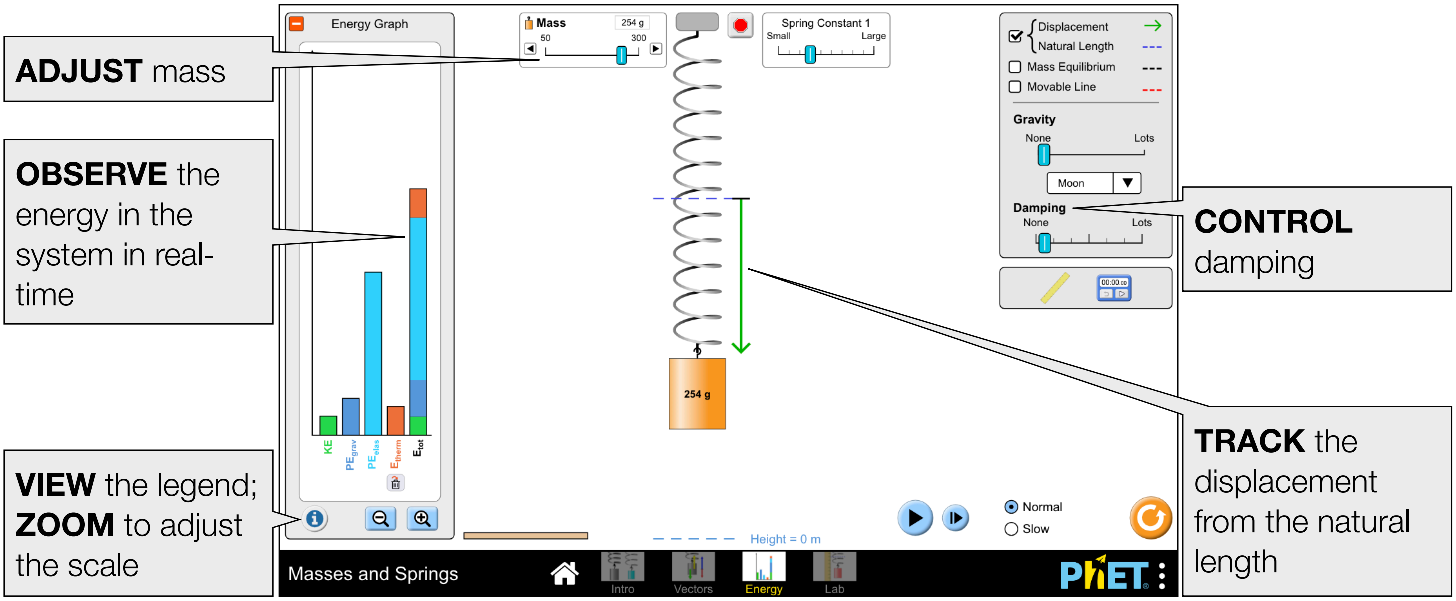
DISPLAY components or net force

PAUSE the sim to set up an experiment; **JUMP** forward by 0.01 seconds

Rouinfar, August 2023

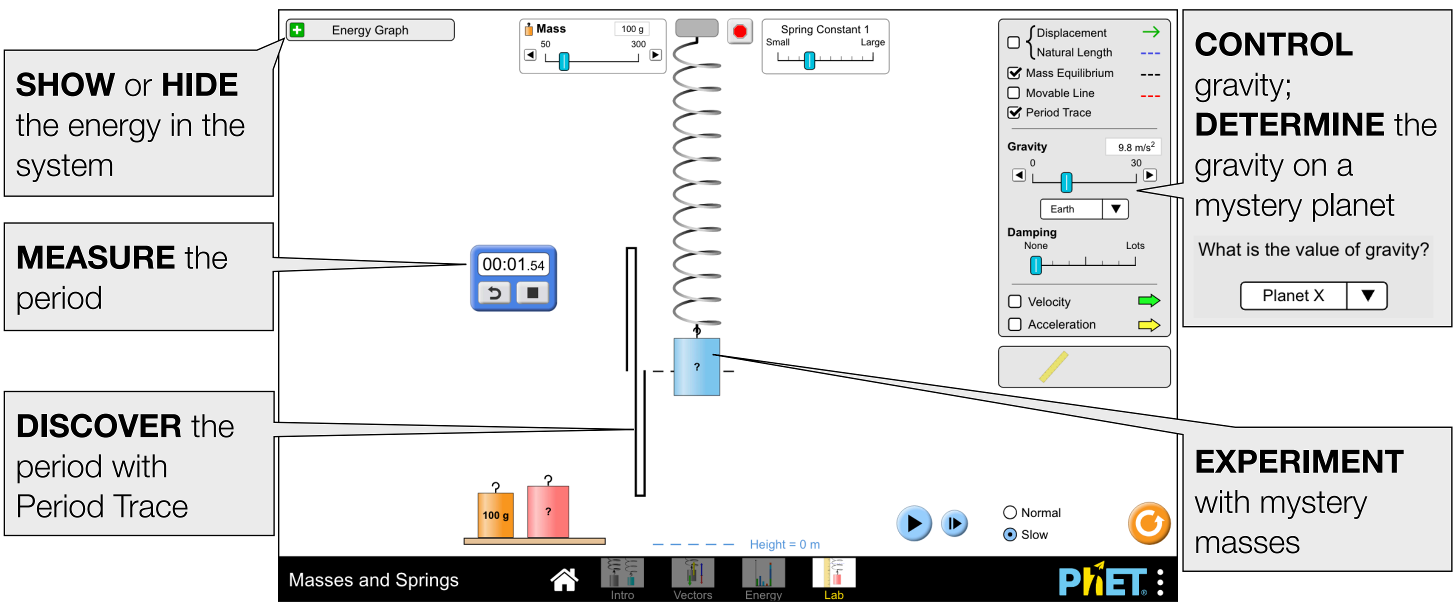
Energy Screen

Explore the energy in the system in real-time and discover the conservation of mechanical energy.



Lab Screen

Collect data and determine the value of the mystery mass or g on Planet X.



Complex Controls

- The remove heat button in the Energy Graph will instantaneously remove the thermal energy from the system. If damping is on, the thermal energy will still continue to accumulate.
- The zero-point of the gravitational potential energy is indicated by the — — — — — Height = 0 m dashed line at the bottom of the screen. GPE will be zero when the bottom of the mass is at this line.
- When the energy is off-scale, an arrow will appear above the bar in the Energy Graph. To re-scale the graph, zoom out until the arrows are no longer visible.

Rouinfar, August 2023

Customization Options

Query parameters allow for customization of the simulation, and can be added by appending a '`?`' to the sim URL, and separating each query parameter with a '`&`'. The general URL pattern is:
`…html?queryParameter1&queryParameter2&queryParameter3`

For example, in Masses and Springs, if you only want to include the 1st and 2nd screens (`screens=1,2`), with the 2nd screen open by default (`initialScreen=2`) use:
https://phet.colorado.edu/sims/html/masses-and-springs/latest/masses-and-springs_all.html?screens=1,2&initialScreen=2

To run this in Spanish (`locale=es`), the URL would become:
https://phet.colorado.edu/sims/html/masses-and-springs/latest/masses-and-springs_all.html?locale=es&screens=1,2&initialScreen=2

Query Parameter and Description	Example Links

`screens` - specifies which screens are included in the sim and their order. Each screen should be separated by a comma. For more information, visit the Help Center.	`screens=1`
	
	`screens=2,1`

`initialScreen` - opens the sim directly to the specified screen, bypassing the home screen.	`initialScreen=1` `initialScreen=3`
`locale` - specify the language of the simulation using ISO 639-1 codes. Available locales can be found on the simulation page on the Translations tab. Note: this only works if the simulation URL ends in "_all.html".	`locale=es` (Spanish) `locale=fr` (French)
`allowLinks` - when `false`, disables links that take students to an external URL. Default is `true`.	`allowLinks=false`

Insights into Student Use

- When setting up an experiment, it may be helpful to first pause the sim.
- Students may notice that the displacement vector is asymmetric about the natural length. You can ask students to find a way to make this displacement equal (g = 0) or ask them to instead compare the displacement about the Mass Equilibrium (always symmetric).

