Chapter Six

Velocity of Sound

Doppler Effect

6.1: Doppler Effect:

- 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 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.

6.2: Observer at Rest and Sound in Motion:

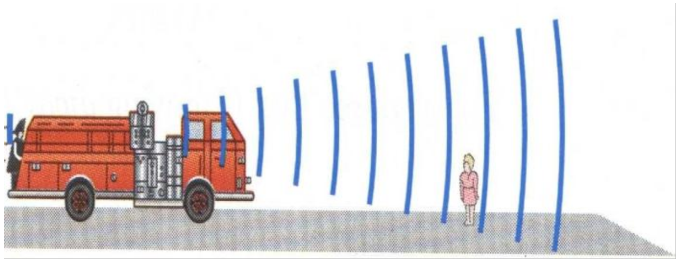
(a) When the source S is moves towards the stationary observer

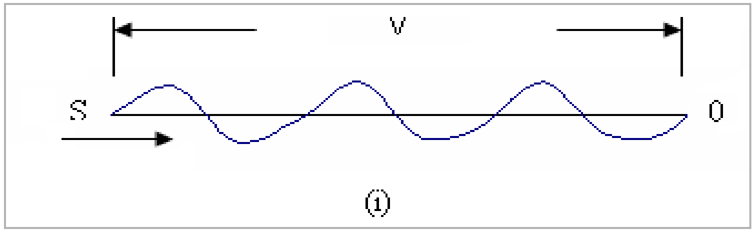
Suppose a source is producing sound of pitch n and wavelength λ. The velocity of sound is v (Figure 6-1). Let the source S move with a velocity (a) towards the observer. In one second, The apparent pitch;

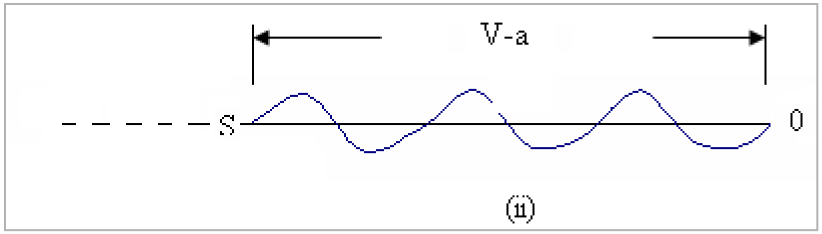
$$n' = \frac{v}{\lambda'}$$

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

$$n' = \left(\frac{v}{v-a}\right)n \quad ----(1)$$







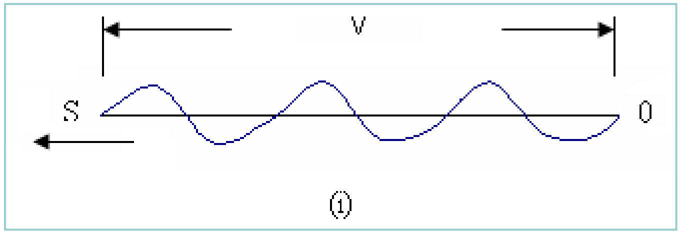
Thus the apparent pitch of the note increases when the source moves towards a stationary observer.

(b) When the source away from the stationary observer

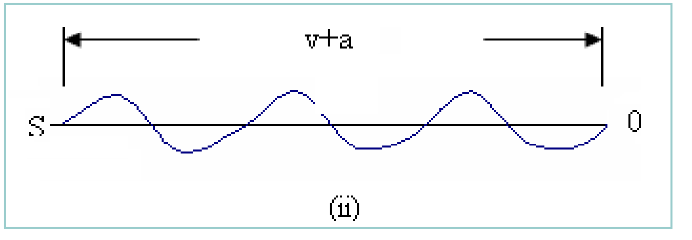
- **Suppose a source is producing sound of pitch n and wavelength λ. The velocity of sound is v (Figure 6-2). Let the source S move with a velocity (a) away from the observer. In one second, n waves will be contained in a length (v+a) and the apparent wavelength;**

