Lectures-1

Course Title: **Heat & Thermodynamics, Structure of Matter, *Waves & Oscillations* and Physical Optics**

Course Code: **Phy 109**
Credit Hours: **4:00 (Level-1, Term-1)**

Total Lecture: **11-13; Lecture per week 01**

Course Teacher: Dr. Mohammad Abu Sayem Karal
Designation: Assistant Professor
Department: Department of Physics, BUET

Lectures

Lecture-1: Differential equation of a simple harmonic oscillator, Total energy and average energy,

Lecture-2: Combination of simple harmonic oscillations,

Lecture-3: Lissajous figures,

Lecture-4: Spring- mass system, Calculation of time period of torsional pendulum,

Lecture-5: Damped oscillation, Determination of damping co-efficient.

Lecture-6 : Forced oscillation, Resonance,

Lecture-7: Two-body oscillations, Reduced mass,

Lecture-8: Differential equation of a progressive wave, Power and intensity of wave motion,

Lecture-9: Stationary wave, Group velocity and phase velocity,

Lecture-10: Architectural acoustics, Reverberation and Sabine's formula.

Lecture-11: CT

Outcome:

- Learn the basic knowledge of waves and oscillation and the relevant examples
- Understand the characteristics of different types of damping motions and their relevant equations with examples
- Practical use in pendulum, Spring-mass system and for wave motion.
- Able to solve the relevant problems.
- Waves and oscillations for building design and for future studies and research.

Reference Book:

- Vibrations and Waves- A.P. French
- Fundamental of Physics- Resnic and Halliday
- Physics for Engineers (Part -1)- Gias Uddin Ahmad

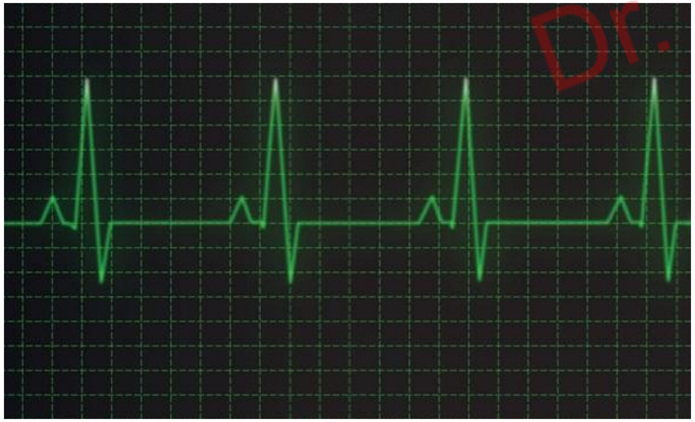
Vibrations or Oscillations

- Vibrations or Oscillations of mechanical system constitute one of the most important fields of study in all physics. Virtually, every system possesses the capability for vibrations, and most systems can vibrate freely in a large variety of ways.

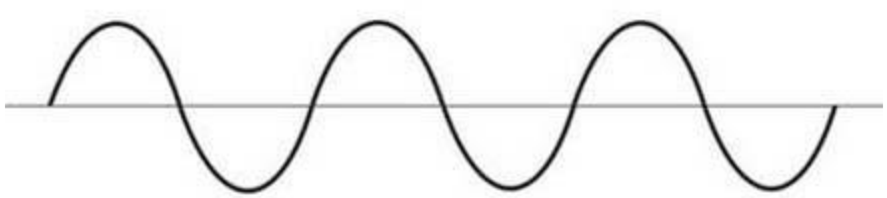
- Broadly speaking, the predominant natural vibrations of small objects are likely to be slow. A mosquito wings, for example, vibrate hundreds of times per second and produce an audible note. The whole earth, are being jolted by an earthquake, may continue to vibrate at the rate of about one oscillation per hour.

Continue…….

- **After all, our hearts beat, our lungs oscillate, we shiver when we are cold, we can hear and speak because our eardrums vibrate, we move by oscillating our legs. We cannot even say "vibration" properly without the tip of the tongue oscillating. Even the atoms of which we are constituted vibrate.**



A complex vibrations: human ECG



Pure Sine Wave

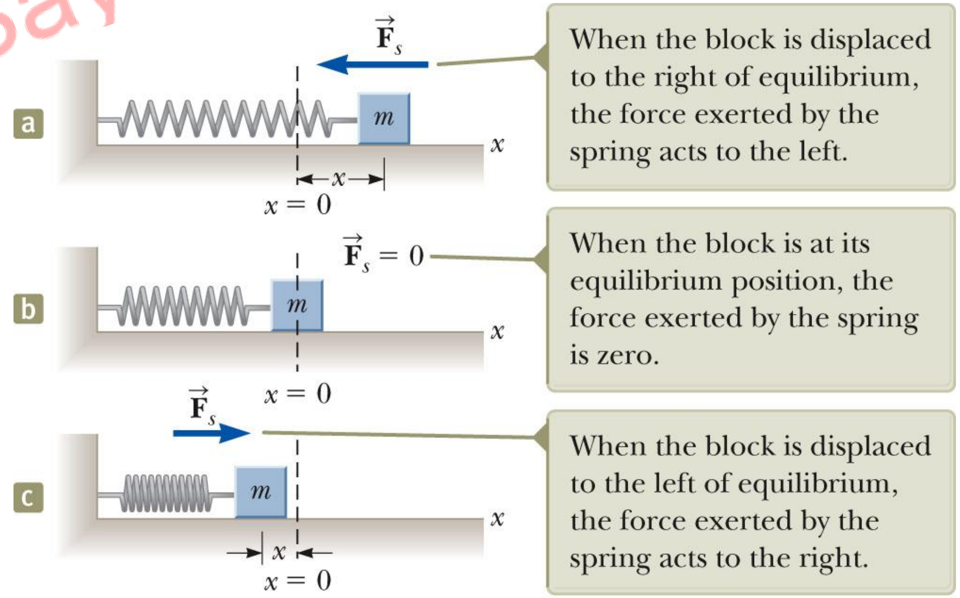
Oscillatory Motion Contain..

