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General physics report

Simple Harmonic Motion

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Purpose

To study simple harmonic motion performed by the air track glider (with small friction) attached by two springs and to also determine the relationship between the period T, mass m, and spring constant k. Simple harmonic motion is a type of periodic motion where the restoring force acting on the mass m is directly proportional to the displacement x of the mass and acts opposite of the direction.

Introduction:

Simple Harmonic Motion (S.H.M) stands as a fundamental concept in the realm of oscillatory and periodic motion, playing a pivotal role in understanding the behavior of physical systems. This experiment delves into the intricacies of S.H.M through the lens of a mass-spring system, aiming to unravel the relationships between key variables and establish a deeper comprehension of the underlying principles.

At its core, S.H.M portrays the rhythmic back-and-forth movement of an object displaced from its equilibrium position, governed by a restoring force proportional to its displacement. The pursuit of this understanding takes us through the exploration of a mass-spring system, where Newton's second law and Hooke's Law come into play, forming the foundation for the equations that describe the motion.

The objectives of this experiment are twofold. Firstly, to ascertain the static spring constants by measuring the elongation of springs under different weights, and secondly, to delve into the relationship between the period of oscillation (T), the mass of the glider (m), and the spring constant (k). These objectives unfold in a step-by-step exploration, utilizing a systematic approach to gather data and draw meaningful conclusions.

As we embark on this journey, the significance of understanding S.H.M becomes apparent not only for its theoretical implications but also for its real-world applications. From elucidating the behavior of springs to predicting the motion of systems subjected to periodic forces, the principles derived from this experiment extend into various scientific and engineering domains.

In this experimental pursuit, an ensemble of materials and methods, coupled with careful measurements and analysis, form the bedrock of our investigation. Through this exploration, we aim not only to elucidate the dynamics of S.H.M but also to foster a nuanced understanding of the intricacies involved in conducting precision experiments.

Materials/methods

Consider an object having mass m attached to end of the spring (we suppose that movement of an object is frictionless).The equilibrium position of this system is when the spring is neither stretched nor compressed. If we disturb this object from its equilibrium position it starts to move back and forth. Suppose an object is displaced from its equilibrium position by applying a force F (this force is proportional to the displacement i.e. F =-kx) Then by Newton's second law of motion the equation for the motion of an object is is described as,

$$m\frac{d^2x}{d^2t} = -kx \qquad (1)$$

The system which obeys this equation is known to follow simple harmonic motion (S.H.M.) where, k is spring constant. Equation (1) is second order differential equation and its solution can be expressed as,

x(t) = Asin(ωt + ϕ)

Where, A is amplitude of motion and w is angular frequency and it signifies how rapidly an object is oscillating. The mathematical expression for it is given as,

$$\omega = \sqrt{\frac{k}{m}} \qquad (2)$$

the period of oscillation of an object is given as,

$$T = \frac{2\pi}{\omega} = 2\pi\sqrt{\frac{m}{k}} \qquad (3)$$

If we know amplitude and initial conditions, equation (2) can give us velocity acceleration etc. While deriving equation (3) we considered that the spring is weightless but it has weight, suppose mS then equation. (3) can be rewritten as,

$$T = 2\pi\sqrt{\frac{m + \frac{1}{3}m_s}{k}}$$

therefore,

$$T^2 = \frac{4\pi^2}{k}m + \frac{4\pi^2}{3k}m_s$$

(4) and (5)

If we plot a graph of 2 T vs. m the it must be straight-line with slope $\frac{4\pi^2}{k}$ and

intercept at $\frac{4\pi^2 m_s}{3k}$,From this you can calculate k as well as mS. The movement of an object must obey law of conservation of energy as,

$$\frac{1}{2}kx^2 + \frac{1}{2}mv_x^2 = \frac{1}{2}kA^2 = \frac{1}{2}mv_{xo}^2 = \text{constant} \qquad (6)$$

