ICT 1107: Physics

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Course Details

There are 4 Chapters in Total

1. Waves and Oscillations

Differential equation of a simple harmonic oscillator, total energy and average energy, combination of simple harmonic oscillations, Lissajous' figures, spring-mass system, calculation of time period of torsional pendulum, damped oscillation, determination of damping co-efficient, forced oscillation, resonance, two-body oscillations, Reduced mass, differential equation of a progressive wave, power and intensity of wave motion, stationary wave, group velocity and phase velocity, architectural acoustics, reverberation and Sabine's formula.

8 Lectures

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2. Heat and Thermodynamics

Principle of temperature measurements: platinum resistance thermometer, thermo-electric thermometer, pyrometer; Kinetic theory of gases: Maxwell's distribution of molecular speeds, mean free path, equipartition of energy, Brownian motion, Van der Waal's equation of state, review of the First Law of thermodynamics and its application, reversible and irreversible processes, Second Law of thermodynamics, Carnot cycle; Efficiency of heat engines, Carnot's Theorem, entropy and disorder, thermodynamic functions, Maxwell relations, Clausius-Clapeyron Equation, Gibbs Phase Rule, Third Law of thermodynamics.

8 Lectures

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3. Structure of Matters

Crystalline and non-crystalline solids, single crystal and polycrystal solids, unit cell, crystal systems, co-ordinations number, crystal planes and directions, sodium chloride and CsCl structure, packing factor, Miller indices, relation between interplanar spacing and Miller indices, Bragg's Law, methods of determination of interplanar spacing from diffraction patterns; Defects in solids: point defects, line defects; Bonds in solids, inter-atomic distances, calculation of cohesive and bonding energy; Introduction to band theory; distinction between metal, semiconductor and insulator.

7 Lectures

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4. Physical Optics

Theories of light; Interference of light, Young's double slit experiment; Displacements of fringes and its uses; Fresnel Bi-prism, interference at wedge shaped films, Newton's rings, interferometers; Diffraction of light: Fresnel and Fraunhoffer diffraction, diffraction by single slit, diffraction from a circular aperture, resolving power of optical instruments, diffraction at double slit & N-slits-diffraction grating; Polarization: production and analysis of polarized light, Brewster's law, Malus law, Polarization by double refraction, retardation plates, Nicol prism, optical activity, polarimeters, polaroid.

7 Lectures

Chapter 1

Waves & Oscillations

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Books Needed

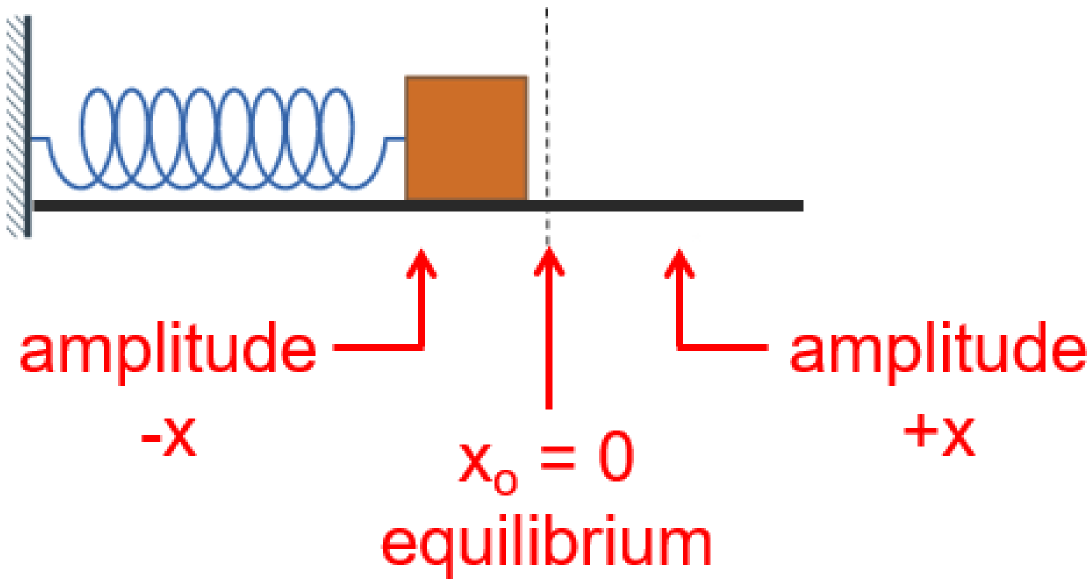
1. Physics for Engineers Vol 1- Gias Uddin Ahmad
2. Waves and Oscillations- N Subrahmanyam, Brijlal
3. Heat and Thermodynamics- N Subrahmanyam, Brijlal
4. Optics- N Subrahmanyam, Brijlal
5. Solid State Physics- Singhal

Simple Harmonic Motion (SHM)

