CHAPTER 8

Doppler Effect

8.1. Doppler Effect

It is commonly observed that the pitch of a note apparently changes when either the source or the observer are in motion relative to each other. When the source approaches the observer or when the observer approaches the source or when both approach each other the apparent pitch is higher than the actual pitch of the sound produced by the source. Similarly, when the source moves away from the observer or when the observer moves away from the source or when both move away from each other, the apparent pitch is lower than the actual pitch of the sound produced by the source.

Suppose a person is standing on a platform. The apparent pitch of the whistle of the engine increases, when the engine is approaching the person. When the engine moves away from the person, the apparent pitch of the whistle of the engine decreases. This apparent change in the pitch due to the relative motion between the source and the observer is called **Doppler effect.**

Doppler effect in sound is asymmetric. When the source moves towards the observer with a certain velocity, the apparent pitch is different to the case when the observer is moving towards the source with the same velocity. But it is not so in the case of light. Doppler effect in light is symmetric. The apparent pitch in different cases is calculated in the subsequent articles.

8.2. Observer at Rest and Source in Motion

(a) When the source moves towards the stationary observer

Suppose a source S is producing sound of pitch n and wavelength λ. The velocity of sound is v. (Fig. 8.1).

Let the source move with a velocity a towards the observer. In one second, n waves will be contained in a length $(v - a)$ and the apparent wavelength,

$$\lambda' = \frac{(v-a)}{n}$$

The apparent pitch,

$$n' = \frac{v}{\lambda'}$$

$$\therefore \qquad n' = \left(\frac{v}{v-a}\right) n \qquad n' > n \qquad \ldots (1)$$

Thus, the apparent pitch of the note increases when the source moves towards a stationary observer.

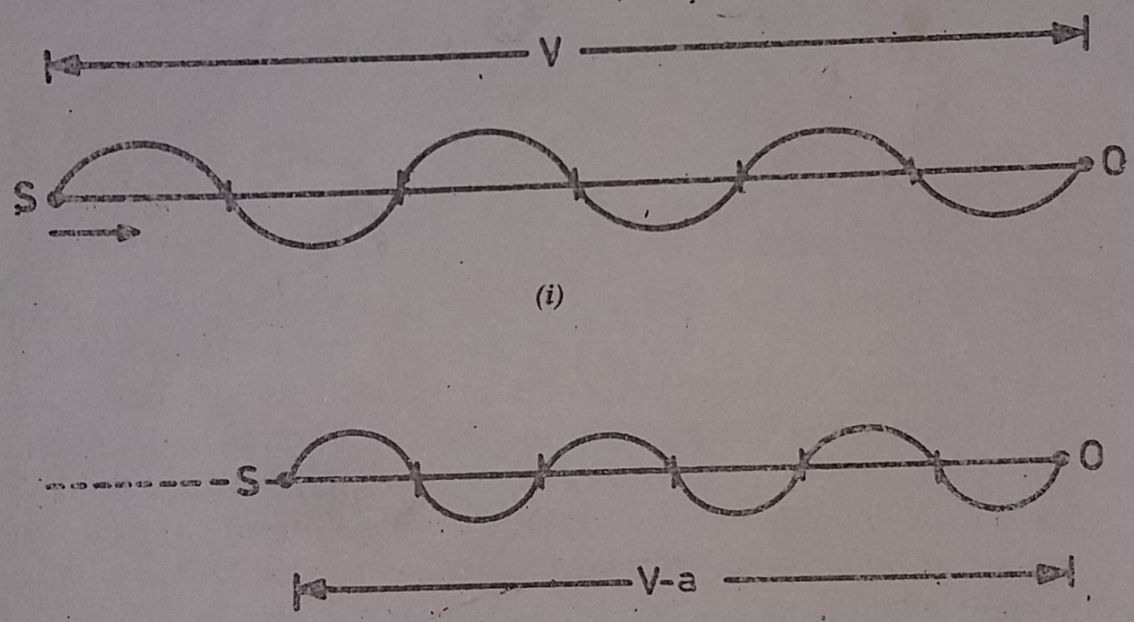

Fig. 8.1.

