PHYSICS 207

Simple Harmonic Motion Lab

This lab uses PhET Masses and Springs Simulations Lab found at:

Procedure

First, some useful information:

Force on spring (Hooke’s Law) \( F_{sp} = -Kx \)

Minus sign means it is a restorative force; always moving toward its equilibrium or rest position.

\( K \) is spring constant or sometimes called force spring constant, unit of measure: \( Nm^{-1} \)

\( X \) is extension of spring over its normal length/equilibrium position.

Recall weight force (due to gravitational acceleration) \( F_g = mg \), where \( m \) is mass of object and \( g = 9.81 \text{ms}^{-2} \)

Simple Harmonic Oscillation

Angular speed \( \omega = \frac{\theta}{t} \) \( \text{[angle } \theta \text{ measured in radians and time } t \text{ in seconds]} \)

Periodic time (time for a complete oscillation) \( T = \frac{1}{f} \) \( \text{or } T = f^{-1} \)

Angular speed \( \omega = \frac{2(\pi)}{T} = 2(\pi)f \)

Acceleration \( a = -\omega^2 x \) \( \text{[minus sign is because it is a restorative acceleration, this would be shown later]} \)

SHM \( \text{ Force } F = ma \) is equivalent to \( F_{sp} \)

Hence \( -m\omega^2 x = -Kx \)
This leads to $\omega = (K/m)^{1/2}$ also, $K = m\omega^2$

For SHM, position of oscillator is given by:

$X = X_0 \cos(\omega t)$

Velocity of oscillator, $v = X' = -X_0 \omega \sin(\omega t)$

Acceleration of oscillator, $a = X'' = -X_0 \omega^2 \cos(\omega t)$

Potential Energy of spring $E_p = 1/2Kx^2$, same as work $W$ done by spring

Kinetic energy of oscillating mass $E_k = 1/2mv^2$

1. Click on ‘Intro’ window

On screen there should be two equal length springs suspended.

Use Spring 1 for this experiment. Select 3 as Spring Constant for spring 1.

Use default Gravity on Earth.

Check boxes at top right corner for ‘Natural Length’ and ‘Equilibrium Position’.
Select ruler and stopwatch for linear and time measure respectively.

Select 250g mass and attach it to Spring 1. Press red stop button at the side of Spring 1 to stop oscillations.

Measure and record value for extension of Spring 1 with 250g mass attached.

Pull mass downward away from its equilibrium position for an extension between 10 cm and 20 cm and release to begin oscillations.

Use stopwatch to time for ten (10) oscillations. Do two time trials and get average of these two runs.

(a) Determine periodic time, $T$

(b) Determine spring constant using two different methods:

(i) $K = F_{sp}/x$

(ii) $K = 4m(\pi)^2/T^2$
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(c) (i) Is there a difference in your two calculated values?

(ii) Why?

(d) Determine the percent difference.

(e) Determine mass of unknown hook type masses.

2. Vectors

At the base of your screen select ‘Vectors’.

This helps in visualizing all vectors at play in oscillation.


Attach 250g mass and observe vectors during oscillation.

(a) At which point is velocity minimum or zero?

(b) At which point is velocity maximum?

(c) At which point is acceleration zero?

(d) At which point is acceleration maximum?

(e) Is Gravity ever zero?

(f) Is spring force ever zero? When?

(g) What happens when Spring constant is increased?

(h) What happens when Gravity is changed to: (1) Moon (2) Jupiter (3) Planet X

(i) Determine value for gravity on Planet X.

3. Lab

At the base of your screen click on ‘Lab’.

Check boxes at top right corner for ‘Natural Length’ and ‘Mass Equilibrium’. Select ruler and stopwatch for linear and time measure respectively.
Set Spring Constant and Damping such that *Spring Constant is greater than Damping*.

Select known 100g mass and attach it to Spring. Adjust mass measure to value greater than 250g.

Press red stop button at the side of Spring to stop oscillations.

(a) Measure and record value for extension of Spring mass attached.

Pull mass downward away from its equilibrium position for an extension between 10 cm and 20 cm and release to begin oscillations.

(b) Use stopwatch to time for ten (10) oscillations. Do two time trials and get average of these two runs.

(c) Determine periodic time, $T$

(d) Calculate Spring Constant.

(e) Determine energy of spring at the top of oscillation.

(f) Determine energy of spring at equilibrium position.

(g) Determine energy of spring at the lowest point in oscillation.

(h) Determine total energy of system

(i) Show that work done on spring is equal to change in spring potential energy: $mg\Delta h = \frac{1}{2}K(x_2^2 - x_1^2)$

Upon completion of Data Table 1, plot the following graphs:

(1) Spring Constant $K$ (N/m) vs. Distance $X_0$ (extension from equilibrium position in meters, m)

(2) Periodic time squared, $T^2$ vs Mass, $m$ (kg)

Complete Data Table 1 below (you will be able to fill in cells for unknown mass and their spring constants after plotting your graphs).
## Data Table 1: SHM Lab

<table>
<thead>
<tr>
<th>Mass (m) kg</th>
<th>Force (F) = mg (N)</th>
<th>Displacement (d) m</th>
<th>Spring constant (k) = F/d (N/m)</th>
<th>Time for 10 oscillation (t) s</th>
<th>Periodic Time (T = t/10) s</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.10 kg</td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>0.15 kg</td>
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<tr>
<td>0.20 kg</td>
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<tr>
<td>0.25 kg</td>
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<tr>
<td>0.3 kg</td>
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</tr>
<tr>
<td>Unknown mass 1 (smaller)</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<td></td>
</tr>
<tr>
<td>Unknown mass 2 (larger)</td>
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</tr>
</tbody>
</table>

Determine mass of unknown masses using spring constant.

What effect does damping have on the spring?

END OF LAB. 😊