AN EXPERIMENTAL STUDY ON DIFFERENCES BETWEEN LINEAR SIMPLE HARMONIC MOTION AND DAMPED OSCILLATIONS

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ABSTRACT

In this paper we are going to perform an experimental study using spring mass system to understand linear simple harmonic motion and damped oscillations. Then we will note their difference both theoretically and experimentally. We are also going to study the applications of both of these motions in real-life and also predict some future applications of damped oscillations.

KEYWORDS: Acceleration, Damped Oscillation, Harmonic Motion

INTRODUCTION

In physics oscillatory motion is a periodic motion. In such oscillatory motion acceleration, velocity and displacement are represented by harmonic functions. Linear simple oscillation is a linear periodic motion. In linear simple harmonic motion the restoring force is always directed towards the initial position and its magnitude is always directed opposite to displacement of particle under oscillation from the mean position.

$F = -kx$ where, F = restoring force

, x = displacement

, K = Proportionality constant.

Due to some limitations simple harmonic motion Dies eventually after some time because of the airs drag force and the fictional force between support and the spring or any oscillating body. Such periodic motions with decreasing amplitude are known as damped harmonic oscillations. In such motion opposing force are also considered during calculations because they play an important role in displacement and amplitude of the oscillating body. There are many real life applications of simple oscillatory motion such as moment of needle in sewing machine, bungee jumping, Car's shock absorber, etc. A system of damped harmonic motion is taken under study by many researchers to understand whether it could be helpful to reduce effects of earthquake or not.

LITERATURE SURVEY

In the paper written by Gowri. P, Deepika and Kritika. [1] A case study on simple harmonic motion was performed using spring mass system. Also the difference in angular frequency (ω), elastic constant (k) and damping factor (¥) with varying spring diameter was studied and analysed. This paper proofs the importance of understanding the equations of simple harmonic motion to solve its real-life based applications problems.

The paper by C.A trianna & F .Fajardo. [2] Is experimental study on the importance of springs geometrical parameters like diameter using spring-mass system. Also the dependency of the angular frequency (ω), damping factor (k), and elastic constant (¥) on spring diameter was theoretically studied. It was found that all principal factors of Simple oscillatory motion like angular frequency damping factor and elastic constant depend on the spring diameter.

The paper by Pirooz Mohazzabi and Shiva P. Shankar. [3] Is both experimental and investigative study report on the role of spring in the role of spring damping of simple pendulum motion. In their conducted experiment a steel ball of 485.9 g mass and 50.9 mm diameter was used to study damped simple harmonic motion. It was interesting to find that their results showed that strings play an important role in damping of simple pendulum's motion.

METHODOLOGY

Equations of kinetic energy potential energy and total energy of a particle under linear simple harmonic motion and damped harmonic oscillations

INDENTATIONS AND EQUATIONS

Equation for linear simple harmonic motion:-

1) Kinetic energy:-

$v= \pm\omega \sqrt{a^2 - x^2}$ Where, v = velocity

a = acceleration

x = displacement

ω = angular velocity

$\therefore v^2 = \omega^2 (a^2 - x^2)$

$\therefore$ Kinetic energy= $1/2\ mv^2 = 1/2\ \omega v^2\ (a^2 - x^2)$

As, $k/m = \omega^2$

$\therefore k = m\omega^2\ \omega^2$

Kinetic energy= $1/2\ k\ (a^2 - x^2)$.