1) **Define periodic motion**
2) **SHM**

SHM = periodic vibration about an equilibrium point

Amplitude = max displacement



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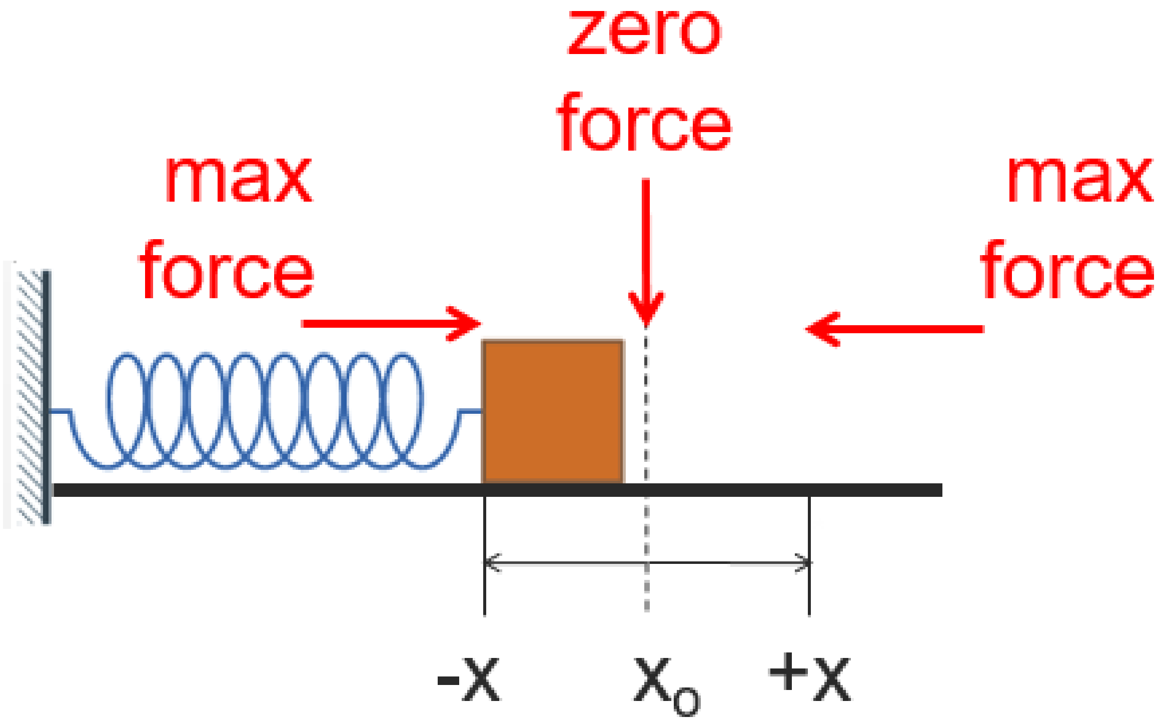
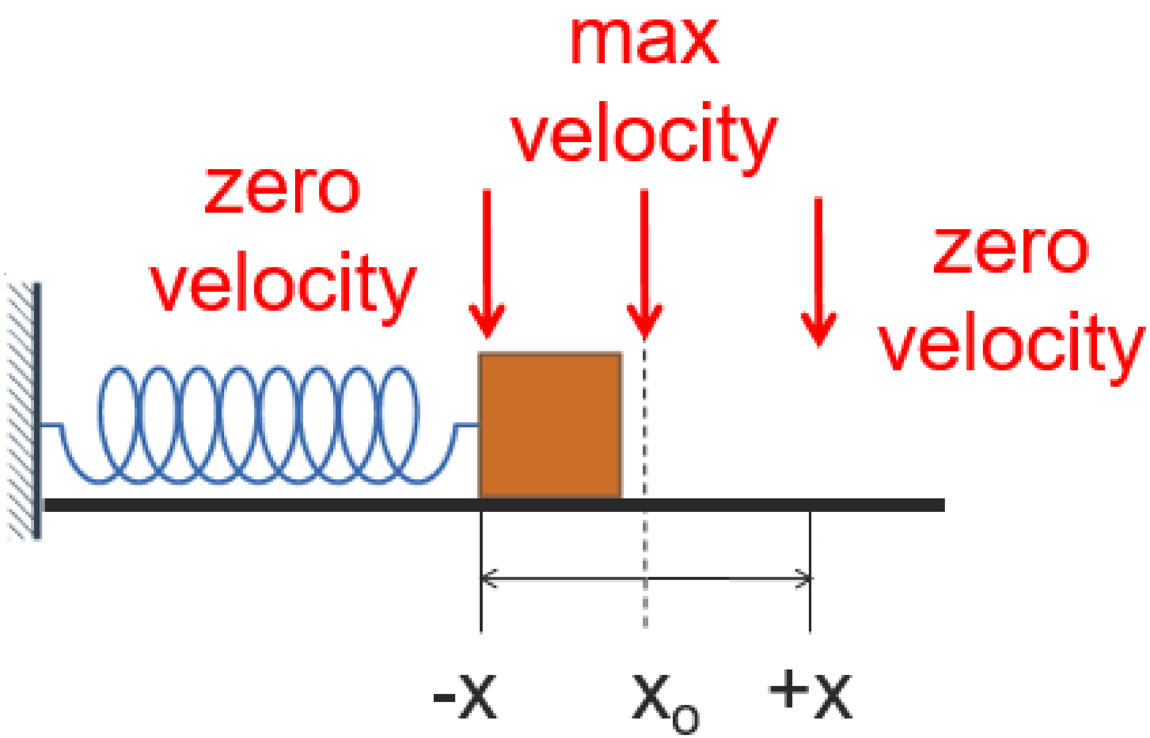
Simple Harmonic Motion (SHM)

- ✓ Max force occurs at amplitude
- ✓ Zero force occurs at equilibrium

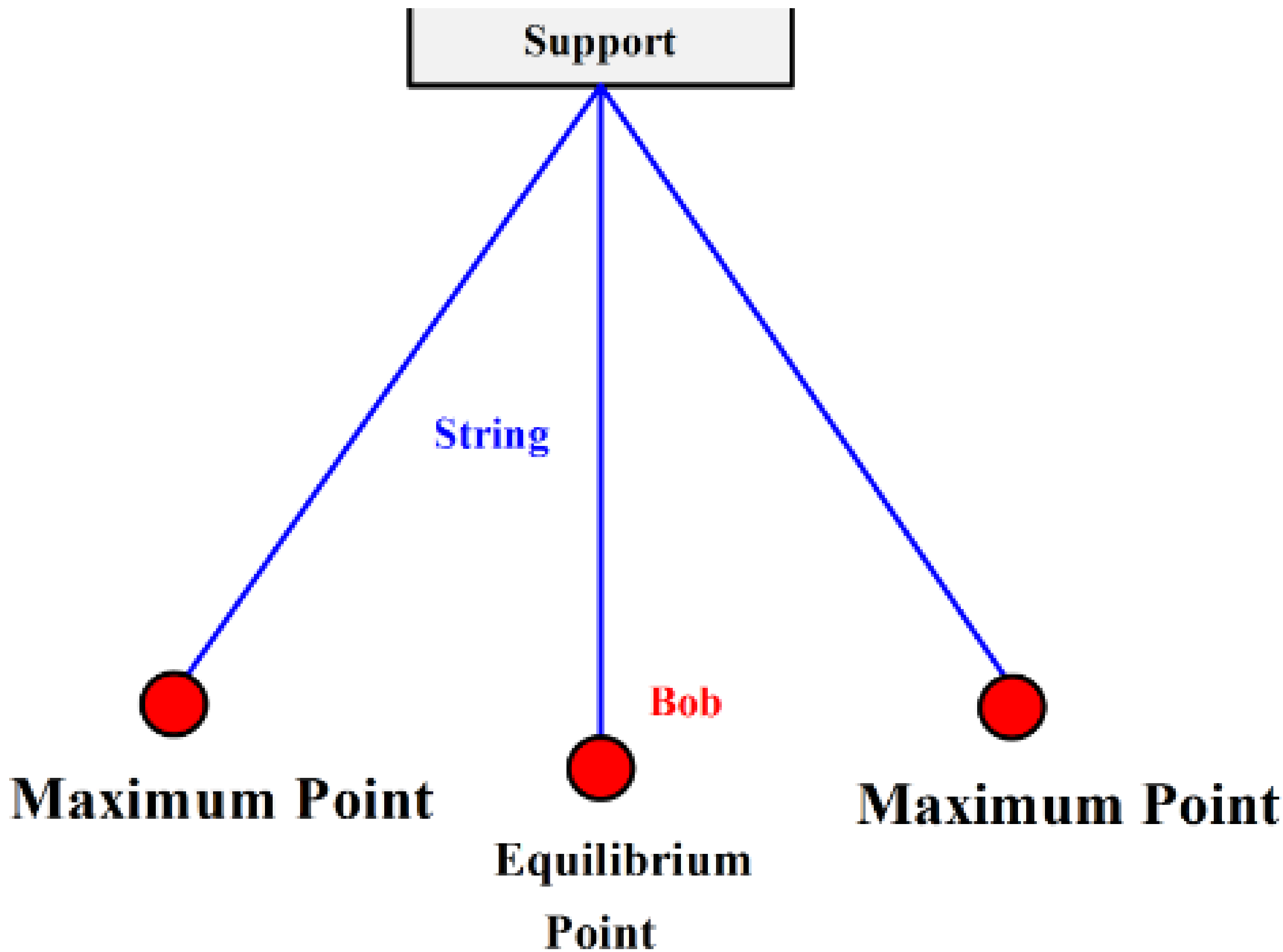


Simple Harmonic Motion (SHM)