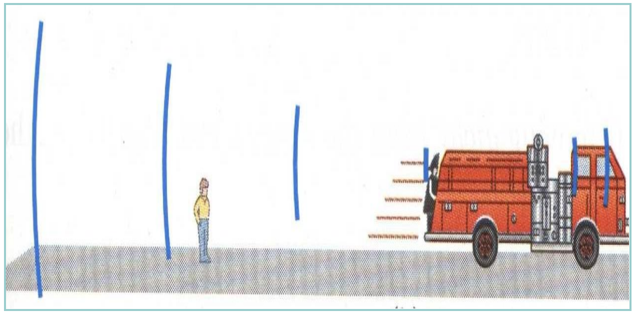
$$\lambda' = \frac{v+a}{n}$$

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



$$n' = \left(\frac{v}{v+a}\right)n \quad ----(2)$$





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

6.3: Source at Rest and Observer in Motion:

(a) When the observer moves towards a stationary observer

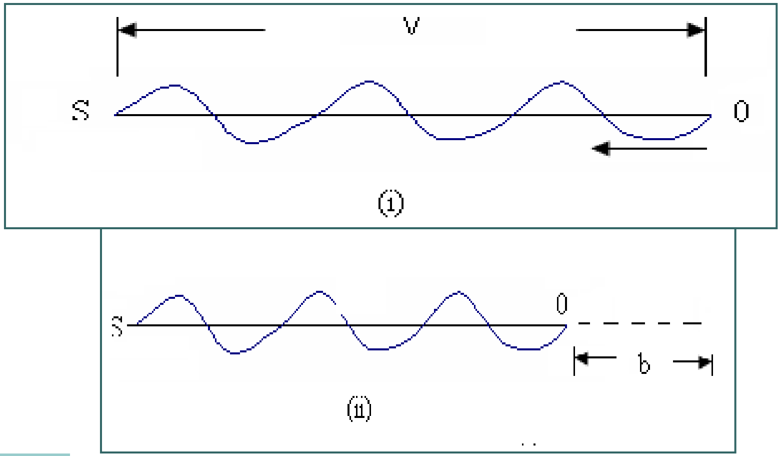
- Suppose a source is producing sound of pitch n and wavelengthλ. The velocity of sound is v (Figure 6-3). Let the observer move with a velocity (b) towards a stationary source. In this case, the observer receives more number of waves in one second. The apparent wavelength remains the same. The apparent frequency;

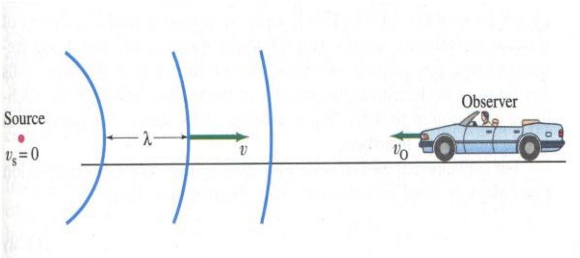
$$n' = n_s + n_o$$

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

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

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





$$n' = \left(\frac{v+b}{v}\right) n \quad -----(3)$$

Thus the apparent pitch of the note <u>increases</u> when the observer moves towards a stationary source.

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

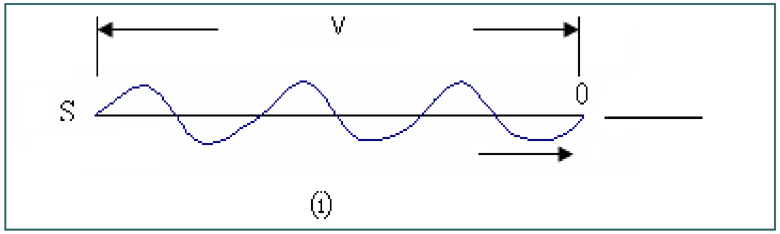
- Suppose a source is producing sound of pitch n and wavelengthλ. The velocity of sound is υ (Figure 6-4). Let the observer move with a velocity (b) away from a stationary source. In this case, the observer receives less number of waves in one second. The apparent wavelength remains the same. The apparent frequency;

