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Virtual experiments of Physics using Scilab

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Abstract: *There are certain areas of Physics where different experimental phenomena are explained using some theoretical concepts. It is often said that a certain theory is able to reproduce experimental results. Some of them can be verified easily, but some theories have very complex computations that cannot be solved easily, and so end results are shown directly by graphs, final values, etc. But as Richard P. Feynman[1] said 'What I cannot create, I do not understand', here we have tried to design experiments using theoretical concepts by writing simple programs, that allow students to observe the results and finally verify them by the available results. All this has been done using Scilab, which is open-source scientific computation software that can be used to perform numerical computations. It is easy to use even for people that have no previous programming experience.*

In this paper we have explained one such virtual experiment which is related to the study of the linear harmonic oscillator in which the student is able to observe the variation produced in the oscillation when mass and spring constant is varied and damping is introduced. Students can visualize each variation produced and interpret the result in a very easy manner. Several other experiments can also be designed by students themselves and make concept learning easier.

Keywords: Virtual lab, Scilab, open source, Linear Harmonic oscillator, Damping

Introduction

In Physics theory and practical go side by side. Theoretical learning provides us knowledge which is the base of doing anything practically. Theoretical learning tells us what the knowledge is about and practical learning is about how the knowledge was learned. Anything done practically can be dangerous sometimes without theoretical learning. But theoretical knowledge without practical is of no use. So to have a perfect learning experience one should gain both practical and theoretical knowledge.

In a virtual theoretical laboratory experiment, the students are able to gain a conceptual understanding of fundamental physics. They are able to interpret, in a simple way, the representation of physical quantities such as numbers, equations and diagrams, and are able to solve physics problems. In this way, they strengthen their understanding of practical knowledge.

There have been several efforts to introduce the concept of virtual labs to enhance the knowledge of Physics. Virtual labs [2]a project that has been initiated by MHRD, Govt. of India aims to provide remote access to Laboratories in various disciplines of Science. Similarly Praxilabs [3], Virtual Labs by Merlot [4], online labs for schools [5] are some other simulation platforms where students can perform virtual experiments. Many apps [6-7] that help students to understand Physics are also available for use.However all these platforms provide a fixed method of performing an experiment and does not allow any variation.

In this paper,we have explained a virtual experiment that is related to the study of the linear harmonic oscillator in which the student is able to observe the variation produced in the oscillation when mass and spring constant is varied and damping is introduced. Students can visualize each variation produced and interpret the result in a very easy manner. Also it can suitably change the program to view different results.

Objective

One of the central problems in physics is the linear harmonic oscillator. It can be used to understand the concept of springs, pendulums with small amplitudes, behavior of some electronic circuits and even some quantum mechanical phenomena. These can further be associated with problems involving a large number of harmonic oscillators or even used to investigate the behavior of coupled oscillators.

A very good example that everyone has observed is a playground swing. Each one of us has an intuitive understanding that a swing moves to & fro and if the rider drags his feet or due to air friction, it finally stops. This movement of swing can be approximated as sinusoidal motion and can therefore be considered as simple harmonic motion. Due to frictional forces damping occurs.

The main objective of this paper is to understand the behavior of objects in simple harmonic motion by examining the behavior of alinear harmonic oscillator system. In order to fulfill our main objective certain sub-objectives have been taken up. These include study of a linear harmonic oscillator and observe the variations produced in the oscillations when mass and spring constant of the system is varied. It also includes study of change in behaviour of linear harmonic oscillator when damping is introduced and damping coefficient is varied.

Requirements for virtual experiment

- First and foremost theoretical model that explains linear simple harmonic oscillator classically.
- Second, computational software to carry out the theoretical calculations.
- In this paper we have used SCILAB [8] which is open source scientific and numerical computation software. It has been chosen as it is free to download and uses very simple programming. Other similar soft wares [9-11] can also be used.

Theoretical concept

Before beginning any experiment in laboratory, virtually or through simulation it is necessary to develop an understanding of the theoretical model being employed so as to get clarity of what we have to observe.

A simple harmonic oscillator is a system that experiences a restoring force F when displaced from its mean equilibrium position. This force F is proportional to the displacement x from its mean position.

$\vec{F} = -kx$ and $\vec{a} = -\frac{k}{m}x$ where k is a positive constant.