- Periodic motion
- Spring-mass system
- Differential equation of motion
- Simple Harmonic Motion (SHM)
- Energy of SHM
- Pendulum
- Torsional Pendulum

Periodic Motion

- Periodic motion is a motion that regularly returns to a given position after a fixed time interval.
- A particular type of periodic motion is "simple harmonic motion," which arises when the force acting on an object is proportional to the position of the object about some equilibrium position.

- The motion of an object connected to a spring is a good example.

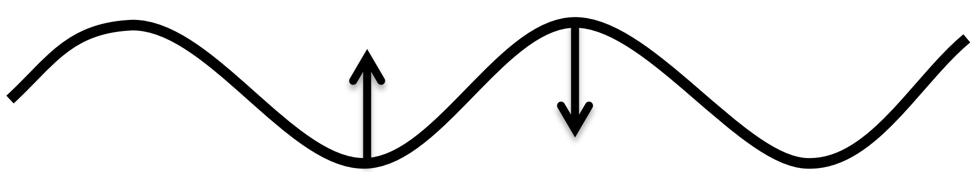


Recall Hooke's Law

Hooke's Law states $F_s = -kx$

- F_s is the restoring force.
  - It is always directed toward the equilibrium position.
  - Therefore, it is always opposite the displacement from equilibrium.
- k is the force (spring) constant.
- x is the displacement.

What is the restoring force for a surface water wave?



Differential Equation of Motion

Using F = ma for the spring of mass m, we have $ma = -kx$
But recall that acceleration is the second derivative of the position:

$$a = \frac{d^2x}{dt^2}$$

So this simple force equation is an example of a differential equation,

$$m\frac{d^2x}{dt^2} = -kx \quad \text{or} \quad \frac{d^2x}{dt^2} = -\frac{k}{m}x \Rightarrow \frac{d^2x}{dt^2} + \omega^2 x = 0$$

ω is the angular frequency. An object moves in simple harmonic motion whenever its acceleration is proportional to its position and has the opposite sign to the displacement from equilibrium. Simple harmonic motion is a prominent possibility in small vibration.

Average Kinetic Energy of a Vibrating Particle

The displacement of a vibrating particle is given below:

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

$$\Rightarrow v = \frac{dy}{dt} = a\omega\cos(\omega t + \alpha)$$

If m is the mass of the vibrating particle, the kinetic energy at any instant

$$K.E. = \frac{1}{2}mv^2 = \frac{1}{2}ma^2\omega^2\cos^2(\omega t + \alpha)$$

The average kinetic energy of the particle in one complete vibration

$$K.E._{av} = \frac{1}{T}\int_0^T \frac{1}{2}ma^2\omega^2\cos^2(\omega t + \alpha)dt$$

$$K.E._{av} = \frac{ma^2\omega^2}{4T}\int_0^T 2\cos^2(\omega t+\alpha)dt$$

$$K.E._{av} = \frac{ma^2\omega^2}{4T}\int_0^T \left[1+\cos 2(\omega t+\alpha)\right]dt$$

$$= \frac{ma^2\omega^2}{4T}\left[\int_0^T dt + \int_0^T \cos 2(\omega t+\alpha)dt\right]$$

But $\int_0^T \cos 2(\omega t+\alpha)dt = 0$

$$K.E._{av} = \frac{ma^2\omega^2}{4T}T + 0 = \frac{ma^2(2\pi n)^2}{4} = \pi^2 ma^2 n^2$$

Therefore, the average kinetic energy of a vibrating particle is directly proportional to the square of the amplitude.

Total Energy of a Vibrating Particle

The displacement of a vibrating particle is given below:

$$y = a\sin(\omega t + \alpha) \Rightarrow \sin(\omega t + \alpha) = \frac{y}{a}$$

$$\therefore \cos(\omega t + \alpha) = \frac{\sqrt{a^2 - y^2}}{a}$$

If m is the mass of the vibrating particle, the kinetic energy at any instant

$$K.E. = \frac{1}{2}mv^2 = \frac{1}{2}m\omega^2(a^2 - y^2)$$

Potential energy of the vibrating particle is the amount of work done in overcoming the force through a distance y,

The potential energy of the vibrating object at any instant

$$P.E. = \int_0^y m\omega^2 y dy = \frac{1}{2} m\omega^2 y^2$$

$$Acceleration, a = -\omega^2 y$$

$$Force, F = -m\omega^2 y$$

The negative sign shows that the direction of the acceleration and force are opposite to the direction of motion of the vibrating particle.

Total energy of the particle at any instant of the displacement y is: E = K.E.+P.E.

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

Therefore, the total energy at any instant of the vibrating particle is constant.