- Max velocity occurs at equilibrium
- Zero velocity at max amplitude position



Simple Harmonic Motion (SHM)



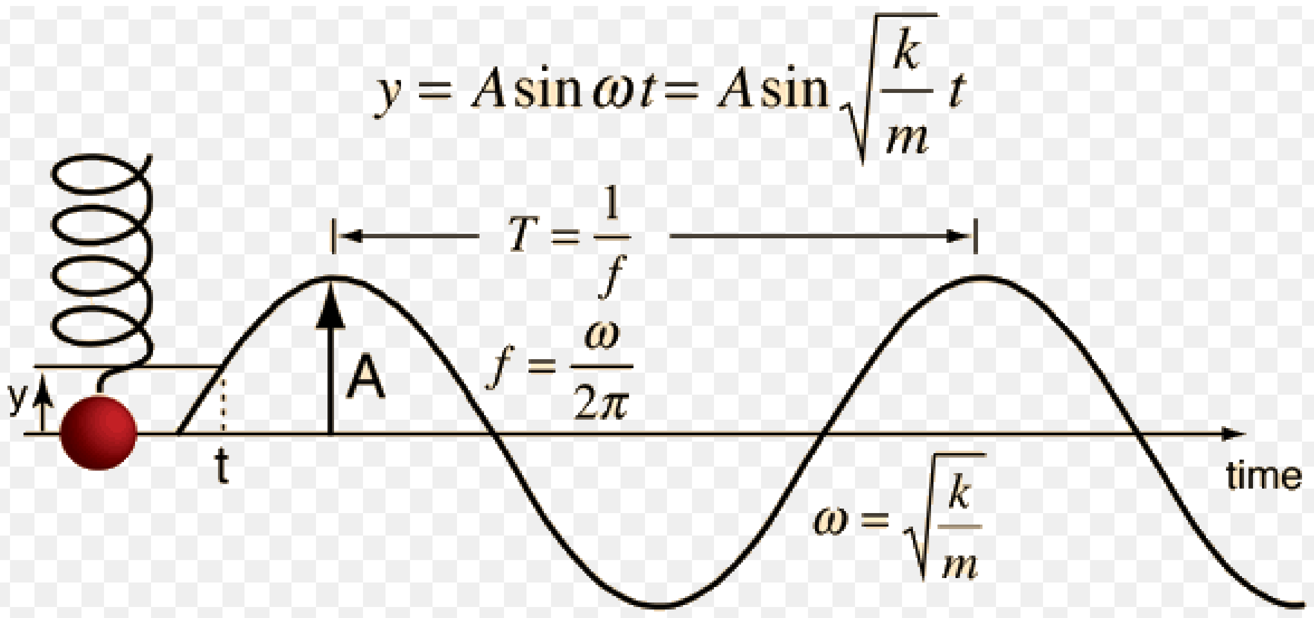
Define the SHM and write the Condition of SHM

A harmonic/periodic motion of constant amplitude in which the acceleration is proportional and oppositely directed to the displacement of the body from the mean/equilibrium position. So the conditions of SHM are:

1. Motion is periodic
2. Acceleration is proportional to the displacement
3. Acceleration is opposite to the displacement
4. Maximum displacement on both sides of the equilibrium position must be equal to each to other

Simple Harmonic Motion (SHM)

A system will oscillate if there is a force acting on it that tends to pull it back to its equilibrium position – a restoring force.



Differential Equation of Simple Harmonic Motion (SHM)

$U(y) = 0$, at mean position.

A restoring force $F = -\frac{dU(y)}{dy}$ acts at every point on the particle except at mean position, tending to bring it back to its equilibrium position.

Differential Equation of Simple Harmonic Motion (SHM)

The potential energy of an oscillating particle is defined as,

$$U(y) = \frac{1}{2}ky^2$$

Then the force acting on the particle is given as,

$$F = -\frac{dU(y)}{dy}$$

$$= -\frac{d}{dy}\left(\frac{1}{2}ky^2\right)$$

$$= -ky$$

Differential Equation of Simple Harmonic Motion (SHM)

$$F = -ky$$

$$\text{Or,} \quad m\frac{d^2y}{dt^2} = -ky$$

$$\text{Or,} \quad \frac{d^2y}{dt^2} = -\omega^2 y$$

$$\omega = \sqrt{\frac{k}{m}}$$

Differential Equation of SHM

$$\frac{d^2y}{dt^2} = -\omega^2 y$$

Or, $\boldsymbol{\frac{d^2y}{dt^2} + \omega^2 y = 0}$

Time Period of SHM

Class Work (show the calculations)

$$\omega^2 = \frac{\frac{d^2y}{dt^2}}{y}$$

$$\omega = \sqrt{\frac{Acceleration}{Displacement}}$$

Solution of the Differential Equation of SHM

Class Work (show the calculations)

Velocity of SHM

Find Maximum Velocity of SHM

$$y = a\,sin(\omega t + \phi)$$

$$v = \frac{dy}{dt} = \pm\omega\text{a}\cos(\omega t + \phi)$$

$$v = \pm\omega\text{a}\sqrt{1 - sin^2(\omega t + \phi)}$$

$$v = \pm\omega\text{a}\sqrt{1 - \left(\frac{y}{a}\right)^2}$$

$$v = \pm\omega\text{a}\sqrt{a^2 - y^2}$$

Acceleration of SHM

Class Work (show the calculations)

Find Maximum Acceleration of SHM

$$\frac{d^2y}{dt^2} = -\omega^2 a sin(\omega t + \phi)$$

$$= -\omega^2 a. \frac{y}{a}$$

$$= -\omega^2 y$$

$$= -\frac{k}{m} y$$

Epoch of a Particle Executing SHM

Home Work

Energy of a Particle Executing SHM

$$PE = \int_0^y F dy$$

Here, $F = mass \times acceleration$

$$= m \times (-\omega^2 y) = -m\omega^2 y$$

$$PE = \int_0^y m\omega^2 y dy$$

$$= m\omega^2 \int_0^y y dy$$

$$= \frac{1}{2} m\omega^2 y^2$$

Total Energy of a Particle Executing SHM

We know the displacement of a particle executing SHM is,

$$y = a\sin(\omega t + \phi)$$

Hence, the PE is

$$PE = \frac{1}{2} m\omega^2 a^2 sin^2(\omega t + \phi)$$

$$= \frac{1}{2} k\, a^2 sin^2(\omega t + \phi)$$

Now, the KE of the particle executing SHM is

$$KE = \frac{1}{2}mv^2$$
$$= \frac{1}{2}m\left(\frac{dy}{dt}\right)^2$$
$$= \frac{1}{2}m\,(\omega a\cos(\omega t + \phi))^2$$
$$= \frac{1}{2}m\omega^2 a^2 \cos^2(\omega t + \phi)$$
$$= \frac{1}{2}k a^2 \cos^2(\omega t + \phi)$$