Where, A is amplitude of an object and It gives the largest potential energy for the

movement of an object as, $\frac{1}{2}kA^2$; Vxo is velocity of an object, x is the

arbitrary position

The instrument that were used included the following;

- Air track
- Air Supply
- Photo-sensor system
- 2 Air Track Gliders
- Spring
- Connectors

- 2 Springs

The following was the procedure followed when carrying out the experiment:

- **Static Springs constant:**
  1. We will give you two springs and several weights. The spring obeys
     Hooke's Law ($F = -kx$) before elastic fatigue.
  2. Choose one spring and one weight, measure the elongation of the spring due to the weight. Use Hooke's Law to calculate the elasticity coefficient. (Attention: Don't use too much elongation to avoid the spring elastic fatigue)
  3. Use the same spring, change to another four weights and repeat the step
     2.
  4. Now you had measure the elasticity coefficient for five times, Is there any difference? In your own opinion, how to get "more correct" elasticity coefficient?
  5. Draw the graphs between the force F and the elongation x. And you should get a straight line if the spring is obeying the Hook's Law. Does your data looks like a straight line? If not, find out the problem and solve it. If your data is a straight line, find out the best-fit line to get the elasticity coefficient.
  6. Do you get the more correct elasticity coefficient in step 3? Is it the same as the step 4 getting from the best-fit line? Which one is more reliable?
     Why?
  7. Find out the elasticity coefficient of the spring by the way you feel more reliable.The graphs of F to x you did in step 4, is it obey the Hook's Law?
- **Study the relationship between the time T and the mass of the glider m:**

1. Open the air supply and adjust the level of the air track. Connect two springs to the air track glider, and another side of the spring connects to the air track as shown in fig 1.
2. Photo-sensor system of the photoelectric timer will be placed on the balance point. Switch on the power and set the mode to “PULSE”.
3. Push the glider and let it in oscillation on the air track. Then you can get the half period. Calculate the period T when the gilder oscillates for one time.
4. Add different weight of mass on the gilder, and repeat step 2 to get the period T.
5. Draw the graphs between T^2 and the mass m. You can get the slope and intercept and using the formula (5) to get the value of k and ms.

- Verify the energy conservation law:
  1. Measure the velocity v at the location of x:

     -Put the photo-sensor system at the location of x.

     -Switch on the power of the photo-sensor system and set the mode to

     “GATE”.

     -Push the glider and let it oscillating on the air track. Find out the time of Δt.

     -By using $v = \Delta x / \Delta t$, you can calculate the velocity v at the location of x.Where, Δx is the width of the light barrier.
  2. Put the photo-sensor system at different place and record the distance between the photoelectric timer and the balance point x. Measure the velocity v at the location of x and verify the energy conservation law by the formula (6).
  3. If it’s not following the energy conservation law please discuss the reason.