2) Potential energy :-

$dw = – fdx$

$– (- kx)\ dx = kxdx$

Total work = $[\int dw = \int kxdx = k \int x\ dx]$

$[P.\ E = 1/2\ kx^2]$

3) Total energy :-

Thus, $T.E. = K.E. + P.E. = 1/2\ k\,(a^2 - x^2) + 1/2\,K\,x^2 = 1/2\,k\,a^2$

Hence, $T.E. = E = 1/2\,m\,\omega^2 a^2$

Equation for Damped harmonic motion:-

The maximum energy for the system occurs at its initial configuration; the spring is stretched to some extent A (initial amplitude). The initial energy for the spring is thus purely of a potential nature. Now, recall that the potential energy of this system can be written

$E_{total} = U(A) = 1/2kA^2$

Where, A is the initial amplitude. You have yourself supplied the time-evolution of the system, $x = x(t)$, which incorporates the amplitude. However, due to this damping the amplitude is time-dependant and we have
$A(t){=}x0e^{-\propto t}$

Thus resulting in
$E_{total}(\mathrm{t}) = 1/2\mathrm{K}x_0^2$

Which is an explicit expression of the energy in the spring-mass system at times .With this, we can write energy is lost in environment (due to the damping friction) as

$E_{out}(t) \equiv E_{total}(t = 0) - E_{total}(t) = 1/2kx_0^2(1 - e^{-2\propto t})$

Working Rules:

Step 1] To study the theoretical values of acceleration, velocity x displacement and period in linear simple harmonic motion and damped oscillations.

Step 2] To set up a spring mass oscillatory system.

Step 3] To study motion of spring-mass oscillatory motion in free air and calculate its displacement period and amplitude.

Step 4] same as step-3 for spring-mass system under water.

Step 5] To study and note the difference between two motions through theoretical and experimental values.