Now, the KE of the particle executing SHM is

$$E = PE + KE$$

$$= \frac{1}{2} m\omega^2 y^2 + \frac{1}{2} mv^2$$

$$= \frac{1}{2} ky^2 + \frac{1}{2} mv^2$$

$$= \frac{1}{2} ka^2$$

Total Energy as a Function of Amplitude

E = maximum value of potential energy

= maximum value of kinetic energy

$$= \frac{1}{2} K a^2$$

$$= \frac{1}{2} m \omega^2 a^2$$

$$= 2\pi^2 m a^2 n^2$$

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Total Energy as a Function of Amplitude

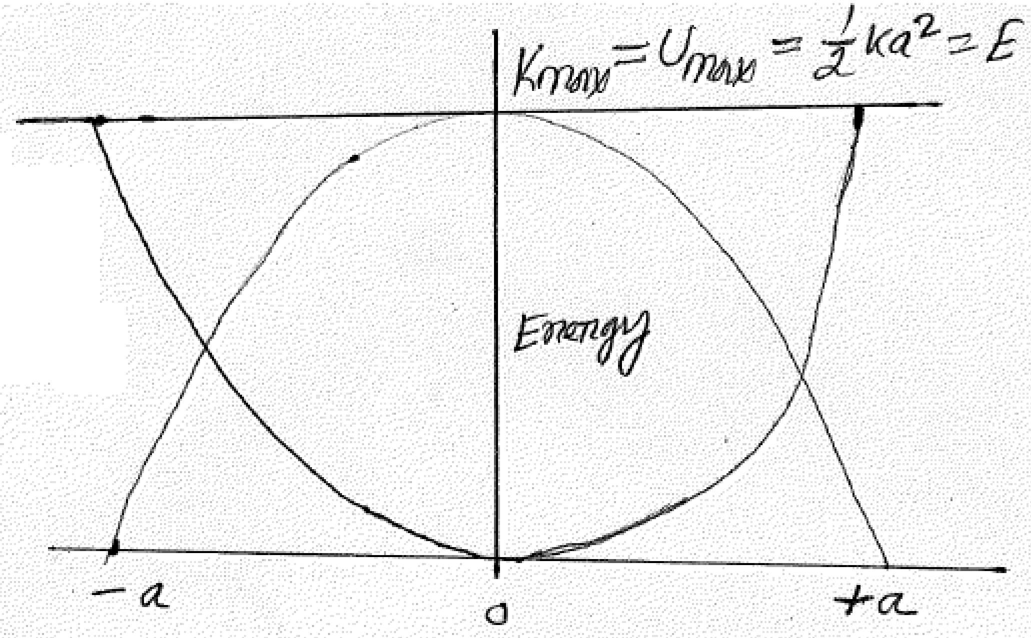

Fig.2 – The total energy as a function of displacement from the equilibrium position.

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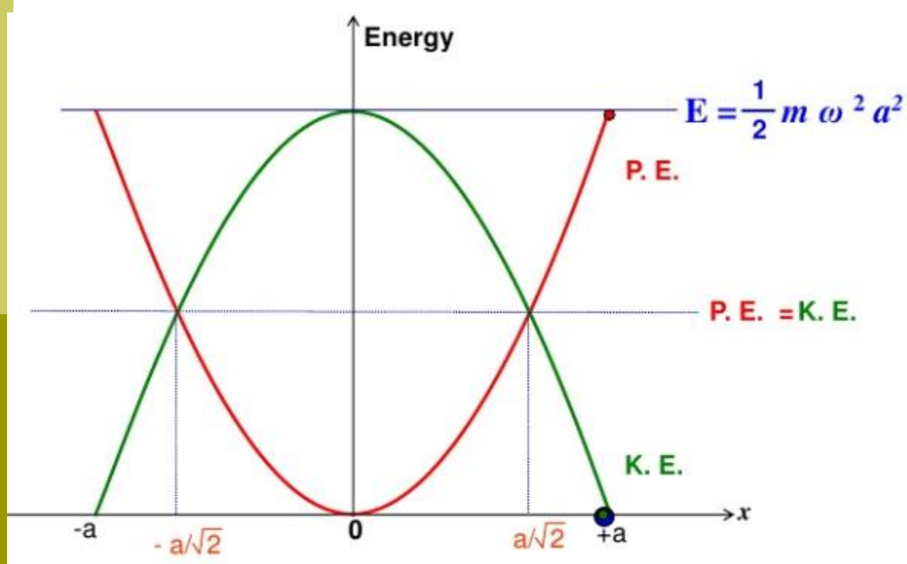
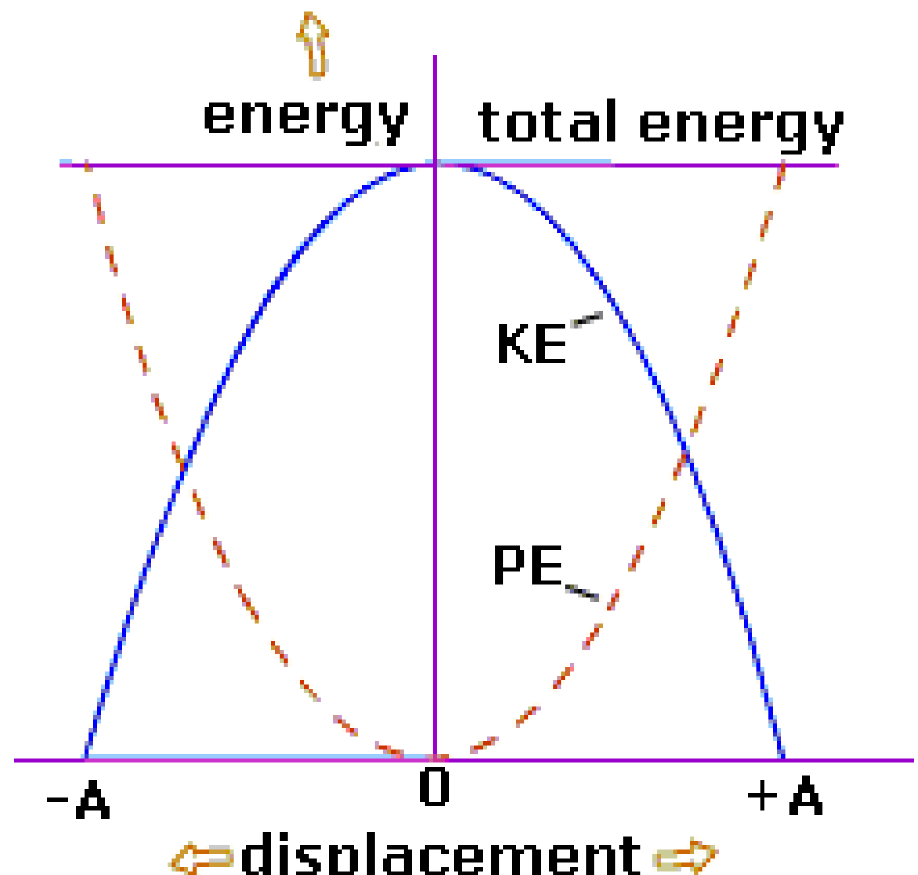
Energy of a Particle Executing SHM