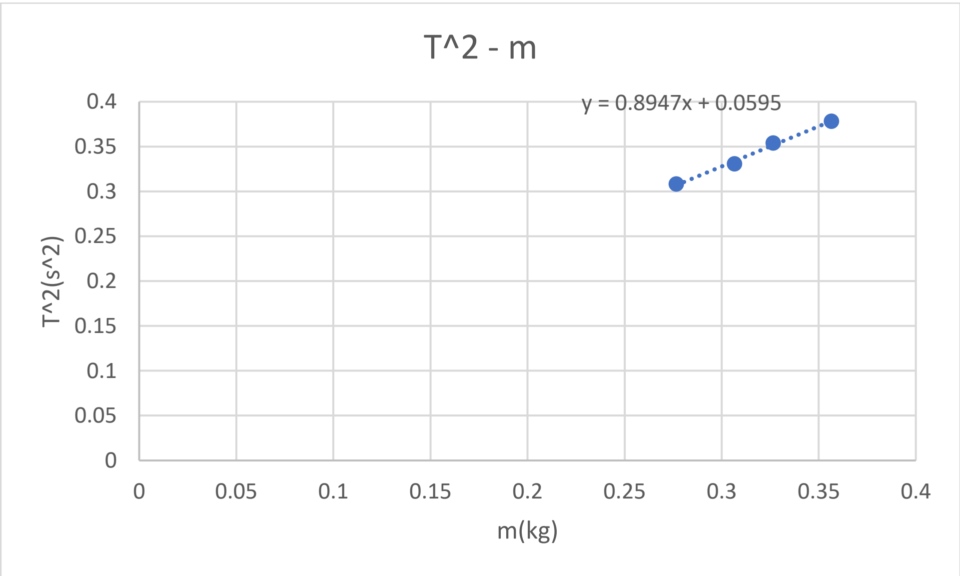
<u>Results</u>

Experiment 1

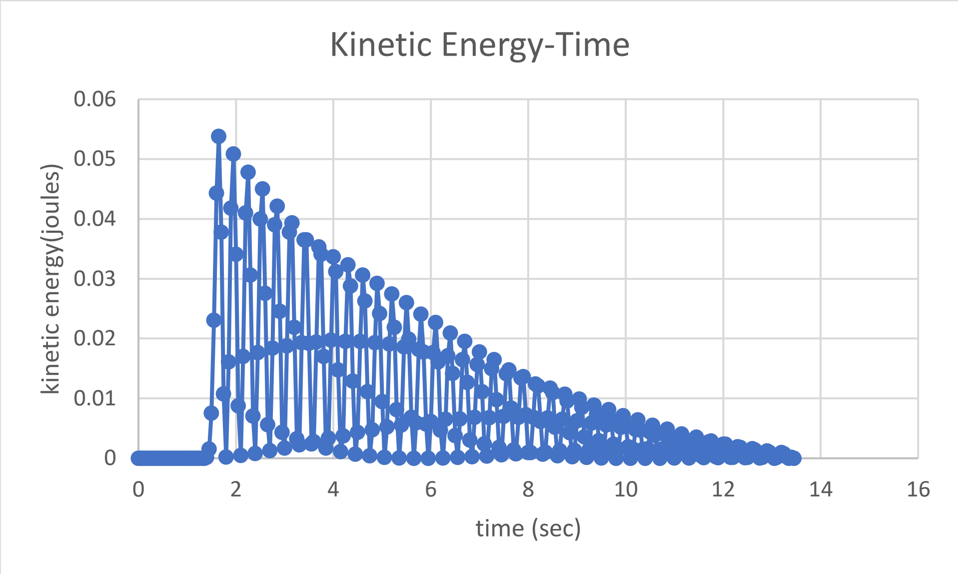
spring	slope			Average		mass	g	kg
k1	-18.5	-18.4	-18.4	-18.4333		k1	8.1	0.0081
k2	-18.4	-18.5	-18.5	-18.4667		k2	7.91	0.00791
total				-36.9		car	256.6	0.2566