Model Simplifications

- The thickness of the spring is used to indicate the spring constant. A spring with n coils can be treated as n identical springs (each with spring constant k) connected in series, with an effective spring constant of $k_{eq} = k/n$. For springs with an unequal number of coils (unequal natural lengths) to have the same effective spring constant, the shorter spring must have a thinner gauge. Similarly, if these two springs have the same thickness, the shorter spring will have the greater effective spring constant.
- The spring constant range is 3-12 N/m, with tick mark intervals of 1 N/m.

- The mystery masses on the Intro and Vectors screens have the same density as the other masses, so their size can be used to (roughly) determine their mass. On the Lab screen, the mystery masses have different densities, so students will need a more sophisticated strategy to determine their value.
- Two equilibrium reference positions can be displayed in this sim: Equilibrium Position (end of spring) and Mass Equilibrium (center of mass). The Equilibrium Position appears on the Intro screen to allow students to discover the displacement. Vectors are drawn with respect to the center of mass, so the Mass Equilibrium is a more useful visual reference on the later screens.
- The damping force is proportional to the velocity ($F = -c \cdot v$), and the damping slider controls c. For more information about the damping or the equation of motion, see Masses and Springs Model.
- If a parameter (e.g. gravity, mass) is changed mid-oscillation, the instantaneous displacement, mass, spring constant, gravity, and velocity will be used as the new initial conditions for the equation of motion. Frequent mid-oscillation changes can lead to hard-to-interpret (though technically still accurate) behavior, so we recommend stopping the mass between experiments.

Suggestions for Use

Sample Challenge Prompts

- Describe the Natural Length and Equilibrium Position in your own words.
- Identify all the ways to increase the displacement at equilibrium.
- Determine the relationship between the applied force and displacement.
- Explain what the period represents, and determine a method to measure it.
- Design a controlled experiment to (qualitatively or qualitatively) determine how a variable — such as mass, gravity, spring constant, or displacement — affects the period.
- Determine a way to give a heavier mass a shorter period than a lighter mass.
- Sketch the gravitational and spring forces at several points throughout the oscillation.
- Predict the direction and magnitude of the velocity and acceleration vectors throughout the oscillation.
- Identify where in the oscillation the kinetic energy, gravitational potential energy, and elastic potential energy are increasing/decreasing, and identify the locations where the energies are maximum or zero.
- Estimate the speed of the mass (e.g. max, medium, zero) or its position from the Energy Graph.
- Determine the mass of the mystery masses or the value of g on Planet X (qualitatively or quantitatively), and explain your method(s).

See all published activities for Masses and Springs here.
For more tips on using PhET sims with your students, see Tips for Using PhET.

Name: Section Date

FACTORS AFFECTING THE FREQUENCY OF A SIMPLE HARMONIC OSCILLATOR

OBJECTIVE: To investigate the dependence of the frequency of oscillation on the following physical quantities: amplitude, spring constant and mass.

MATERIALS masses-and-springs-en.html, spreadsheet

ONLINE RESOURCES Masses and Springs PhET simulation: https://phet.colorado.edu/sims/html/masses-and-springs/latest/masses-and-springs_en.html