(Show the calculations)





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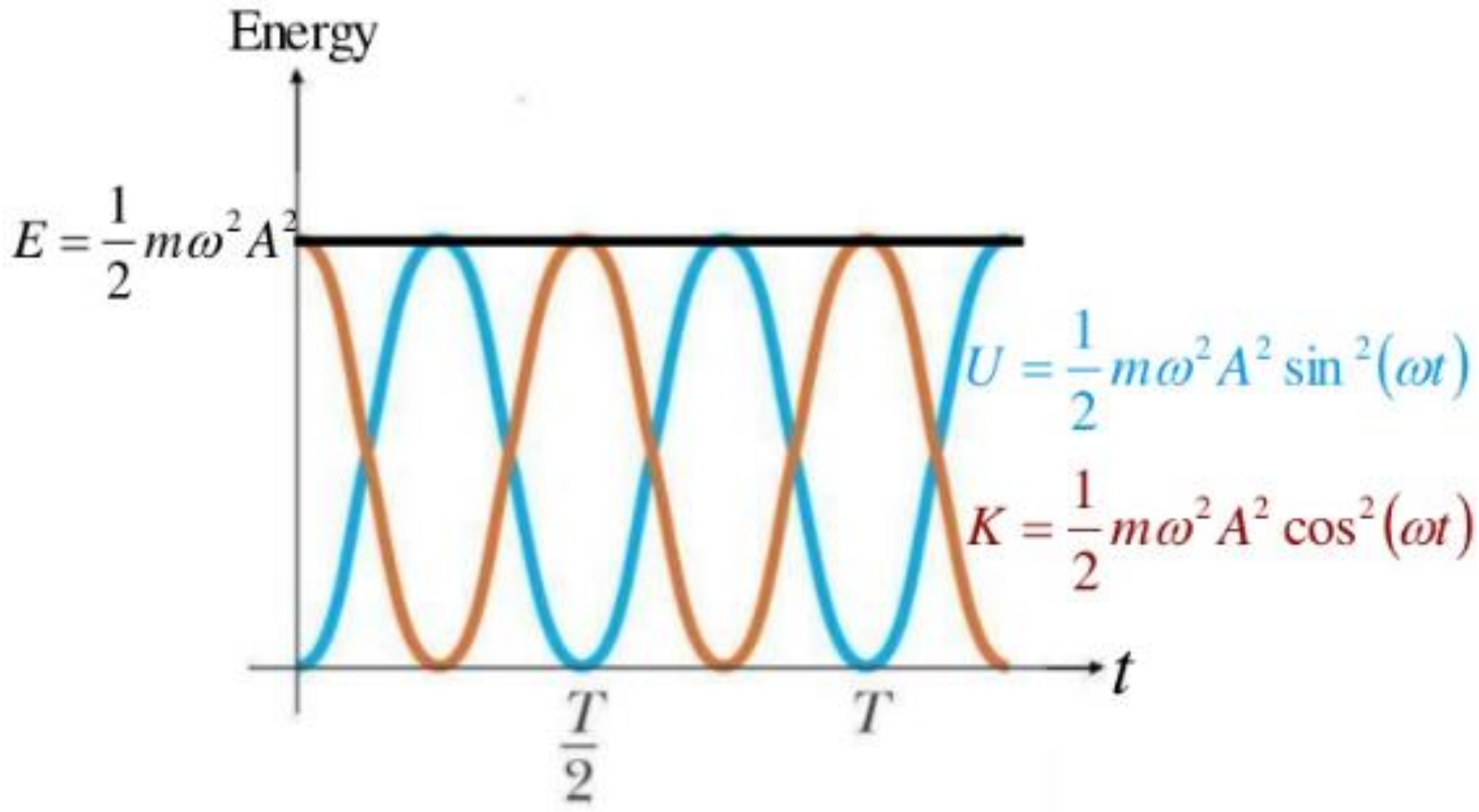
Energy of a Particle Executing SHM



Velocity from Total Energy of a Particle Executing SHM

The equation for the energy associated with SHM can be solved to find the magnitude of the velocity of the particle:

$$E = \frac{1}{2}ky^2 + \frac{1}{2}mv^2 = \frac{1}{2}ka^2$$

Hence, the velocity of the particle at any position:

$$v = \sqrt{\frac{k}{m}(a^2 - y^2)}$$

Average values of the KE and PE of a particle executing SHM

H/W: Show the details calculations

Linearity & Superposition Principle

Class Work

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SHM of a loaded spring

Home Work

Page 37 (N Subrahmanyam)

Problems & Solutions

A particle performs SHM given by the equations, $y = 20 sin(\omega t + \phi)$. If the time period is 30 seconds and the particle has a displacement of 10 cm at t = 0, find

(i)Epoch

(ii)The phase angle at t = 5 seconds

(iii)The phase difference between two positions of the particle 15 seconds apart.

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Problems & Solutions

A body of mass 0.5 kg is suspended from a spring of negligible mass and it stretches the spring by 0.07 m. For a displacement of 0.03 m it has a downward velocity of 0.4 m/s. Compute

(i)The time period

(ii)The frequency

(iii)The amplitude of vibration of the spring

Lissajou's Figures

Basic Theory of Lissajous Figures

Combination of two SH vibrations of same frequency but different amplitude and phase

Lissajou's Figures

1. Combination of two SH vibrations at Right Angles to each other having of same frequency but different amplitude and phase.

Lissajou's Figures

2. Combination of two SH vibrations at Right Angles to each other having a time period in the ration of 1:2.

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Problems (Home Work)

A particle is vibrating with SHM of amplitude 15 cm, and frequency 4 Hz. Calculate

(a) The maximum values of the acceleration and velocity

(b) The acceleration and velocity when the displacement is 9 cm.

Uses of Lissajou's Figures

1. Laptop and PC screen savers
2. Science fiction movies
3. TV shows
4. Laser shows
5. To design new logos
6. Space stations and satellites
7. To detect the phase shift and time periods of signals

Problems (Home Work)

For a particle is vibrating simple harmonically the displacement is 8 cm at the instant velocity of 6 cm/s and the displacement is 6 cm at the instant velocity of 8 cm/s. Calculate the amplitude, frequency and time period of vibration.

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Problems (Home Work)

A particle execute simple harmonic motion about the point x = 0. At t= 0, it has displaced y = 0.37 cm, and zero velocity. If the frequency of motion is 0.25/s. Calculate the period, amplitude, the maximum speed and the maximum acceleration.

