

Coupled Pendulum and Normal Modes of Vibration

Prepared by:

Dr. Usha Kumari

Assistant Professor, Physics

1. Introduction to Coupled Pendulum

When two or more pendulums are connected in such a way that the motion of one affects the motion of the other, the system is called a **coupled pendulum system**.

Coupling is usually achieved by connecting the pendulums with a **light spring, string, or elastic wire**.

In such systems, energy can be transferred from one pendulum to the other, leading to complex oscillatory motion.

2. Definition of Normal Mode of Vibration

👉 Normal Mode of Vibration:

A **normal mode of vibration** is a particular type of motion of a coupled system in which **all parts of the system oscillate with the same frequency and in a fixed phase relation**, such that the motion of each particle is a simple harmonic motion (SHM).

In normal modes, the system vibrates in a stable and characteristic pattern.

3. Description of a Coupled Pendulum System

Consider **two identical simple pendulums** of equal length and mass, suspended from a rigid support and connected by a light spring.

- Each pendulum can oscillate independently.
- Due to the coupling spring, motion of one pendulum influences the other.
- The system exhibits **two normal modes of vibration**.

4. Normal Modes of Coupled Pendulum

(a) First Normal Mode – In-Phase Mode

- Both pendulums oscillate **in the same direction** at the same time.
- The spring remains almost **unstretched**.
- Coupling force has **no significant effect**.

Characteristics:

- Frequency is **minimum**
- Motion resembles that of a single pendulum
- Energy remains equally distributed

(b) Second Normal Mode – Out-of-Phase Mode

- Pendulums oscillate in **opposite directions**.
- The spring is **alternately stretched and compressed**.
- Restoring force increases due to spring tension.

Characteristics:

- Frequency is **maximum**
- Strong effect of coupling
- Energy alternates between kinetic and potential forms

5. Importance of Normal Modes

- Simplifies analysis of complex vibrating systems
- Basis for understanding:
 - Molecular vibrations
 - Crystal lattice vibrations
 - Mechanical and electrical oscillators
- Used in **quantum mechanics and solid-state physics**

6. Conclusion

A coupled pendulum system demonstrates how interaction between oscillators leads to **normal modes of vibration**. Each normal mode has a definite frequency and pattern of motion. The study of normal modes is fundamental in understanding oscillatory systems in classical as well as modern physics.