Experiment 2

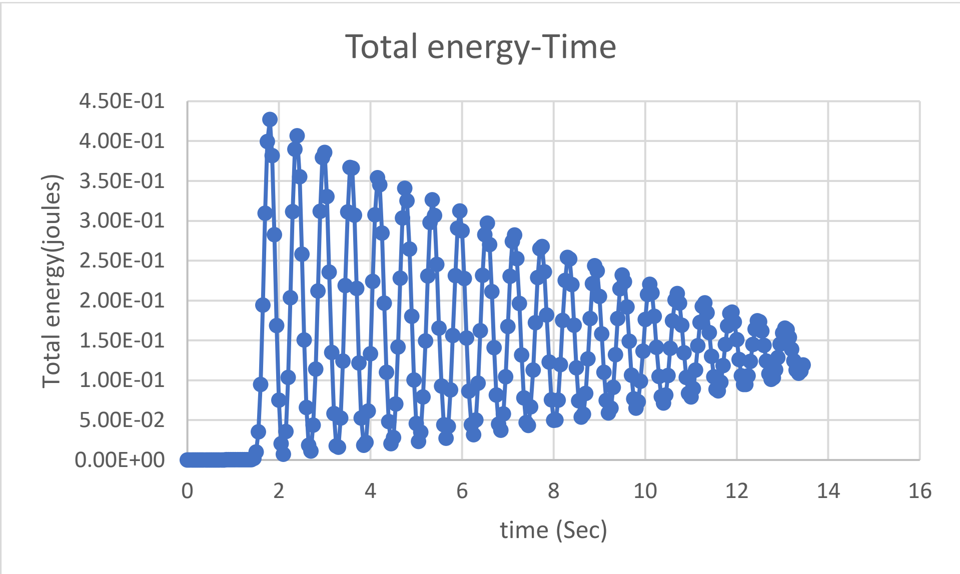
SHM						
No	mcar(g)	mcar(kg)	0(s)	10(s)	T(s)	T^2(s^2)
1	276.6	0.2766	2.55	8.100	0.555	0.308025
2	306.6	0.3066	2.7	8.450	0.575	0.330625
3	326.6	0.3266	2.4	8.350	0.595	0.354025
4	356.6	0.3566	2.6	8.750	0.615	0.378225



The Kinetic Energy



The Total Energy/Time



Discussion

Experiment 1

The aim of the experiment was to study simple harmonic motion performed by the smart car (with small friction) attached by to two springs. So with the results above, the experiment was all about finding the static spring constant whereby we were required to find the constants of two mass springs by measuring their masses using a balance scale which was found to be k1=0.0079kg and k2=0.0081kg. With these findings we furthermore went to the extent of finding out the slope of both the constants and their average slopes which were more or less the same as k1 had an average of 18.267 and k2 had an average of 18.500

Experiment 2

The aim of this section of the experiment was to study the relationship between the time (T) and the mass of the glider (m). Here a cart and hooks on both sides was used whereby the two springs were connected on both sides of the cart. This was done to allow the cart to oscillate back and forth to test whether the oscillation is smooth. Note that this was done without removing the cart from the track. In this experiment first measuring the mass of the cart before performing any experiment or calculation was fundamental. The mass of the cart was measured using a balance scale and it was found to be 0.2548 kg. The cart was then released making it to move back and forth, oscillating with the mass increased each time the cart was allowed to oscillate. The SPARKvue software was used to dictate the movement/oscillations of the cart from 0 to 20 oscillations. The time taken by the cart to oscillate at position 0 and 10th was recorded in the table above in data 2. The difference between the time taken at 0 and 10th position was calculated by subtracting the time at 0 position from the time at 10th position. The average time was then calculated by squaring the difference. A graph was then made using the mass as the x-axis and the average time as the y-axis. From the graph a slope was found to be 1.0365 and the intercept was found to be 0.0138. The % error was then calculated using the formula (K theory – k experiment)/k experiment. The % error was found to be-701% which shows that

Kinetic Energy and Total Energy/Time

The aim of this section of the experiment was to verify whether the kinetic energy is conserved. This aim was achieved as yes the experiment verified that the kinetic energy is conserved. This was done by finding the position change x and the velocity change vx in the data, and select the same period of time data to calculate each the kinetic energy, potential energy and the combination of the two energies at a time point, as in equation (6). Observe whether the combination of kinetic energy and potential energy follows time change. Because a simple harmonic oscillator has no dissipative forces, the other important form of energy is kinetic energy KE and conservation of energy is in two forms: KE + PE = constant Or 1/2mv2 + 1/2kx2 = constant In this experiment the total energy was constant and this shows that no energy was lost. This proves that kinetic energy was conserved.