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Problems (Home Work)

A SHM is represented by equation $y = 10\,sin\left(10t - \frac{\pi}{6}\right)$, where *y* is measured in meters, *t* in seconds, and the phase angle in radians. Calculate

(i)The frequency

(ii)The period

(iii)The maximum period

(iv)The maximum velocity

(v)The maximum acceleration

(vi)Displacement, velocity and acceleration at t = 0, and t = 1 second.

Problems (Home Work)

Two SHMs acting simultaneously on a particle are represented by equation $y_1 = 2\,sin\left(\omega t + \frac{\pi}{6}\right)$, and $y_2 = 3sin\left(\omega t + \frac{\pi}{3}\right)$,

where *y* is measured in meters, *t* in seconds, and the phase angle in radians. Calculate

(i)The amplitude
(ii)The phase constant
(iii)The time period of the resultant vibration

Problem

The displacement of an oscillating particle at an instant of time is represented by equation $y_1 = a\cos\omega t + b\sin\omega t$, where y is measured in meters, and t in seconds. Show that it execute SHM. If a = 5 cm, b = 12 cm and ω = 4 radian/sec, calculate

(i)The amplitude
(ii)The time period
(iii)The maximum velocity, and
(iv)The maximum acceleration of the particle.

Sample Questions

1. Define simple harmonic motion with its characteristics and give 2 examples.
2. Establish the differential equation of SHM and solve it to obtain an expression for the displacement of a particle executing SHM.
3. Establish the differential equation of SHM and find its time period.
4. Explain simple harmonic motion. Obtain expressions for the frequency, amplitude, velocity, and acceleration of a body executing SHM.
5. Calculate the mechanical energy of a particle executing SHM, and show that it remains conserved. Also show that its energy, on average, half kinetic and half potential.

Sample Questions

6. Calculate the average kinetic and total energy of a particle executing SHM. Show that the principle of conservation of energy is obeyed by a harmonic oscillator.

7. Show that the motion of a simple pendulum is harmonic. Obtain an expression for the frequency of oscillations of the simple pendulum.

Free Vibrations

Damped Vibrations

Forced Vibrations

Free/Undamped Vibrations

If an object such as the bob of a simple pendulum is displaced from its mean position, and the released, it will show simple harmonic motion. If there is no loss of energy due to friction or otherwise, the pendulum will go on oscillating with the same time period and amplitude for any length of time without any damping or decay of oscillations. Such types of motions are referred as the undamped or free vibrations.

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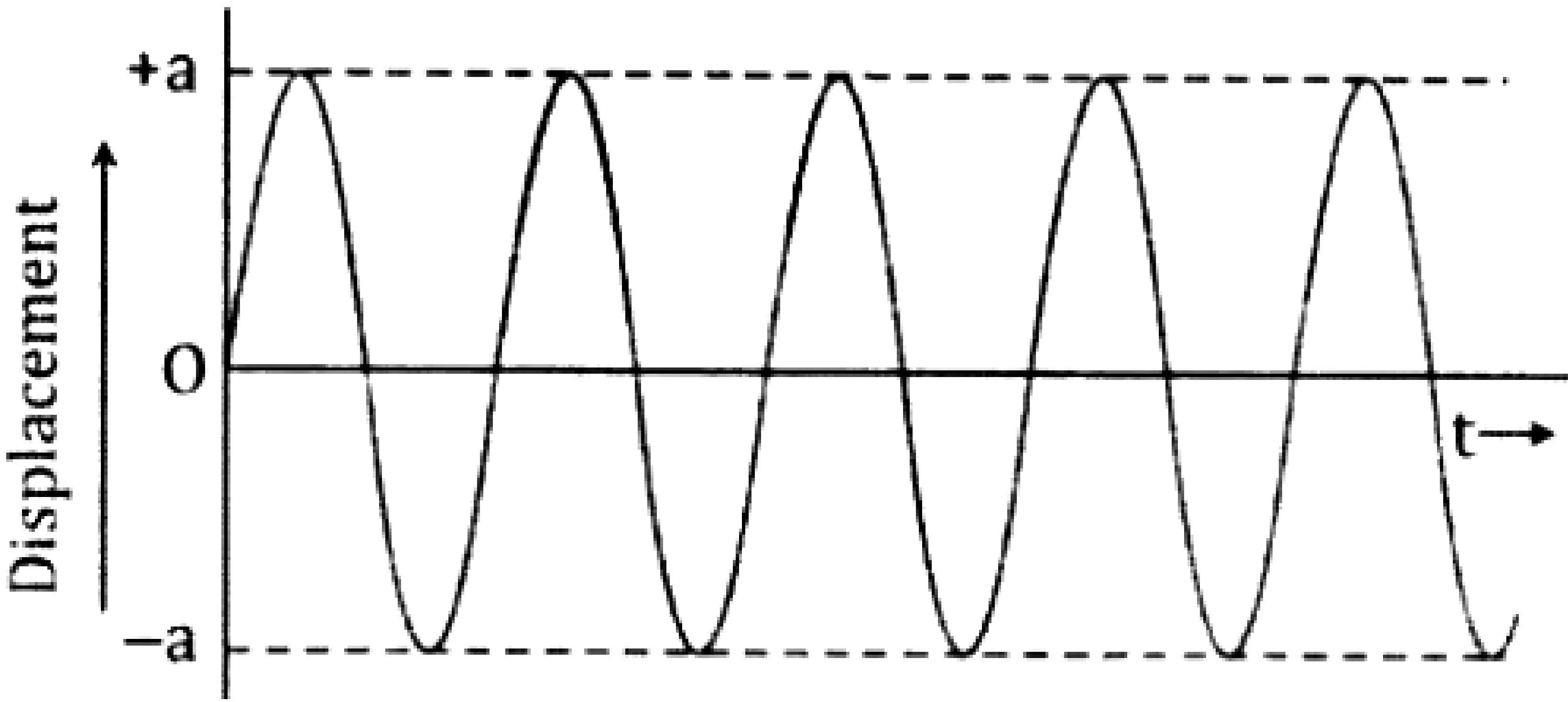
Free/Undamped Vibrations

The displacement—time graph for a body executing free vibrations is given below:



Free/Undamped Vibrations

The free vibrations of a body actually occur only in vacuum because the presence of a medium offers some resistance due to which the amplitude of vibration does not remain constant and decreases continuously. Thus, we define free vibrations as the periodic vibrations of a body of constant amplitude in the absence of any external force on it.

Damped Vibrations

Generally, a simple harmonic oscillator vibrates in a resisting medium such as air and energy is gradually dissipated in each vibration in overcoming the opposing frictional/resistive forces. As a result, the amplitude of vibration gradually goes on decreasing with time. In the absence of any kind of resistive or damping forces, the oscillations will continue indefinitely without the change of amplitude and time period however, in the presence of damping the amplitude of vibrations decreases continuously with time and finally the oscillations die out. These kinds of vibrations are known as the damped vibrations.