Theoretical calculations

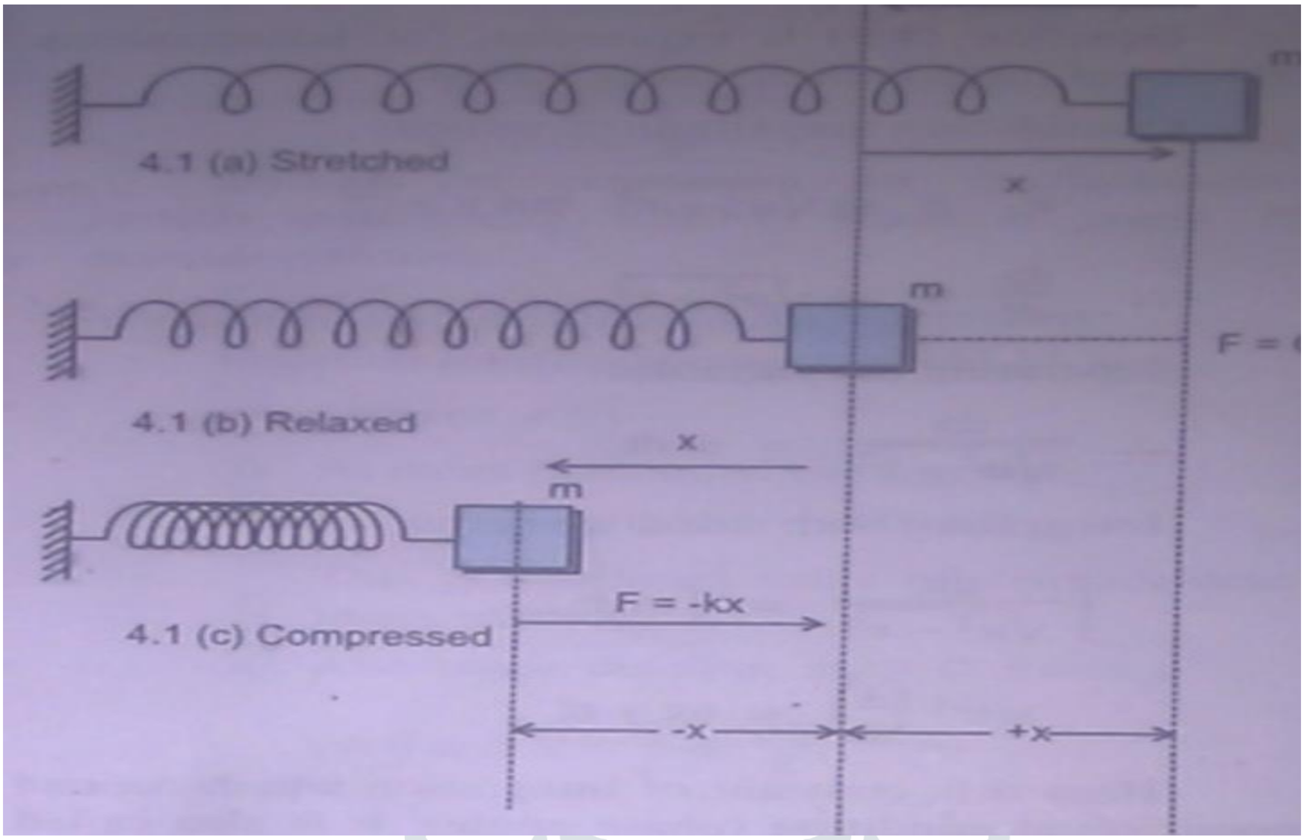


Fig 1: Compression and rarefactions of the spring

$f \sim\sim x$

i.e. $f = -kx$

$m * a = -kx$

$a = -\left(\frac{k}{m}\right) * x$

$where\ , w = -(\frac{k}{m})$

$\left(\frac{dx^2}{dt^2}\right) = -wx$

$[acceleration = \ -wx]$

$acceleration = \frac{dv}{dt}$

$= \frac{dv}{dt} * \frac{dx}{dt}$

$= \mathrm{v} * \frac{\mathrm{dv}}{\mathrm{vt}}$

From (1) and (2)

$\mathrm{V} * \frac{\mathrm{dv}}{\mathrm{dt}} = -\mathrm{wx}$

$\mathrm{Vdv} = -\mathrm{wxdx}$

BY TAKING INTEGRATION ON BOTH SIDES ,

$$\left(\frac{V^2}{2}\right) = -\left(w^2 * \frac{x^2}{2}\right) + c$$

By putting Values of v and x of particle at extreme position (v=0 and x = a) in the above equation we get ,

$$C = \frac{w^{2a^2}}{2}$$

$$v^2 = w^2(a^2 - x^2)$$

We get,

$$x = \mathrm{asin}(wt + \alpha)$$

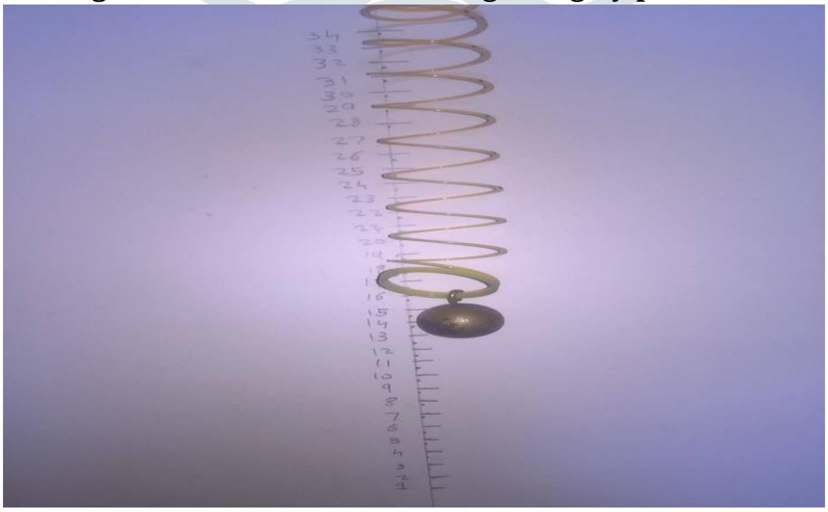
EXPERIMENTAL PROCEDURE AND OBERVATIONS

REQUIREMENTS: Scale, metal sphere, spring, hook.

