Title: Analysis of oscillation motion using a smartphone

Field: Physics and Astronomy

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Abstract:
This project aimed to design and build a replica set of oscillation motion which could help students to understand basic concepts in physics. In our view, performing experiments and analyzing measured data are effective ways to realize interactive engagement. While some experiments need special equipment, measuring instruments or laboratories, this replica set allows students to use only their smartphones to produce experimental data. Applying their own devices and measuring waves from everyday life can improve student interest in oscillation, while still allowing for precise analysis of data, which can give deeper insight into scientific thinking and provide a good opportunity for inquiry-based learning. In this experiment, the data were first processed by an Accelerometer Meter application, which showed a graph of frictional forces that diminished the amplitude of oscillation until eventually the system was at rest. Next, the independent variables affecting the system were studied to increase the mass and change the pair of springs that had similar spring constants. Then, the effective spring constant of each of the three pairs was measured to be 30.049, 35.518 and 38.618 N/m, respectively. According to the results, the smallest difference was 0.204 % and the largest difference was 7.428%.

Keywords: Oscillation motion, Amplitude, Frictional forces, Smartphone

Introduction:
In the presence of a harmonic force and viscous friction, we can write the net force as:

\[-kx - \gamma x' = mx''\]

Where k is the spring constant and \( \gamma \) stands for the viscous friction coefficient.

Solving the motion equation applying this force leads to an oscillation with exponentially damping amplitude. In this case for the acceleration we get:

\[x(t) = Ae^{-\frac{\gamma t}{2m}} \cos(\omega t + \phi)\]

Where A is the amplitude of the acceleration, \( \frac{\gamma}{2m} \) is the damping constant, and \( \omega \) is the modified circular frequency. In the case of a rolling cart, a damping force arises because of the rolling resistance. This force was treated in analogy with sliding friction, with constant magnitude and direction opposite to the velocity.
Methodology:

First, measure a spring constant using Hooke’s Law and hang the spring with a clamp stand. Next, calculate the length of the changing spring and record the results of the test. Then, design an experiment set with the main elements. Attach the C-shaped hook screws to the cart on both sides. Attach a smartphone holder to a cart with a screw. Hook one spring on the cart and the other end of the spring to both sides of the box. Install the Accelerometer Meter application on the smartphone. After that, measure the acceleration from the Accelerometer Meter application. Our measurements were performed with a smartphone, which had a wide range of sensors and thus is optimal for physics experiments. In this arrangement, the x-axis of the built-in accelerometer sensor was parallel to the direction of the oscillations. Both ends of the cart were connected to springs slightly stretched with fixed ends. Wheels with wheel bearings were rotated on a clean and hard surface and the smartphone was fixed to the cart with the C-shaped hook screws to prevent it from slipping while in motion. At the beginning of the experiment, the cart was moved away from its equilibrium position and then was released. The mass was increased by 100 grams at a time up to 400 grams and repeated. When finished, the pair of the springs that had similar spring constants were changed. Then, the data measured by the acceleration sensor embedded in the smartphone were collected with the accelerometer meter application that was developed by the Keuwsoft Company. Finally, the data was inputed into graphs with a computer program.

Results and Conclusion :

1. Spring constant analysis results.

   Table 1 Shows the spring constant

<table>
<thead>
<tr>
<th>Spring</th>
<th>Spring constant (N/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No.1</td>
<td>15.689</td>
</tr>
<tr>
<td>No.2</td>
<td>15.578</td>
</tr>
<tr>
<td>No.3</td>
<td>17.301</td>
</tr>
<tr>
<td>No.4</td>
<td>17.631</td>
</tr>
<tr>
<td>No.5</td>
<td>19.026</td>
</tr>
<tr>
<td>No.6</td>
<td>19.514</td>
</tr>
</tbody>
</table>

2. The results of the replica set

Fig.1 (a) replica set of oscillation motion (b) attached smartphone on smartphone holder
3. Acceleration measurement results from spring movement on applications

![Graph showing acceleration measurement results](image)

Fig. 2 The graph shows the acceleration of the movement of the spring on the smartphone application.

4. Data analysis with the program on the computer

![Graph showing data analysis](image)

Fig. 3 The graph shows the acceleration of the movement of the spring on the smartphone application.

**Table 2** Shows the parameter from the graph of springs No.1 and No.2

<table>
<thead>
<tr>
<th>Value A</th>
<th>Value B</th>
<th>Value C</th>
<th>Value D</th>
<th>R-Square</th>
<th>k</th>
<th>Percentage error (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.103</td>
<td>0.374</td>
<td>8.307</td>
<td>-1.196</td>
<td>0.97422</td>
<td>31.618</td>
<td>1.122</td>
</tr>
</tbody>
</table>

A is the amplitude, B is the coefficient for rolling resistance, C is the angular frequency, D is the initial phase angle, k is the spring constant and the maximum percentage error is 1.122%. 
5. The mass that affects oscillation motion

From the experiment, a study of the mass that affects the spring constant

![Graphs from fitting in the program computer when increasing mass of the springs by 0, 0.10, 0.20, 0.30, 0.40 kg, respectively.]

Fig. 4 Graphs from fitting in the program computer when increasing mass of the springs by 0, 0.10, 0.20, 0.30, 0.40 kg, respectively.

When increasing mass, the amplitude and angular frequency of vibrations decreased. Due to increased friction, the coefficient for rolling resistance decreased and the effective spring constant from the experiment had an error of 0.473%. The replica was invented to help students understand the basic concepts and instructional media in physics.

References:

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