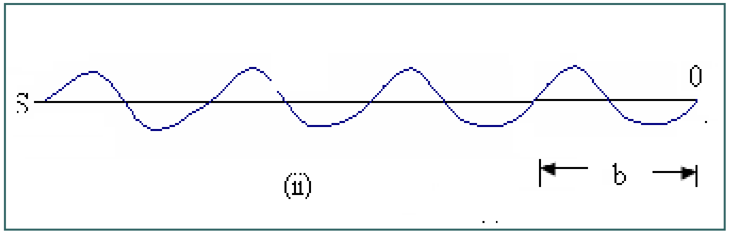
$$n' = n_s - n_o$$

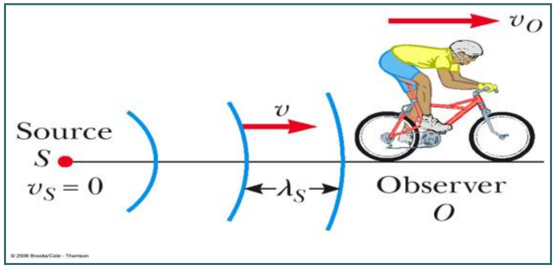
$$n' = n - \frac{b}{\lambda}$$

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

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







$$n' = \left(\frac{v-b}{v}\right) n \quad ----(4)$$

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

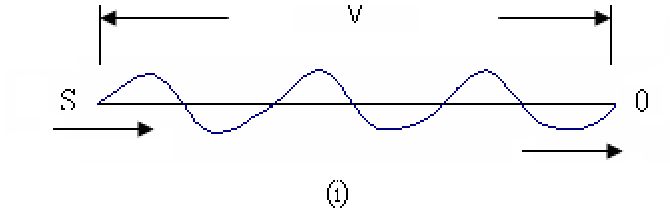
6.4: When both the Source and the Observer are in Motion:

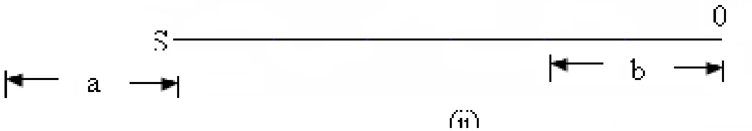
- When the source moves towards the observer and the observer moves away from the source. Suppose a source S is producing sound of pitch n and wavelength λ. The velocity of sound is v (Figure 6-5). The velocity of the source is (a) and the velocity of the observer is (b).
- Let the source move towards the observer with a velocity (a) and the observer move away from source with a velocity (b).

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

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

$$n' = \left(\frac{v-b}{v-a}\right) n \quad ----(5)$$

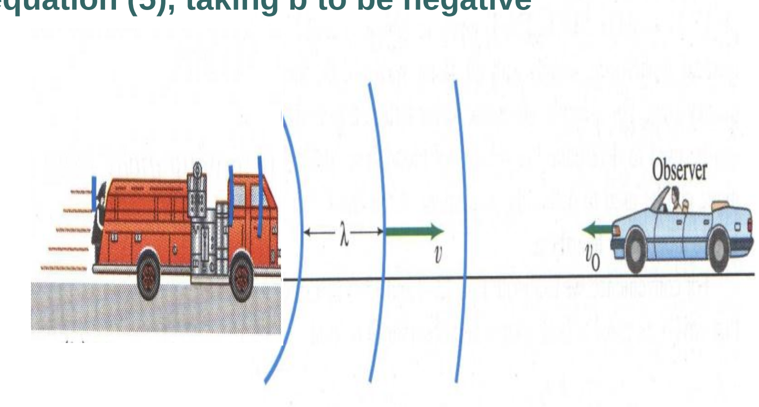




(a) When the source and the observer moves towards each other, In equation (5), taking b to be negative

