**Introduction to Oscillations**

Oscillations are a fundamental concept in physics, describing any motion that repeats itself at regular intervals. This chapter explores the principles and applications of oscillatory motion, which is prevalent in various natural and man-made systems.

In this chapter, you will learn about:

1. **Periodic and Oscillatory Motion**: Understanding the difference between periodic motion, which repeats after a fixed time interval, and oscillatory motion, which involves a back-and-forth movement around an equilibrium position.
2. **Simple Harmonic Motion (SHM)**: A type of oscillatory motion where the restoring force is directly proportional to the displacement and acts in the direction opposite to that of displacement.
3. **Energy in SHM**: How potential and kinetic energy interchange in a system undergoing simple harmonic motion, and the concept of total mechanical energy remaining constant.
4. **Damped and Driven Oscillations**: Real-world oscillations often involve damping (energy loss) and driving forces (external forces that sustain the motion), which affect the amplitude and frequency of oscillations.
5. **Resonance**: A phenomenon where an oscillating system responds with maximum amplitude when the frequency of the driving force matches the system’s natural frequency.

One mean position and two extreme positions

Distance between mean and extreme is called amplitude

Mean to extreme: P.E `uparrow text( and K.E )downarrow`

Extreme to mean: P.E `downarrow text( and K.E )uparrow`

At mean position:

X = 0 F = 0, a = 0, v = max, K.E = max, P.E = min

At extreme position:

X= `plusminus` A, F = max, a = max, K.E = 0, P.E = max

A particle acted upon by force `f=kx^n`

If n = even force along –ve x axis always

If n = odd

Force along –ve axis for x > 0

Force along +ve x axis for x < 0

Zero for x = 0

So particle oscillating along mean position is called restoring force

If `F=-kx` then SHM  
(it is called simple harmonic cause for all other periodic motion [`F=-kx`] the mathematics is complex)

SHM: linear(spring system) and angular (single pendulum)

`tantheta` = slope of F - x = `-k`

`text(Acceleration )= F/m = (-kx)/m = -omega^2x`

`omega=sqrt(k/m)`

`T=2pi sqrt(m/k)`

Graph

`tantheta = text( slope )= -omega^2`

Acceleration opposite to x

Velocity = ± `omega sqrt(A^2 – x^2)`

On rearranging we get ellipse equation

Graph

-A to +A (upper half) = +v

+A to –A (lower half) = -v

Energy equation

Total Mechanical energy

`T = U\_{0} + omega = U\_{0}` (initial P.E) `+ 1/2 m omega^2 A^2`(work for displacement)

`U (P.E) = U\_{0} + 1/2 m omega^2 x^2` (spring P.E)

`K.E= T – U = 1/2 m omega^2(A^2 – x^2)`

Mean position(`x = 0`)

`T= U\_{0}+ 1/2m omega^2 A`

`U = U\_{0}text( (min) )K.E = 1/2m omega^2 A^2` (max)

Extreme( x = ± A)

`T= U\_{0} + 1/2 m omega^2 A`

`U = U\_{0} + 1/2m omega^2 A^2` (max) `K.E = 0` (min)

Graph

`a = -omega^2 x`

`(d^2x)/(dt^2) = - omega ^2 x`

` x= A sin(omegat ± theta)`

`omega = (2 pi )/ T` `v = (dx)/(dt) = omega A cos(omega t ± theta)`

`a = - omega ^2 A sin(omegat ± theta) = - omega^2 x `

`theta` = phase angle

at `t = 0 `

`u= 0` if the body moves from +A and –A

`u = ±omega A` when at mean postion ( `-omegaA` if move to –A, `+omegaA` if moves to +A)

`K.E = 1/2 mv^2 = 1/2 m omega^2A^2cos^2(omegat)`

K.E is `cos^2` function of `omega` and `U`(potential energy) is `sin^2` funtion of `omega`

…………… relation between SHM and uniform circular motion

Time period

`T = 2pi sqrt(m/k) rightarrow` spring block sytem

`T= 2pisqrt((|displacement|)/(|acceleration|))`

`T = 2pisqrt((m + m\_{s}/3)/k)text( )m\_{s}` = spring mass and m= mass suspended

`T = 2pisqrt(l/g)` → pendulum, U shaped tube

`omega= sqrt(C/I)` where C= rigidity coefficient (`tau= Ctheta`) I is the momemt of inertia of body

`omega= sqrt((mgL)/I)` L = length of the axis from the centre of mass

In L if radius of gyration exists `L\_{eq} = L + k^2/ L`

`omega = sqrt(k/I)`

Simple pendulum

T=2s → seconds pendulum

Length = 1m

Temperature (T) increase time lost

Temperature decrease time gained

`Deltat= (DeltaT)/T \* t`

`DeltaT` = change in temperature

Spring system

Two springs with spring constant `k\_{1} , k \_{2}`

Series means the system all spring experience different force such as two springs connected end to end

Parallel mean system in which two or more springs experience same force of comprestion or relaxation such as pulling two springs together

Series

`1/k\_{s} = 1/k\_{1} + 1/k\_{2}`

Parallel

`k\_{p}= k\_{1}+ k\_{2}`

Spring constant `k prop 1/l`

Case

`m\_{1}`---------00000--------`m\_{2}`

`T = 2pisqrt(mu/k )`

`mu` = reduce mass

`1/mu= 1/m\_{1}+ 1/m\_{2}`

Amplitude of oscillation

`A prop 1/m rightarrow A\_{1}/A\_{2}= m\_{2}/m\_{1}`

Two bodies in phase

`theta\_{1} = theta\_{2} +2npi`

`omega\_{1}t = omega\_{2}t +2pi`

Vibration per second = `omega/(2pi)`

`omega\_{1}A\_{1} = omega\_{2}A\_{2}`

Time period of pendulum is independent of mass

Velocity = `omega`

`T= 2pisqrt(1/g(1/L +1/R))`