(b) When the source moves away from the stationary observer

Suppose a source S is producing sound of pitch n and wavelength λ. The velocity of sound is v (Fig. 8.2). Let the source move with a velocity a away from the observer. In one second, n waves will be contained in a length $(v + a)$ and the apparent wavelength,

$$\lambda' = \frac{v+a}{n}$$

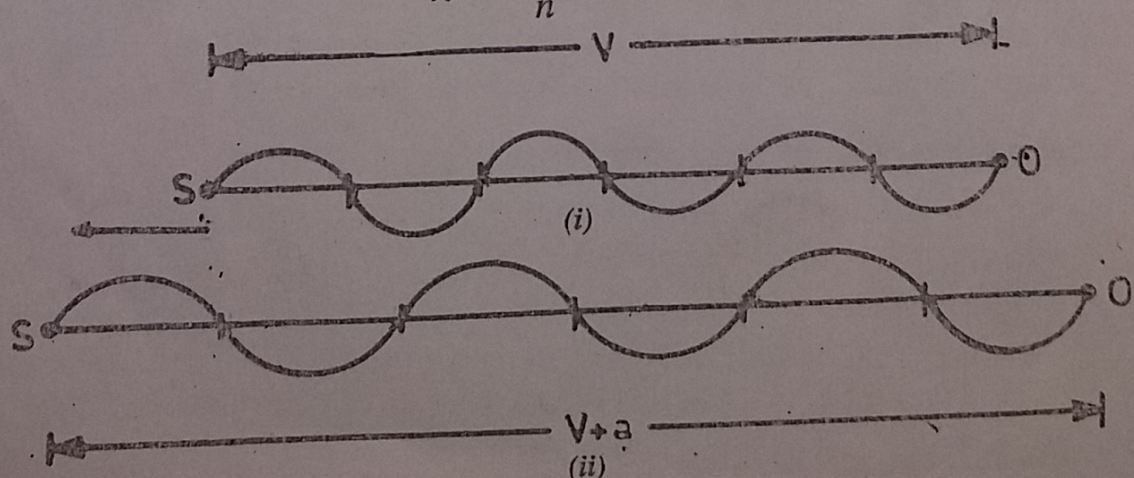

Fig. 8.2.

The apparent pitch,

$$n' = \frac{v}{\lambda'}$$

$$\therefore \quad n' = \left(\frac{v}{v+a}\right) n \qquad n' < n \qquad \ldots (2)$$

Thus the apparent pitch of the note decreases when the source moves away from a stationary observer.

Note. For the same values of v, a and n, the values of n' in equations (1) and (2) will be different.

8.3. Source at Rest and Observer in Motion

(*a*) When the observer moves towards a stationary source

Suppose a source S is producing sound of pitch n and wavelength λ. The velocity of sound is v (Fig. 8.3). Let the observer move with a velocity b towards a stationary source. In this case the observer receives more number of waves in one second. The apparent wavelength remains the same. The apparent frequency