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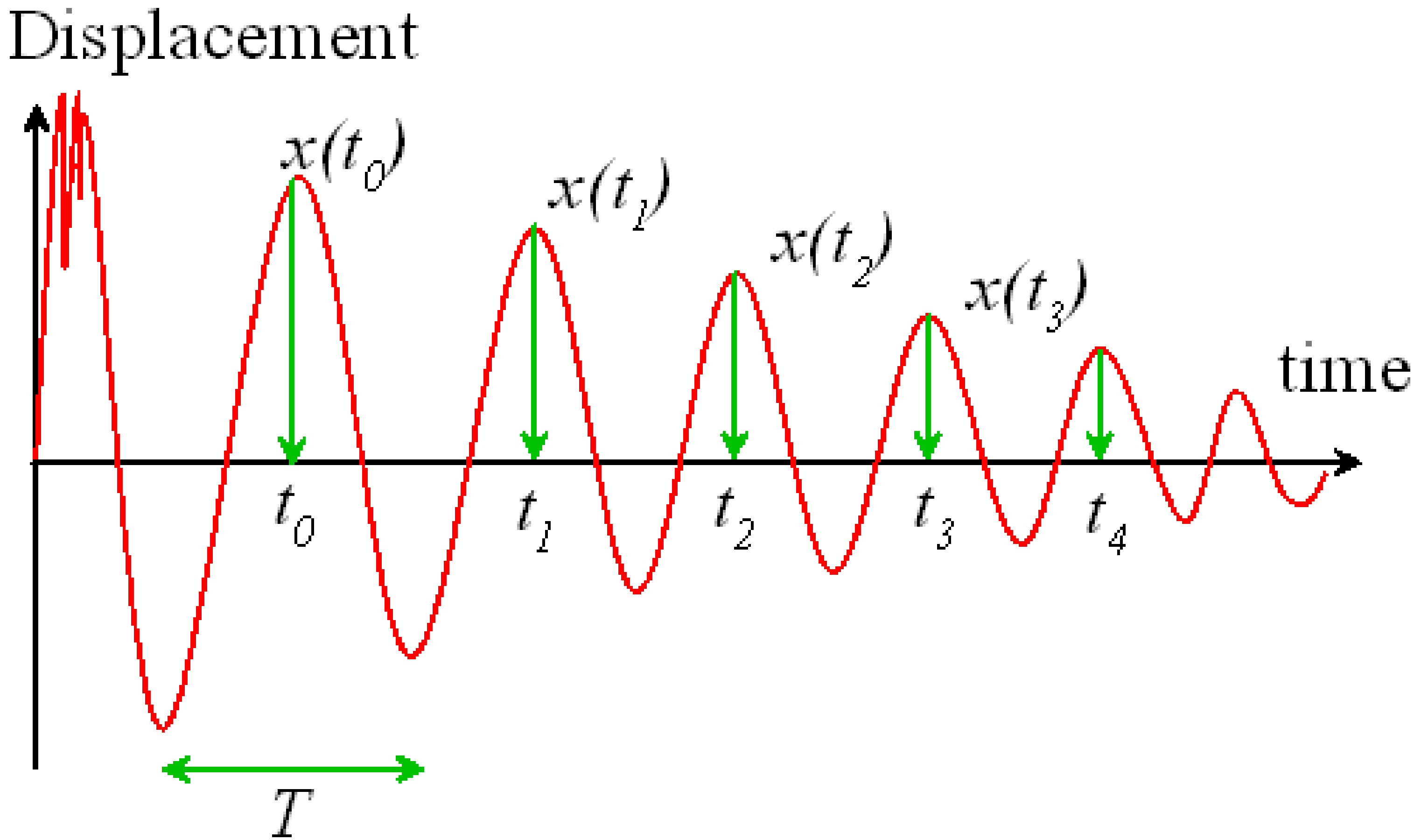
Damped Vibrations



Damped Vibrations

An object showing simple harmonic motions in a damping medium will be simultaneously subjected to the following opposing forces:

1. The restoring force (-*ay* where *a* is a force constant)

2. Damping force (-*bv*, where *b* is the damping constant or damping coefficient, and *v* is the velocity of the object)

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Damped Vibrations

Thus, the differential equation of motion of the object showing simple harmonic motions in a damping medium is given as,

$$F = -ay - bv$$

$$m\frac{d^2y}{dt^2} = -ay - b\frac{dy}{dt}$$

$$\frac{d^2y}{dt^2} + 2\lambda\frac{dy}{dt} + \omega^2 y = 0 \ldots\ldots\ldots(1)$$

Where $2\lambda = \frac{b}{m}$, and $\omega^2 = \frac{a}{m}$

Home Work

Solve this equation (1) to obtain the displacement of the particle vibrating in a damping medium.

Types of Damping

1. Underdamping (Slight/light damping)
2. **Critical damping**
3. **Overdamping (Heavy/strong damping)**

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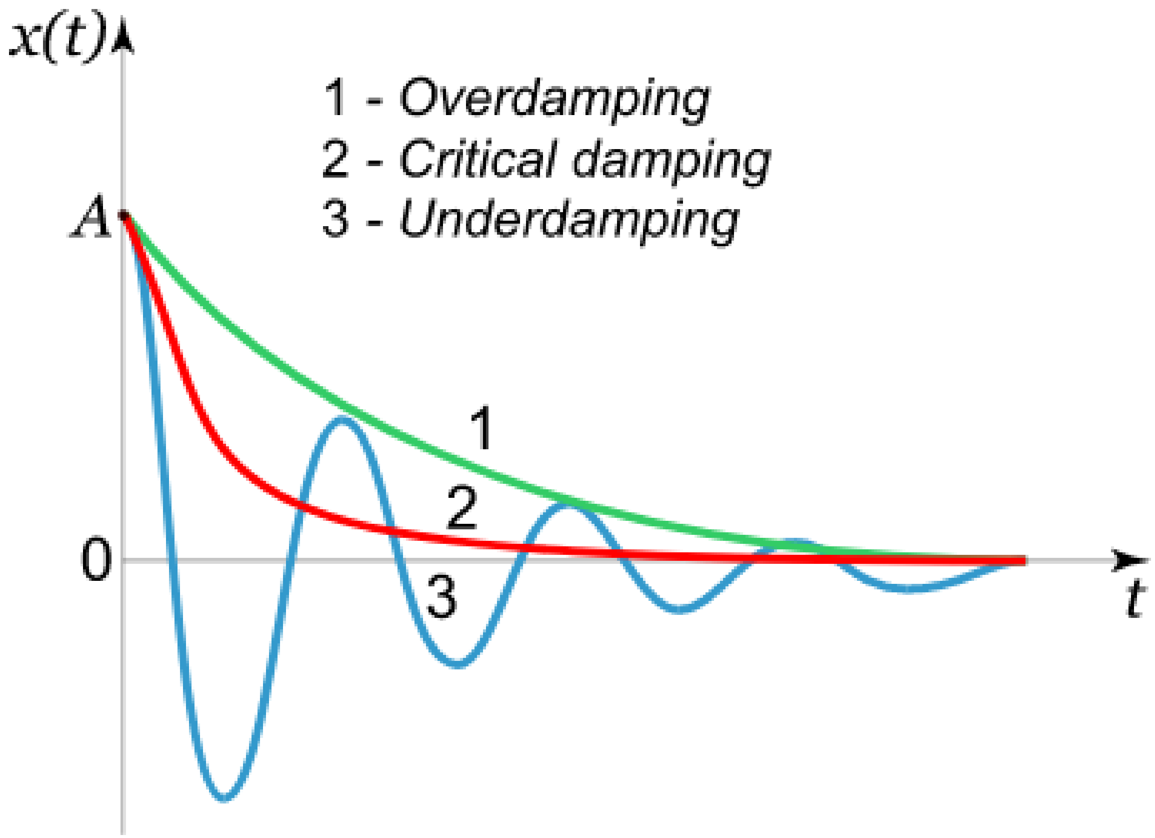
Types of Damping



