Simple Harmonic Motion

Purpose:

To conduct a simple harmonic motion analysis for a vibrating mass on a vertical spring.

Getting Ready:

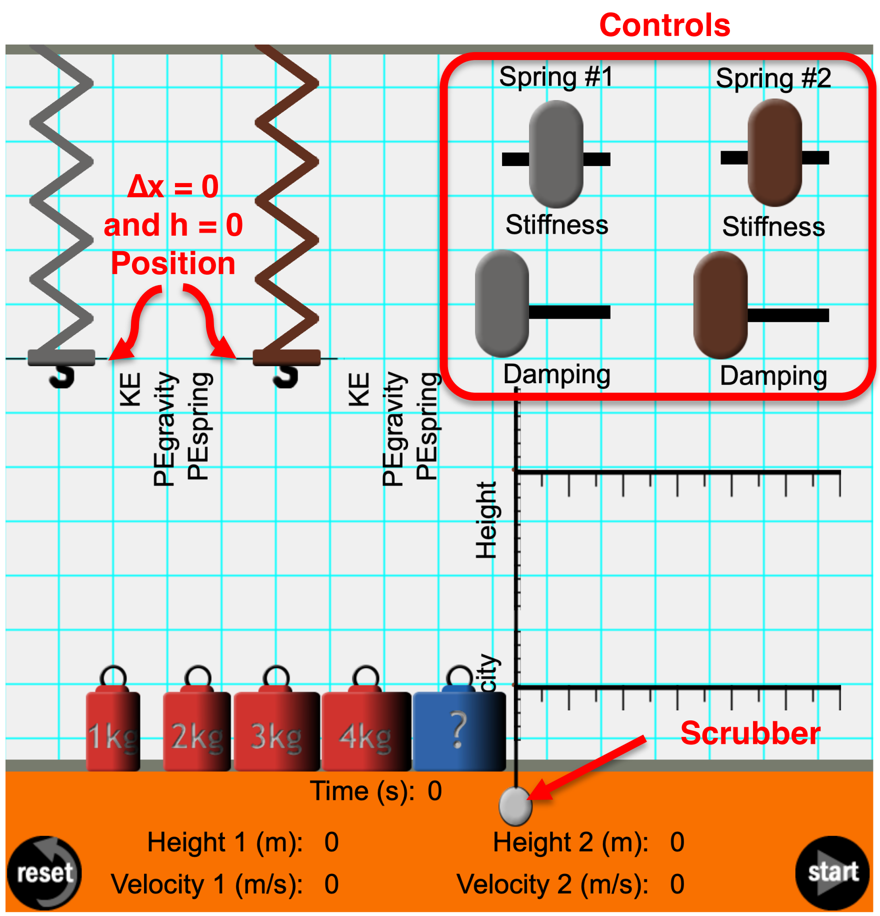
Navigate to the **Vibrating Mass on a Spring** Interactive at The Physics Classroom website:

http://www.physicsclassroom.com/Physics-Interactives/Waves-and-Sound/Mass-on-a-Spring

Navigational Path:

www.physicsclassroom.com ==> Physics Interactives ==> Waves and Sound ==> Vibrating Mass on a Spring

Getting Acquainted:



Once you've launched the Interactive and resized it, experiment with the interface. Notice there are two springs – a grey one and a brown one. Drag a mass onto the end of a spring, pull it down, and release. Click/tap the **Start** button to view the plot of its vertical position and vertical velocity as a function of time; observe that their graphs are color coded - consistent with the color of the spring. **Reset** the system and try a different spring or a different mass. Notice that the time, height, and velocity of the mass are reported below the graphs. Observe how the vertical line (i.e., the scrubber) on the graph can be moved along the axis in order to obtain values of height and velocity at various times on the graph. Notice that there are bar charts positioned between the two springs that indicate the kinetic energy (KE), the gravitational potential energy ($PE_{gravity}$) and the elastic potential energy (PE_{spring}); these update in *real-time* as the mass is vibrating. Finally, observe that there are two controls for each spring – one for its **Stiffness** and one for the **Damping** effects. The conventions used are that the **h = 0 location** is where the spring naturally stretches to without a mass (equivalent to the x=0 location) and the upward direction is the positive direction.

Part A: What Does Damping Do?

1. Adjust the **Damping** slider for Spring 1 to a maximum (far right).
2. Drag a 1-kg mass to Spring 1; pull the mass down and release. Observe the motion of the mass on the spring when there is maximum damping.
3. Drag the **Damping** slider for Spring 1 to zero (far left). Pull the 1-kg mass down and release again. Observe the zero-damping motion of the mass on the spring.
4. Compare and contrast the vibrational motion with and without damping.

5. As you have observed, a vibrating mass eventually stops when damping is present. As such, if you ever need to stop a vibrating mass, momentarily turn damping on.