$$n' = n + \frac{b}{\lambda}$$

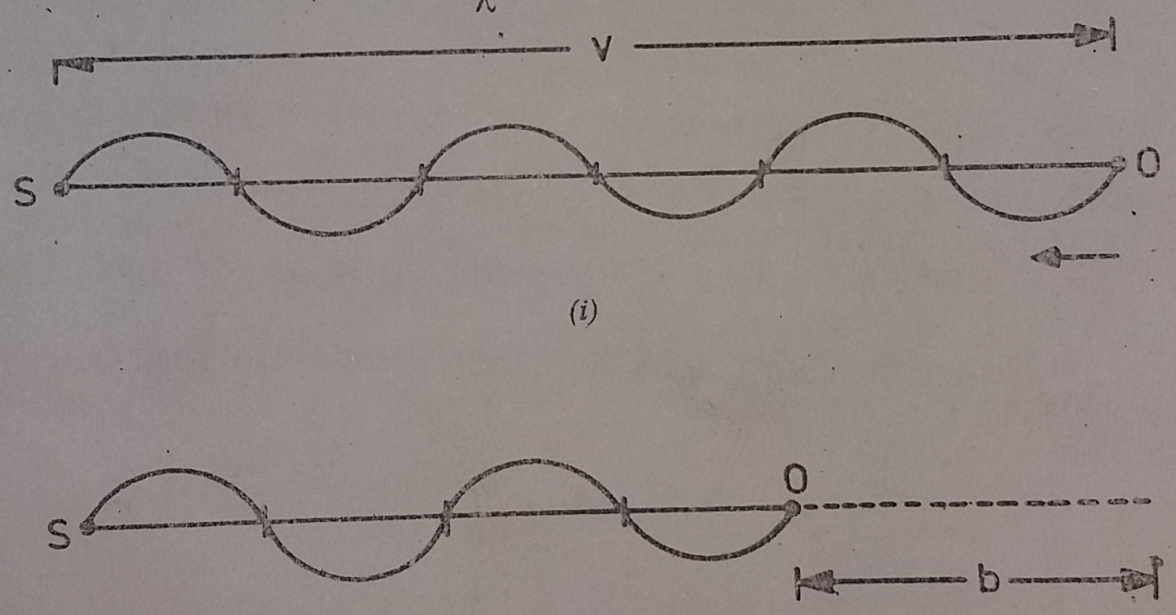

Fig. 8.3.

$$n' = \frac{v}{\lambda} + \frac{b}{\lambda}$$

$$n' = \left(\frac{v+b}{\lambda}\right)$$

But $$\lambda = \frac{v}{n}$$

$$\therefore \quad n' = \left(\frac{v+b}{v}\right) n \qquad n' > n \qquad \ldots (1)$$

Thus the apparent pitch of the note increases when the observer moves towards the stationary source.

(*b*) **When the observer moves away from a stationary source**

Suppose a source *S* is producing sound of pitch *n* and wavelength λ (Fig. 8.4). The velocity of sound is *v*. Let the observer move with a velocity *b* away

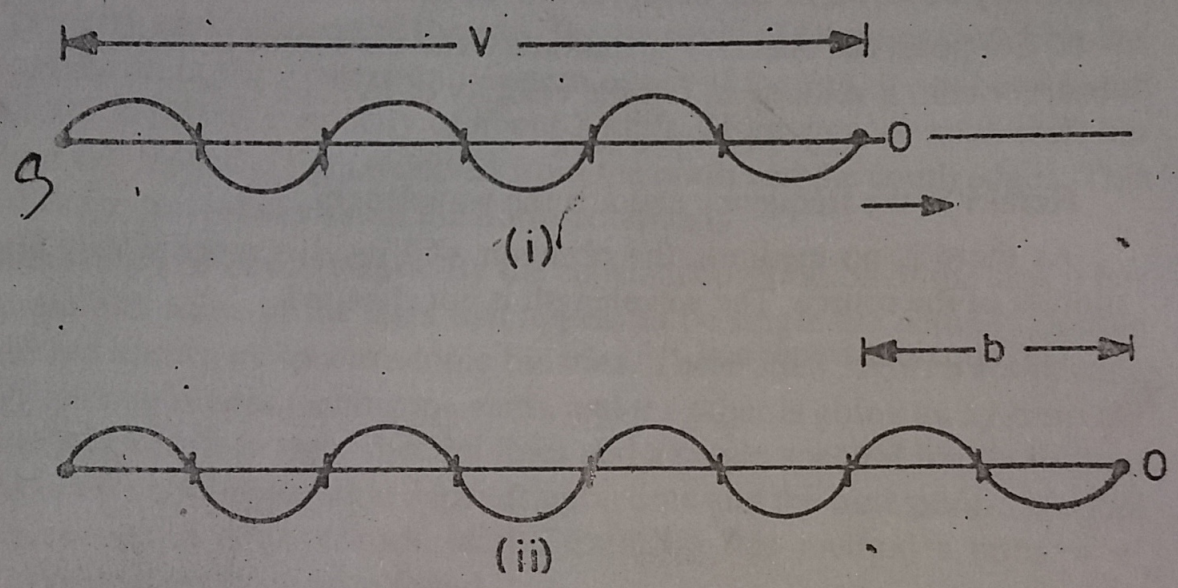

Fig. 8.4.

from a stationary source. In this case, the observer receives less number of waves is one second. The apparent wavelength remains the same. The apparent frequency

$$n' = n - \frac{b}{\lambda}$$

$$n' = \frac{v}{\lambda} - \frac{b}{\lambda}$$

$$n' = \left(\frac{v-b}{\lambda}\right)$$

But $$\lambda = \frac{v}{n}$$

$$\therefore \quad n' = \left(\frac{v-b}{v}\right) n \qquad n' < n \qquad \ldots (2)$$

Thus the apparent pitch of the note decreases when the observer moves away from a stationary source.

Note. For the values of *v*, *b* and *n*, the values of *n'* in equations (1) and (2) will be different.