If F is the only force acting on the system, the system is called a **simple harmonic oscillator**, and it undergoes simple harmonic motion to and fro about its mean position. The oscillations produced have constant amplitude and a constant frequency[12].

If a frictional force or damping is also present, then sucha harmonic oscillator is described as a **damped oscillator**. In this case

$\vec{F} = -kx - \mu\frac{dx}{dt}$ or $\frac{d^2x}{dt^2} + \frac{\mu}{m}\frac{dx}{dt} + \frac{k}{m}x = 0$

Depending on the friction coefficient, the system:

- Oscillates with a frequency lower than in the undamped case where its amplitude decreases with time (under damped oscillator).
- Does not oscillate and decays to the equilibrium position, without oscillations (over damped oscillator).
- At a particular value of the friction coefficient, the boundary solution of an under damped oscillator and an over damped oscillator occurs at same point and this condition is called critically damped.

Steps to follow

1. Writing a program for studying linear simple harmonic oscillator in scilab.
2. Keeping k= constant vary m and keeping m= constant vary k, obtain time period along with graph between x and t for each case in linear simple harmonic oscillator.
3. Interpret the results obtained.
4. Next modify the above program for damped linear simple harmonic oscillator.
5. Vary damping coefficient to obtain conditions for under damping, critical damping and over damping.
6. Observe the graphs obtained and interpret the results.

Observations

Parameters chosen for linear simple harmonic oscillator---

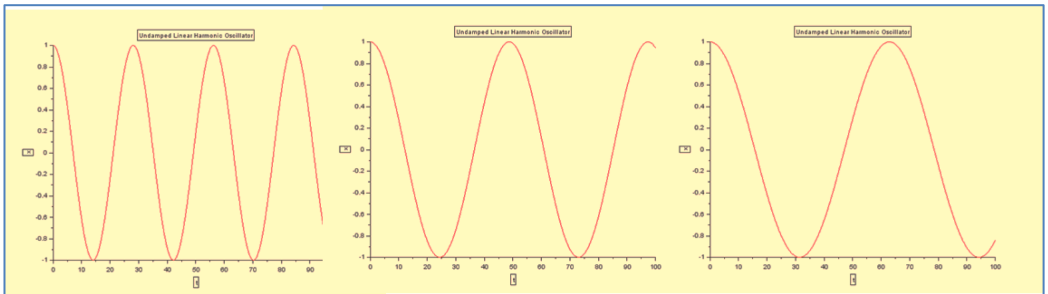
At t=0, x=1, (dx/dt) =0, Scilab function chosen = Ode(x0;x0p;t0;t;f)

Parameters chosen for damped linear simple harmonic oscillator---

At t=0, x=1, (dx/dt) =0, Scilab function chosen = Ode(x0; x0p; t0; t; f)

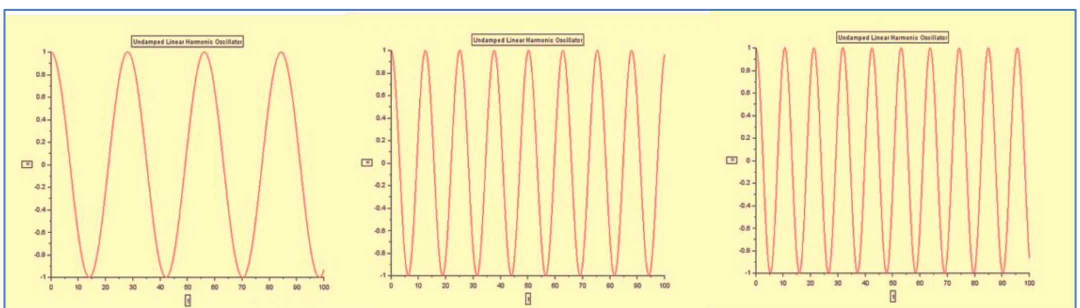
Table 1: Time period obtained for undamped case

Keeping spring constant (k= 0.1) constant		Keeping mass (m= 2) constant	
Mass	Time Period	Spring constant	Time Period
2	28.0993	0.1	28.0993
6	48.6693	0.5	12.5663
10	62.8318	0.7	10.6205



k= 0.1, m=2 k= 0.1, m=6 k= 0.1, m=10

Fig 1: Variation in frequency when k is constant and m is varied for undamped case



k =0.1, m=2 k =0.5, m=2 k =0.7, m=2

Fig 2: Variation in frequency when k is varied constant and m is constant for undamped case