1) Linear simple harmonic motion :

Amplitude	9 cm
Period	5 sec
Forces acting on system	Only one force restoring force

Fig 2: Observation of stretching string by practical.



A) Observations : "Table 1 : observations from above fig"

GRAPH FOR DISPLACEMENT OF SPRING-MASS SYTEM IN FREE AIR:

A) THEORETICAL

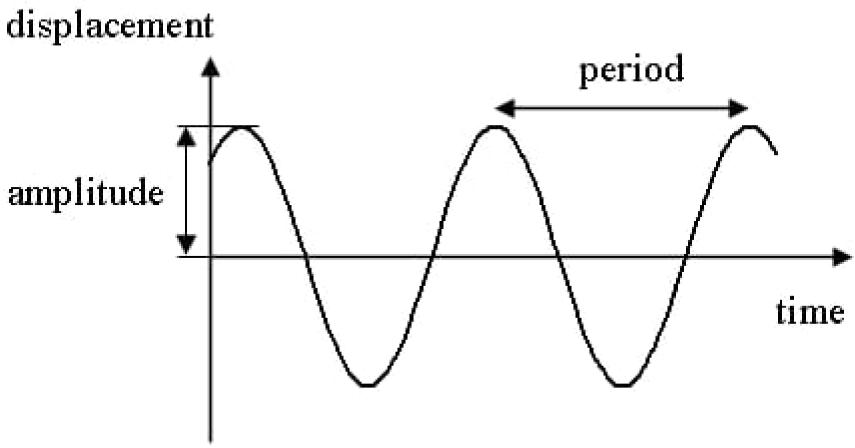


Fig 3: Diagram for displacement of spring in free air

B) PRACTICAL :

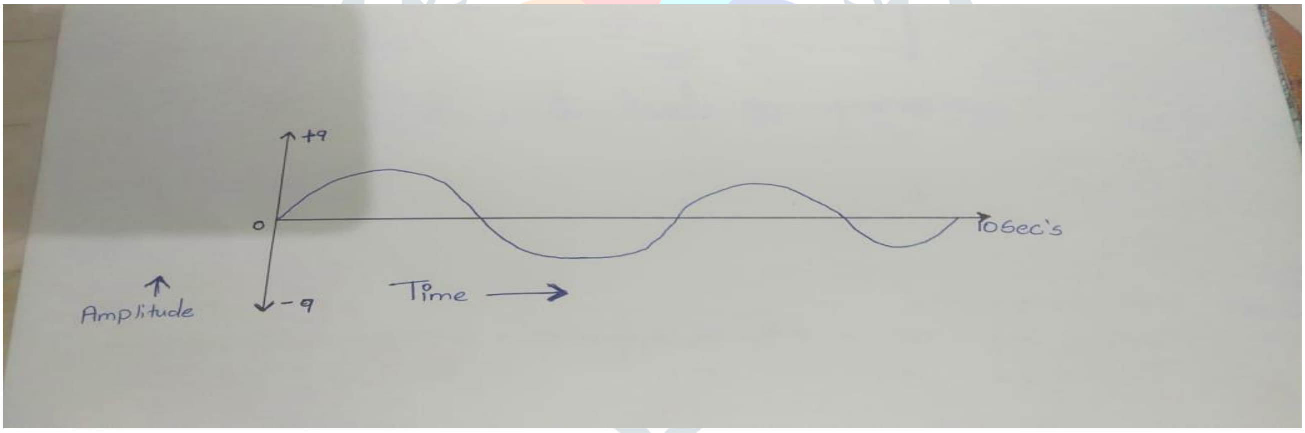


Fig 4: Diagram from table 1

1) DAMPED HARMONIC OSCILLATIONS (UNDER WATER) :

A) OBSERVATIONS : "Table 2 "

AMPLITUDE	4 cm
PERIOD	3 sec
FORCES ACTING ON SYSTEM	One is water and other is restoring force

