Simple Harmonic Oscillator

Simulation Used: Masses and Springs from the PhET at the University of Colorado.

- **Theory:** When an object is hanging from a spring, the spring stretches to a new length, for which the gravitational force on the object is balanced by the elastic force by the spring.

  $$mg - k\Delta y = 0$$

  The stiffness of the spring, therefore, can be determined by plotting the dependence of the stretching, y, vs. the hanging mass, m.

  $$\Delta y = \frac{g}{k} m$$

  The graph should be a straight line with a slope equal to:

  $$slope = \frac{g}{k}$$

  Conversely, you can use the slope to determine "g" if you know the stiffness of the spring.
  For objects removed slightly from equilibrium, the period of oscillations is given by:

  $$T = 2\pi\sqrt{\frac{m}{k}}$$

  Thus, if you measure the period of oscillations for different masses, and plot the dependence of "T^2 vs. m", the graph should be a straight line with a slope equal to:

  $$T^2 = \frac{4\pi^2}{k} m$$

  Once again, the stiffness "k" can be determined from the slope.

- **Initial settings:**
  - Open a stopwatch by clicking on the box "Stopwatch" from the menu on the right.
  - Make sure the "Earth" and "real time" radio buttons are selected.
  - Make sure the friction indicator is in the middle.

- **Activity 1: Determine the stiffness constant, k, of the spring 3.**
  - Additional Settings:
    - Drag the meter stick so that the "0" mark is at the same level as the bottom end of the spring (the dashed line)
  - Perform the experiment:
    - Drag a 50-g weight and hang it from the spring. Wait until the weight has stopped moving and the system is in equilibrium.
    - Record how much the spring has stretched.
    - Repeat the procedure for the 100-g and 250-g weights.
  - In your lab notebook, write down the data in the following format:

mass (g)	Δy (cm)
0	0
50	
100	
250	

  - Results:
    - Plot the dependence "Δ y vs. m". **Make sure you have converted in SI first!**
    - Find the slope of the graph. You can use your calculator, spreadsheet, or you can go to this website. If you choose the latter, clear the data and type in your own data. The slope of the

line is given by "m" in the box below the graph.
- Calculate "k" from the slope. Write down the result in your notebooks. Make sure you keep at least 3 significant digits in your result.

slope	
k (N/m)	

- **Activity 2: Determine the stiffness constant, k, of the spring 3 (2-nd method).**
  - Additional Settings:
    - Select "1/2 time" radio button on the right. The time measured by the stopwatch is going to be the real time, only everything is slower so it is easier to count.
    - Drag the friction indicator to the far left, so that the spring is frictionless.
  - Perform the experiment:
    - Hang a 50-g weight. Drag it about 5 cm below the equilibrium point and release it.
    - Measure the time for 20 oscillations. Write it down in a table in your notebook. The period is 1/20 of the total time.
      Note. Make sure you count 20 full oscillations (and not 19!)
    - Repeat the measurement two more times. Average the time.
    - Repeat the procedure for the 100-g and 250-g weights.
  - In your lab notebooks, write down the data in the following format:

mass (g)	time1 t_1 (s)	time2 t_2 (s)	time3 t_3 (s)	av.time t_{av} (s)	Period T (s)	T^2 (s^2)
50						
100						
250						

  - Results:
    - Plot the dependence "T^2 vs. m".
    - Find the slope of the graph. You can use your calculator, spreadsheet, or you can go to this website. If you choose the latter, clear the data and type in your own data. The slope of the line is given by "m" in the box below the graph.
    - Calculate "k" from the slope. Write down the result in your notebooks. Make sure you keep at least 3 significant digits in your result.
    - Compare the results from Activity 1 and Activity 2. How well do they agree?

Slope from Activity 1	k_1 (N/m)	
Slope from Activity 2	k_2 (N/m)	
average k (N/m)	k_{av} (N/m)	
Percent difference (%)	$\lvert k_1-k_2\rvert/k_{av} \times 100\%$	

- **Activity 3: Determine the gravitational acceleration of the Planet X**
  - Additional Settings:
    - Drag the meter stick so that the "0" mark is at the bottom end of the spring (the dashed line)
    - Drag the friction indicator back to the middle. For faster measurements, you can drag the friction indicator further to the right.
    - Select "Planet X" radio button from the menu on the rigth.
  - Perform the experiment:

- Drag a 50-g weight and hang it from the spring. Wait until the weight has stopped moving and the system is in equilibrium.
- Record how much has the spring stretched.
- Repeat the procedure for the 100-g and 250-g weights

- In your lab notebook, write down the data in the following format:

mass (g)	Δ y (cm)
0	0
50	
100	
250	

- Results:
  - Plot the dependence

$$\Delta y = \frac{g}{k} m$$

  - Find the slope of the graph. You can use your calculator, spreadsheet, or you can go to this website. If you choose the latter, clear the data and type in your own data. The slope of the line is given by "m" in the box below the graph.
  - Using your result for "k" from Activity 1, calculate "g" from the slope. Write down the result in your notebooks. Make sure you keep at least 3 significant digits in your result.

slope	
g (m/s^2)	

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