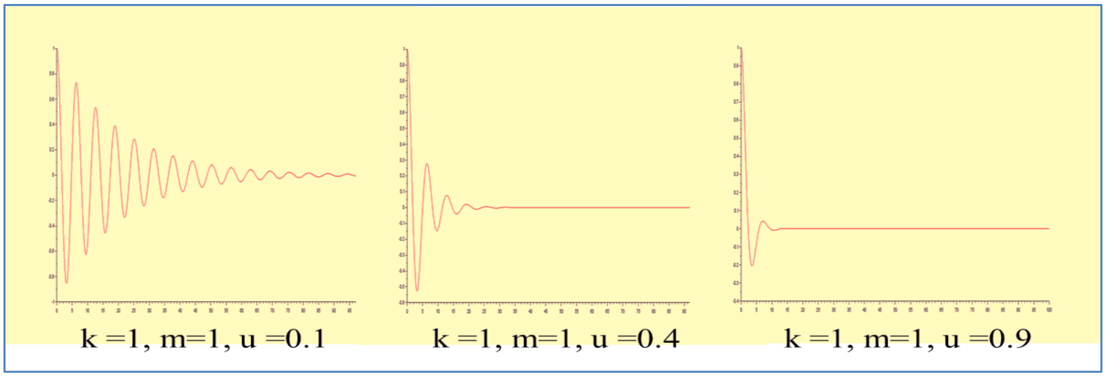


Fig 3: Variation in frequency when k and m are constant and u varied for under damped case

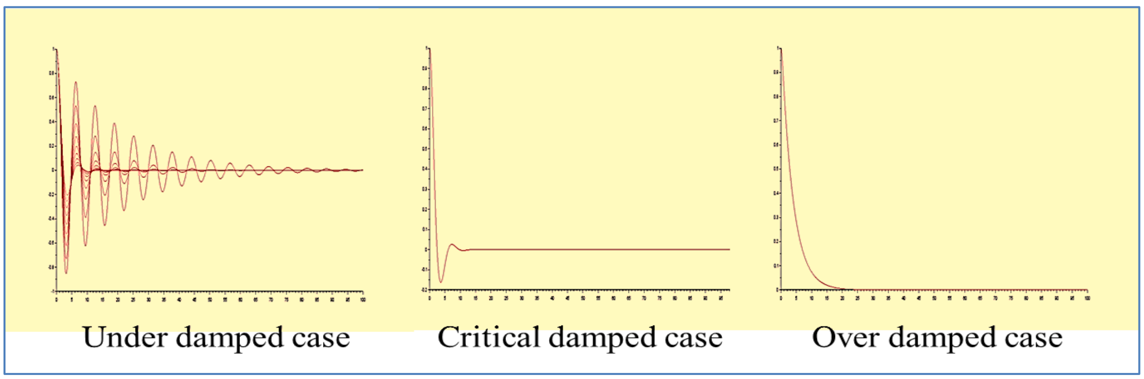


Fig 4: Variation in frequency damping coefficient is varied for wide range

Interpretation of observed results

It is observed as spring constant is increased keeping mass constant, time period increases for undammed harmonic oscillator. Also if spring constant is kept constant and mass is varied, time period decreases for the same case. The motion is oscillatory and change in frequency can be observed from fig 1 and fig 2. The amplitude of oscillations for both cases remains constant.

It is also observed when both spring constant and mass are kept constant and damping is introduced, the motion is still oscillatory but amplitude of oscillations decrease exponentially with time as can be observed from fig 3. Fig 4 shows that as damping coefficient is increased slowly from 0.1 to 6 for k=1 and m=1 we can observe underdamped, critically damped and overdamped cases. For overdamped case motion is no longer oscillatory and is dead beat.

Conclusions

This paper reports a systematic study of the variations produced in oscillations that arise when spring constant, mass and damping coefficient of linear harmonic oscillator are varied by performing a virtual experiment using scilab. Students will be able to observe and verify the results from the theory provided in their books. Similarly several other experiments e.g. charging and discharging of RC circuit, LCR circuit, Planck's radiation law, solving Schrodinger Equation etc. can be designed to explain the related theoretical concepts.

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