GRAPH OF DISPLACEMENTOF LINAER SIMPLE HARMONIC MOTION UNDERWATER:

B) THEORETICAL :

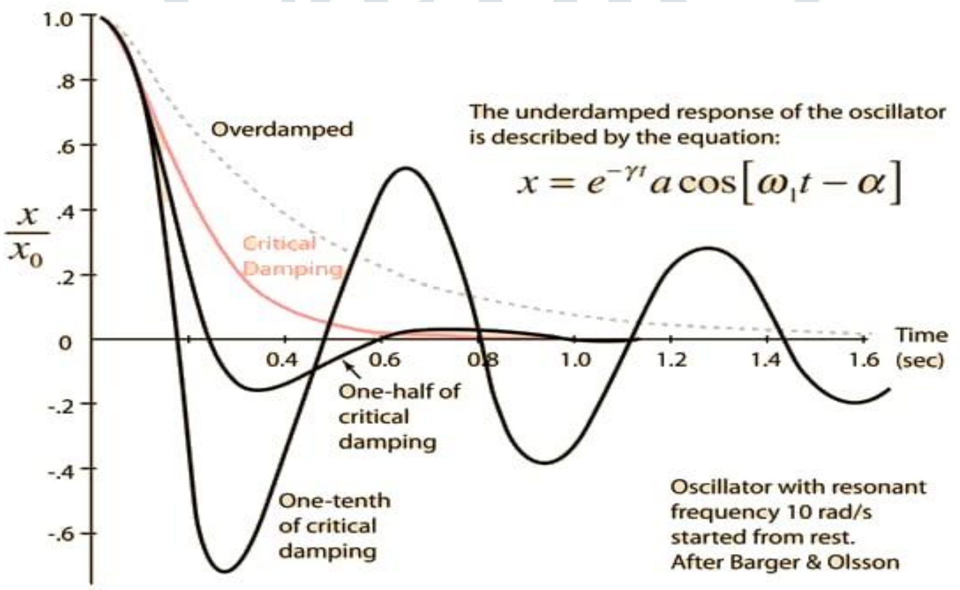


Fig 5: Diagram for damped harmonic oscillation underwater

C) PRACTICAL :