Part B: Effect of Mass on the Equilibrium Position

1. Tap the **Reset** button. Make sure **Damping** is off.
2. Drag a 1-kg mass onto the spring. Slowly drag it down and release. Using either the **Damping** function or your mouse, attempt to settle the mass to a resting position. We will call this the **equilibrium position**. At this position, the upward spring force balances the downward force of gravity. Identify the **stretch length** (**Δx**) of the spring for this equilibrium position. It is equivalent to the height relative to the zero position (dashed line) and listed at the bottom of the simulation. Record in the table.
3. Repeat for the other three masses and record the stretch length for each equilibrium position.
4. Describe the effect of mass on the Δx value for the equilibrium position.

Mass (kg)	Δx (m)
1.0	
2.0	
3.0	
4.0	

Part C: What Does Stiffness Do?

1. There are five different levels of spring **Stiffness**. Place the 1-kg mass on the spring and pull it down to its equilibrium position where it is at rest.
2. Drag the **Stiffness** slider to a minimum and settle the mass on its new resting position. Make a note of the stretch length (Δx) at the equilibrium position.
3. Repeat the procedure for a spring with maximum **Stiffness**. Repeat for as many stiffness values as needed in order to answer the question …

   Describe the effect of stiffness on the stretch length (Δx) that a spring-mass system will have when it is at its equilibrium position.

Part D: Kinematic Analysis of Simple Harmonic Motion

1. Reset the Stiffness to its middle setting. Drag a 2-kg mass onto the spring and settle it on its **equilibrium position** using either your mouse or the **Damping** function.

   Is there a Δx value at the equilibrium position? Circle: Yes No

   Does the mass experience a spring force at equilibrium? Circle: Yes No

   Does the mass experience a net force at equilibrium? Circle: Yes No

2. Pull the mass down below the equilibrium position and release. As the mass is vibrating up and down, tap on the **Start** button to acquire a plot of height as a function of time and velocity as a function of time. Describe the shape of the plots.

3. Analyze the two plots and accompanying animation and use them to complete the following statements. Drag the **Scrubber** (vertical bar on the graph) from along the graph to assist in your analysis.

   - The velocity is 0 m/s when the mass is located ….
     a. at its *middle position* b. only at its lowest extreme position
     c. at both its lowest and highest extreme positions.
   - The velocity is a maximum, positive value when the mass is located ….
     a. at its *middle position* b. at its lowest extreme position
     c. at its highest extreme position
   - The velocity is a maximum, negative value when the mass is located ….
     a. at its *middle position* b. at its lowest extreme position
     c. at its highest extreme position

Part E: Energy Analysis of Simple Harmonic Motion

1. Tap the **Reset** button. Drag a 2-kg mass onto the spring and settle it on its **equilibrium position** using either your mouse or the **Damping** function. Recall that the dashed line in the simulation window represents the position of $\Delta x = 0$ and $h = 0$.
2. Answer the following questions for when the object is at rest at the equilibrium position:

   Is there a Δx value at the equilibrium position? Circle: Yes. No

   Does the mass possess elastic PE at this position? Circle: Yes. No

   Does the mass possess gravitational PE at this position? Circle: Yes. No

   The gravitational PE is _____ (+, -, or 0) and the elastic PE is _____ (+, -, or 0).

3. As precisely as you can, make a note of where the mass is when at the equilibrium position. Then pull the mass down about 1-2 squares (no more) and release. If the mass vibrates upward above the x=0 mark, then stop it from vibrating and repeat. Once is its vibrating up and down but never higher than the x=0 mark, tap the **Start** button. Once the graph is completed, use the **Scrubber** to rewind through the cycles. Study the energy bar charts and answer the following questions:
   - At what location is the KE a 0 value?
     a. Never b. At the lowest point c. At the highest point d. At equilibrium
   - At what location is the PE_{grav} a 0 value?
     a. Never b. At the lowest point c. At the highest point d. At equilibrium
   - At what location is the PE_{spring} a 0 value?
     a. Never b. At the lowest point c. At the highest point d. At equilibrium
   - At what location is the PE_{spring} the largest?
     a. Never b. At the lowest point c. At the highest point d. At equilibrium
   - Is the PE_{spring} ever a negative value?
     a. Never b. At the lowest point c. At the highest point d. At equilibrium
   - As the height ↓ (the Δx ↑) PE_{spring} _____ (↑or ↓) and PE_{grav} _____ (↑or ↓).

4. In #3, the spring is always stretched. It is never compressed relative to its natural stretch length (the Δx=0 position). That is, the mass never rises above the dashed line and causes spring compression. In this step, pull the mass down farther so that it travels higher and compresses the spring. Study the energy bar chart. How does this change the behavior of the PE_{grav} bar and the PE_{spring} bar?