PROCEDURE

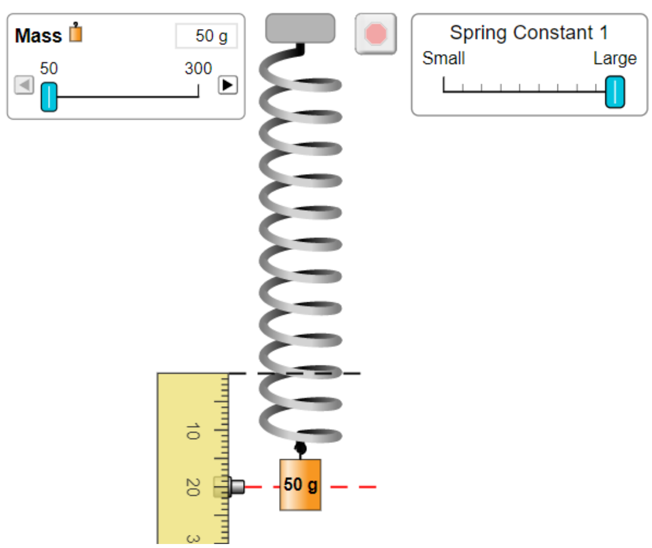
Frequency and Amplitude of Oscillation

1. Open the Masses and Springs PhET simulation. Select LAB.

2. Set the following parameters:

Simulation	PAUSED
Mass	50 g
Spring Constant	"Large"
Mass Equilibrium	Enabled
Movable Line	Enabled
Gravity	Earth
Damping	None
Simulation Speed	Slow

3. Hook the 50-g mass and adjust the position of the movable line tracer 20 cm below the equilibrium line. This will be the starting position of the 50-g mass.



4. Start the simulation by clicking on the Pause/Play button. Using the built-in stopwatch, determine the time it takes the 50-g mass to make 10 complete oscillations. Make two trials.

5. Adjust the starting position to 40 cm and repeat procedure no. 4. Record your measurements and calculations in Data Table I.

Data Table I

Starting Position	Time for 10 complete oscillations (s)			Frequency (Hz)
	Trial 1	Trial 2	Ave.	
20 cm				
40 cm				

QUESTIONS:

- What does the starting/initial position of the 50-g mass represent?
- What happens to the length of the path travelled by the 50-g mass when the starting position is increased from 20 cm to 40 cm? What happens to its speed?
- Does the starting position of the object affect the frequency of the object-spring system? Explain.

Frequency and Spring Constant

1. Set the following parameters:

Simulation	PAUSED
Mass	50 g
Spring Constant 1	1 unit from "Small"
Mass Equilibrium	Enabled
Movable Line	Enabled
Gravity	Earth
Damping	None
Simulation Speed	Slow
Starting position from equilibrium line	30 cm

2. Run the simulation by clicking on the Start/Stop button. Determine the frequency of oscillation of the 50-g mass.

3. Using the same parameters in (1), make several trials, each time, increasing the spring constant by 2 units from "Small" until the spring constant = 9 units. In each trial, make sure that the starting position is always kept at 30 cm below the equilibrium line. Summarize your measurements in Data Table 2.

Data Table 2

Spring constant k	Frequency of Oscillation
1	
3	
5	

4. Using a spreadsheet, plot the values of the frequency against the values of the spring constant. Describe the graph formed.

5. Plot the values of f^2 against the values of k. Describe the graph formed.

QUESTIONS:

- What happens to the frequency of oscillation of the mass-spring system as the spring constant increases?
- What does the graph of f^2 against k suggest about the relationship between the frequency and the spring constant? Explain

Frequency and Mass

1. Set the following parameters:

Simulation	PAUSED
Mass	50 g
Spring Constant 1	LARGE
Mass Equilibrium	Enabled
Movable Line	Enabled
Gravity	Earth
Damping	None
Simulation Speed	Slow
Starting position from equilibrium line	30 cm

2. Run the simulation. Determine the frequency of oscillation of the 50-g mass.

3. Using the parameters in (1), make several trials, in each time increasing the mass of the object by 50 g until the mass equals 300 g. For each trial, make sure to set the starting position from the equilibrium line to 30 cm. Enter your measurements in Data Table 3

Data Table 3

Mass (g)	Frequency of Oscillation (Hz)
50	
100	
150	
200	
250	
300	

4. Plot the values of the frequency against the values of the mass. Describe the graph formed.

5. Plot the values of f^2 against the values of 1/m. What is the shape of the graph?

QUESTIONS:

- What happens to the frequency of oscillation as the mass of the oscillator increases?
- What does the graph of f^2 against 1/m suggest about the relationship between f and m? Explain.

CONCLUSION(S)

GOING FURTHER

In the simulation, the mass of the blue and the red weights are not known. Develop a procedure on how you will determine the masses of these objects.