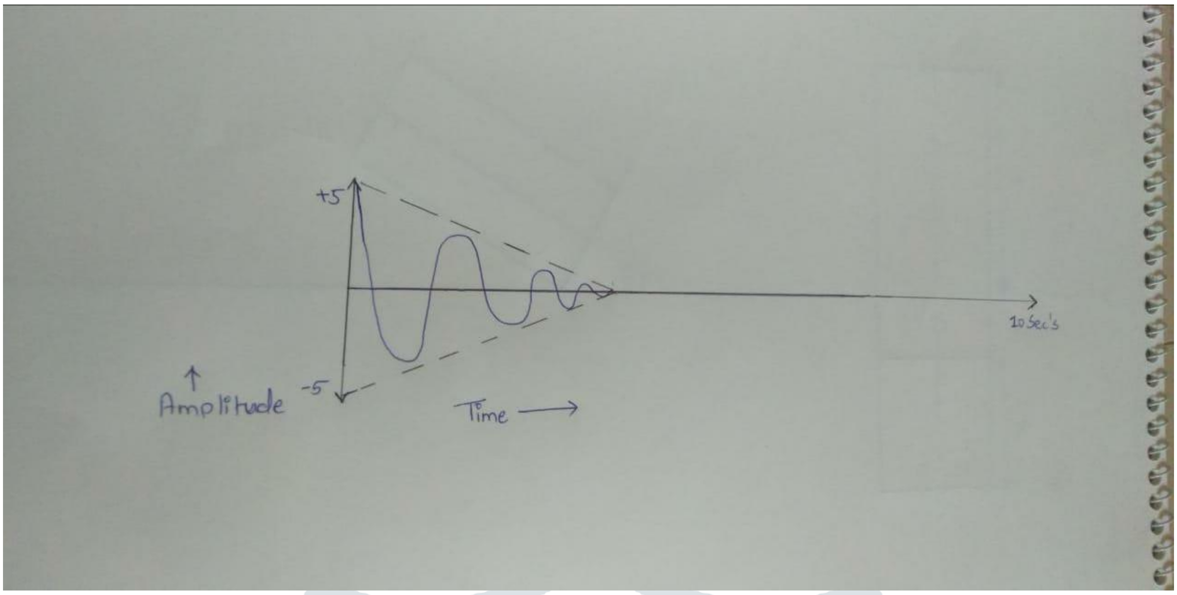


Fig 6: Diagram from table 2

APPLICATIONS OF LINEAR SIMPLE HARMONIC MOTION:-

1) Clock

The basic function of any clock is to show the accurate time. A clock is made up of a large pendulum or a quartz crystal. The periodic motion of such crystal or pendulum helps the clock to show time accurately. Since these oscillators are in simple harmonic motion they have a constant period.

2. Musical Instruments

Music is played using many other musical instruments which works on the basic concept of oscillation. In almost every musical instruments oscillations of air produces sound. The air blown in any wind instrument causes air molecules in side it to get excited and start oscillations. For other instruments like guitar or violin strings are used to produce sound.

3. Bungee Jumping

Almost all of the kids love bungee jumping sports. It is simple to play and children have fun while playing on it. The body of a person jumps on a elastic platform which then starts a series of vertical oscillations. This is repeated again and again on every other jump of the person.

4. Diving Board

Diving is water sports performed mostly in sea-water with good tides throughout the day with the help of a diving board. The diving board is mostly made-up of a wooden board. Diving with the help of diving board is an oscillating system called as a cantilever.

5. Hearing

In all living beings there is an organ called ear which to use for hearing. The ear consists of many components including eardrum which are connected to the brain. These ear drums vibrate due to the hitting of air or sound waves. These vibrating movements of the eardrum transmit special signals to the brain regarding the sound waves. Then the brain further intercepts these signals and recognises the sound.

6. Metronome

A metronome helps musicians to play a piece at a constant speed. Its working is similar to the working of a simple pendulum. The structure is a variation of the pendulum. Only difference in this case is that the oscillating arm is anchored at the bottom.

APPLICATIONS OF DAMPED HARMONIC OSCILLATIONS:-

1. Car Shock Absorbers

Springs are attached to the wheels of a car which oscillates for some time and then soon gets damped during the bumping of car on road. These damping oscillatory motion of the spring helps to avoid the irregular movement of car during its bumping on road. This reduces the risk of the death-causing accidents on the roads due to irregular movement of cars after getting bumped on the road.

2. Earthquake

Earthquake is a natural disaster which causes lots of destruction of life throughout the world every year. We cannot predict the time of next earthquake nor can we totally control it. But we can definitely control the amount of damage caused by such earthquakes.

Some Tall buildings in seismic regions have damping system built-in using springs to protect them during earthquakes.

"Table 3: Difference between L.S.H.M and Damped oscillations"

Linear simple harmonic motion	Damped oscillations
Amplitude is greater	Amplitude is less
Amplitude = a	Amplitude = $Ae^{-\frac{bt}{2m}}$
Period of such motion is more	Period is less and motion dies immediately
Less friction acts (only by support on spring and air)	More friction acts (By water)
X = a*cos*wt (from extreme position)	$x = Ae\hat{}(-\frac{bt}{2m})\cos(w't + \&)$

CONCLUSION

Linear simple harmonic motion takes place when a spring-mass system is allowed to oscillate in the free air. It takes place for a longer period, with more amplitude and effectively than the same system when allowed to oscillate under water. Water exerts an opposing force to the oscillatory body and due to this force the displacement of particle oscillating decreases periodically. On the other hand only one (restoring) force acts on particle in oscillatory motion in free air.

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