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

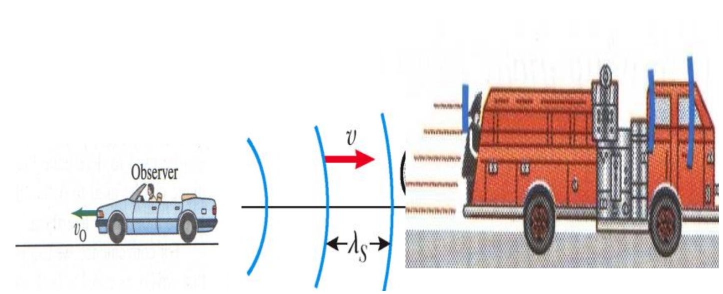
$$n' = \left(\frac{v + b}{v - a} \right) n \quad -----(6)$$



(b) When the source and the observer moves away from each other , In equation (5), taking a to be negative;

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

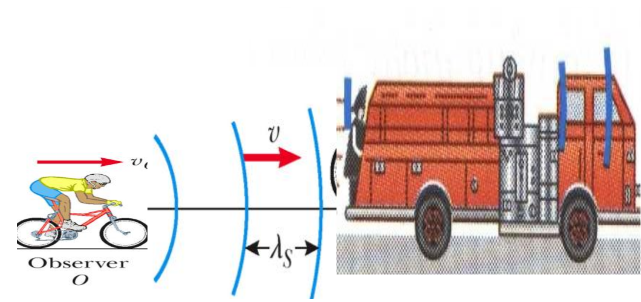
$$n' = \left(\frac{v - b}{v + a} \right) n \quad -----(7)$$



(c) Source moving away from the observer and the observer moving towards the source In equation (5), taking a and b to be negative

$$n' = \left(\frac{\upsilon - (-b)}{\upsilon - (-a)} \right) n$$

$$n' = \left(\frac{\upsilon + b}{\upsilon + a} \right) n \quad -----(8)$$



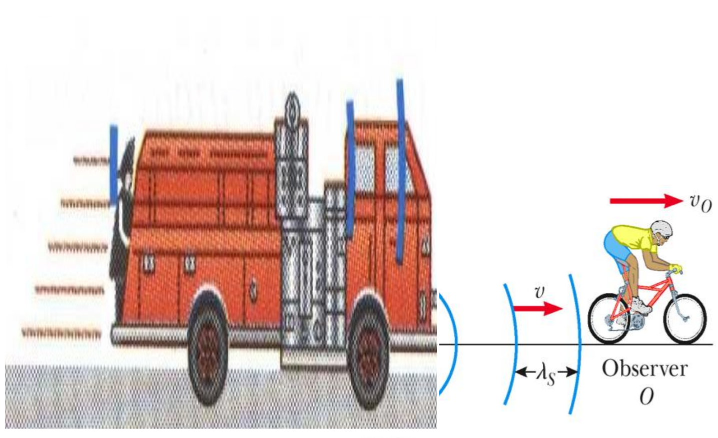
6.5: Effect of Wind Velocity:

- Suppose the wind is moving with a velocity w in the direction of propagation of sound, the apparent velocity of sound will be (v+w). In all relations, in place of v, (v+w) should be used. If the wind is blowing in a direction opposite to the direction of propagation of sound, the apparent velocity of sound will be (v-w). In all relations, in place of v, (v-w) should be used.

$$n' = \left(\frac{(v+w)-b}{(v+w)-a} \right) n \quad ......(9)$$

Here the wind direction is the same as the direction of propagation of sound. When the direction of wind is opposite to the direction of propagation of sound;

$$n' = \left(\frac{(v-w)-b}{(v-w)-a} \right) n \quad ......(10)$$


v_O
v
λ_S
Observer
O