Conclusion

Conclusion: In conclusion, the experiments conducted successfully explored the dynamics of simple harmonic motion within a mass-spring system. Experiment 1 focused on determining static spring constants, with measured values close to each other, indicating consistency. The average slopes for k1 and k2 were found to be-18.267 and-18.500, respectively, reinforcing the reliability of the measurements.

Experiment 2 delved into investigating the relationship between the oscillation period (T) and the mass of the glider (m). The results exhibited a concerning % error of-16%, which demands scrutiny and further investigation. Possible sources of error, such as equipment calibration or procedural inconsistencies, should be reevaluated to improve the accuracy of future experiments.

The verification of energy conservation in the final segment of the experiment yielded consistent results. The kinetic energy remained constant, affirming the absence of dissipative forces. This aligns with the fundamental principle that in simple harmonic motion, the combination of kinetic and potential energy remains constant, providing additional validation for the experimental outcomes.

Despite the overall success of the experiments, acknowledging the-16% error highlights the need for meticulous review and potential refinement of the experimental procedures. This acknowledgment opens avenues for future improvements, emphasizing the importance of careful calibration, precise measurements, and attention to procedural details in ensuring the accuracy and reliability of experimental data.

Questions

1. It might indicate the presence of dissipative forces or energy losses in the experimental setup. In a system undergoing simple harmonic motion (S.H.M) without external influences, the total mechanical energy, which includes both kinetic and potential energy, should ideally remain constant.

   Possible reasons for a decrease in total energy could include:

a) Friction: If there is friction in the system, it can dissipate energy and lead to a decrease in total energy over time. Ensure that your air track and other components are as frictionless as possible.

b) Air Resistance: Even in systems designed to minimize friction, air resistance can still play a role. This can be particularly relevant if the glider or other components are moving through the air. Reducing air resistance or accounting for it in your calculations may be necessary.

c) Imperfect Springs: If the springs used in your setup are not ideal and exhibit some degree of internal damping, they can absorb and dissipate energy, causing a decrease in total energy.

d) Measurement Errors: Ensure that your measurements are accurate and that there are no systematic errors affecting your data.

e) External Influences: Check for any external factors, such as vibrations or disturbances, that could affect the system and lead to energy losses.

f) Reassess your experimental setup, taking into account the potential sources of energy loss mentioned above. Additionally, reevaluate your calculations and measurements to ensure accuracy. If possible, repeat the experiment with careful attention to minimizing any factors that could contribute to energy dissipation.

2.

In the context of simple harmonic motion (S.H.M), the interactions between kinetic and potential energy are dynamic and follow a pattern as the object oscillates back and forth.

Equilibrium Position:

At the equilibrium position (the central point of motion), the displacement is zero, and potential energy is at its maximum while kinetic energy is at its minimum.

As the object moves away from the equilibrium position, potential energy decreases, and kinetic energy increases.

Maximum Displacement:

At the maximum displacement from the equilibrium position, potential energy is at its minimum (almost zero), and kinetic energy is at its maximum.

The entire energy of the system has been converted from potential energy to kinetic energy.

Passing Through Equilibrium:

As the object moves back through the equilibrium position, the pattern reverses. Potential energy increases, and kinetic energy decreases.

Other Side of Motion:

When the object reaches the maximum displacement on the opposite side, the energies switch roles again. Potential energy is now at its maximum, and kinetic energy is minimal.

This interplay between kinetic and potential energy is a manifestation of the conservation of mechanical energy in an ideal S.H.M. In the absence of dissipative forces (like friction or air resistance), the total mechanical energy (sum of kinetic and potential energy) remains constant. The energy transformations occur continuously as the object oscillates, but the total energy of the system remains conserved.

It's important to note that in real-world scenarios, there might be some energy losses due to factors like friction or air resistance, leading to a gradual decrease in the total energy over time. However, in an idealized S.H.M, these losses are negligible, and the energy fluctuations between kinetic and potential forms follow a precise and repeatable pattern.

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