Power Dissipation in a Damped Harmonic Oscillator

Home Work

(p. 91, GU Ahmad)

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Forced Vibrations

Whenever a particle oscillates in a medium it gets damped *i.e.*, its amplitude falls exponentially with time to zero due to dissipation of energy. If an external periodic force is applied to maintain the motion against the damping force, initially the amplitude of oscillation will increase, then decreases with time, becomes minimum and again increases. Finally the particle will start to oscillate with frequency of the applied force at a constant amplitude as long as the force remains active. Such vibrations of the body are called the forced vibrations.

Forced Vibrations

Let the periodic force which is applied on a damped harmonic oscillator be

$$F = F_0 sinpt$$

Where F_0 is the amplitude of the force and $\frac{p}{2\pi}$ is the frequency.

Forced Vibrations

Then the equation of motion for forced vibration is given as,

$$F = -ay - bv + F_0 sinpt$$

$$\frac{d^2y}{dt^2} + 2\lambda\frac{dy}{dt} + \omega^2 y = f_0 sinpt \text{.........}(1)$$

Where $2\lambda = \frac{b}{m}$, $\omega^2 = \frac{a}{m}$, and $f_0 = \frac{F}{m}$

Forced Vibrations

Home Work

Solve this equation (1) to obtain the displacement of the particle having a forced oscillation.

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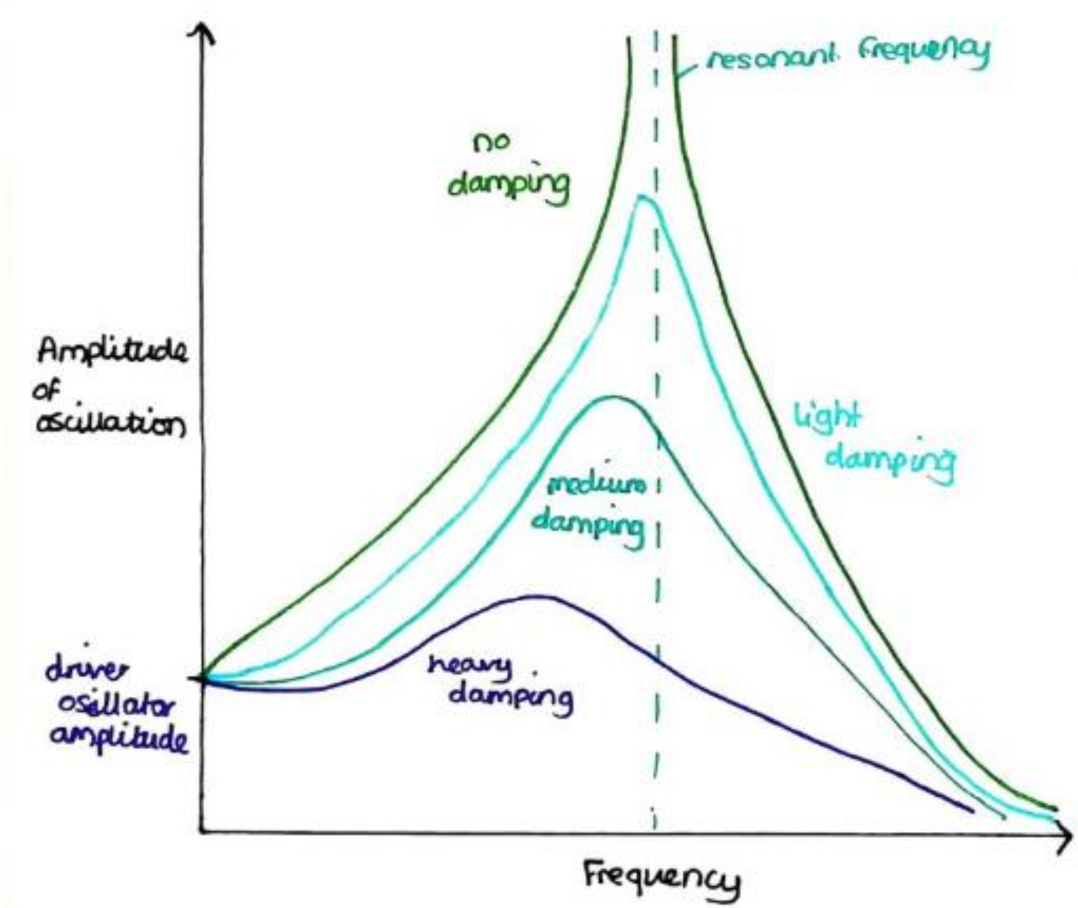
Resonance in Forced Vibrations



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More Study from

Book

Physics for Engineers Vo. 1(Gias Uddin Ahmad)

Chapter III

Pages 81-89, 91-94, 107-114

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Home Work: Sample Questions
(from More Study)

1. What is meant by a damping or dissipative force? Establish the differential equation of a damped harmonic oscillator and solve it to obtain an expression for the displacement of the oscillator.

2. What is meant by the terms: (a) logarithmic decrement, and (b) quality factor of damped harmonic oscillator. Obtain expressions for these.

3. Calculate the average power dissipation in a damped harmonic oscillator. (Show that the average power dissipation in a damped harmonic oscillator $= 2\lambda E$.)

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Home Work: Sample Questions
(from More Study)

4. What are free, damped, and forced vibrations? A particle showing damped harmonic motion is subjected to an external periodic force. Establish the differential equation of motion of the particle, explain each terms and solve it to obtain an expression for the displacement of the oscillator.

5. Explain the phenomena of quality factor and sharpness of resonance of forced harmonic oscillator and clearly explain the factors on which the sharpness of resonance depends.

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In the Subsequent Slides, We Discuss

- ✓ **Waves & Its Types**
- ✓ Progressive Waves
- ✓ Power and Intensity of Wave Motion
- ✓ Stationary Waves
- ✓ Phase Velocity
- ✓ Group Velocity
- ✓ Architectural Acoustics
- ✓ Reverberation
- ✓ Sabine's Reverberation Formula

"Thank You"

Thank You for Listening