

Free, Damped and Forced Vibration



2.1. Introduction

In the previous chapter, we have discussed free simple harmonic motion where the amplitude of vibration is constant. Now, we will observe, how this amplitude of free vibration will change with time due to, (i) viscous resistive force of the medium or due to (ii) applied periodic force. Hence, we want to study damped and forced vibration. Before discussing damped and forced vibration, let us recapitulate free vibration.

2.2. Free Vibration

If a body is made to vibrate by disturbing it from its state of equilibrium and leaving to vibrate itself, the body vibrates with its own definite natural frequency. Such a vibration, which takes place only under the influence of its own elastic force is called natural or free vibration. The frequency of vibration depends upon mass, shape and elastic properties of the body.

When a body of mass m is displaced by a distance x from the position of rest, the equation of free vibration as discussed earlier can be written as,

$$m \frac{d^2x}{dt^2} = -ax, \quad a = \text{constant} = \text{restoring force per unit displacement.}$$

i.e. $\frac{d^2x}{dt^2} + \omega^2x = 0$, where $\omega = \sqrt{\frac{a}{m}}$ = natural angular frequency. ... (2.1)

This is the differential equation of S.H.M. and its solution is,

$$x = A \sin(\omega t + \delta) \quad \dots (2.2)$$

Here, A is the amplitude of vibration and it is constant with time [Fig. 1(a)]. The natural cyclic frequency of vibration of the body is, $f_0 = \frac{\omega}{2\pi}$. Consequently, the total energy for free vibration remains constant.

Ideally, the body vibrates with its natural frequency for an indefinite time with a constant amplitude. In practice, the free vibration of a body can never be realized as the amplitude decays with time due to the viscosity of the medium or other frictional forces (external or internal) and finally the body comes to rest at its mean position. Such vibrations of decaying amplitude are known as *damped (or resisted) vibrations*.

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