Sound

Lecture No. 10

Topic: Doppler's Principle

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Doppler’s Principle

- “The apparent change in the frequency due to the relative motion between the source and the observer is called **Doppler effect**.”
- For sound waves, Doppler effect is asymmetric. When the source moves towards the observer with a certain velocity, the apparent frequency is different to the case when the observer is moving towards the source with the same velocity.
- **Apparent pitch of sound > actual pitch of sound:**
  - When either source approaches the observer
  - Or observer approaches the source
  - Or both the source and the observer approaches each other.
- **Apparent pitch of sound < actual pitch of sound:**
  - When either source moves away from the observer
  - Or observer moves away from the source
  - Or both the source and the observer move away from each other.

❑ Observer at rest and source in motion:

A. When the source **moves towards** the stationary observer

Let, n = frequency of the sound produced by source S

λ= wavelength of the sound

v=velocity of the sound

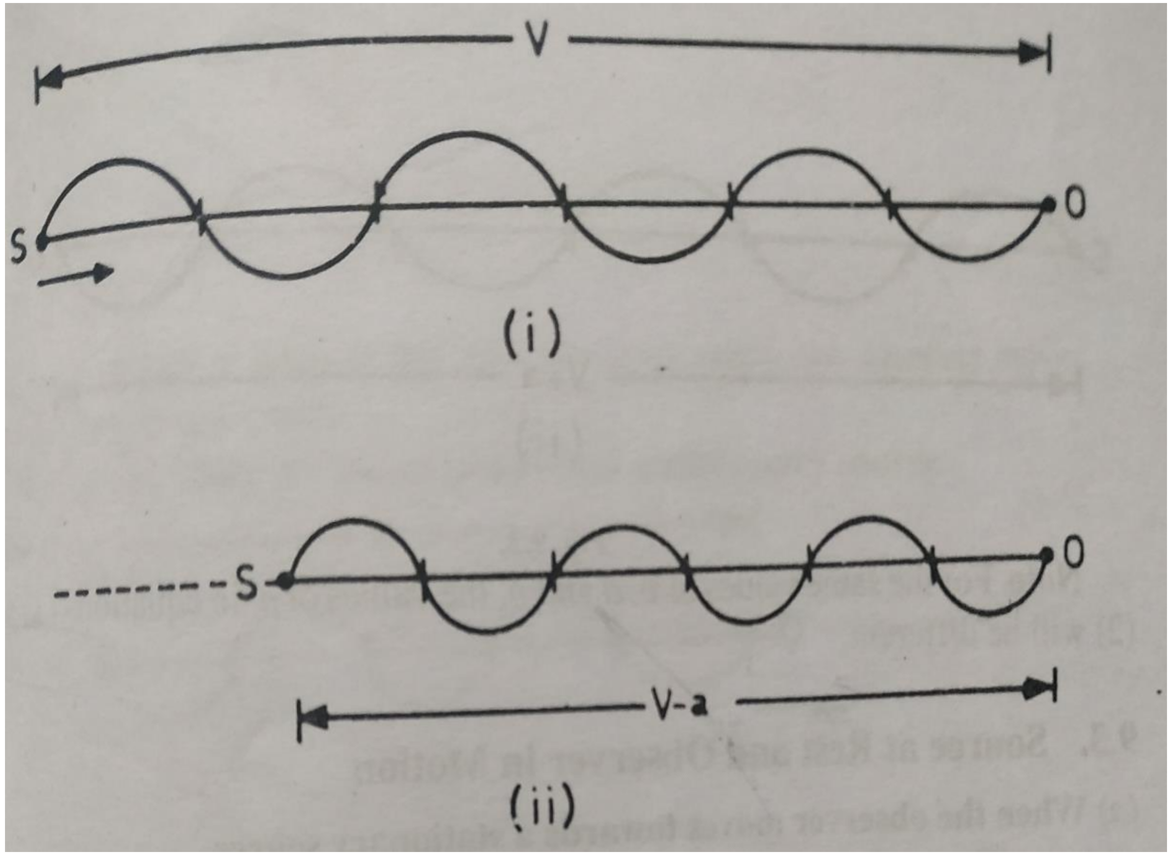
a= velocity of the source while moving towards the observer.

In one second n waves will be contained in the length (v-a) and the apparent wavelength,

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

Apparent frequency, $n' = \frac{v}{\lambda'}$

So, $n' = \left(\frac{v}{v-a}\right) n$ That is, $n' > n$



In the figure, S is the source and O is the observer.

❑ Observer at rest and source in motion:

B. When the source **moves away from** the stationary observer

Let, n = frequency of the sound produced by source S

λ= wavelength of the sound

v=velocity of the sound

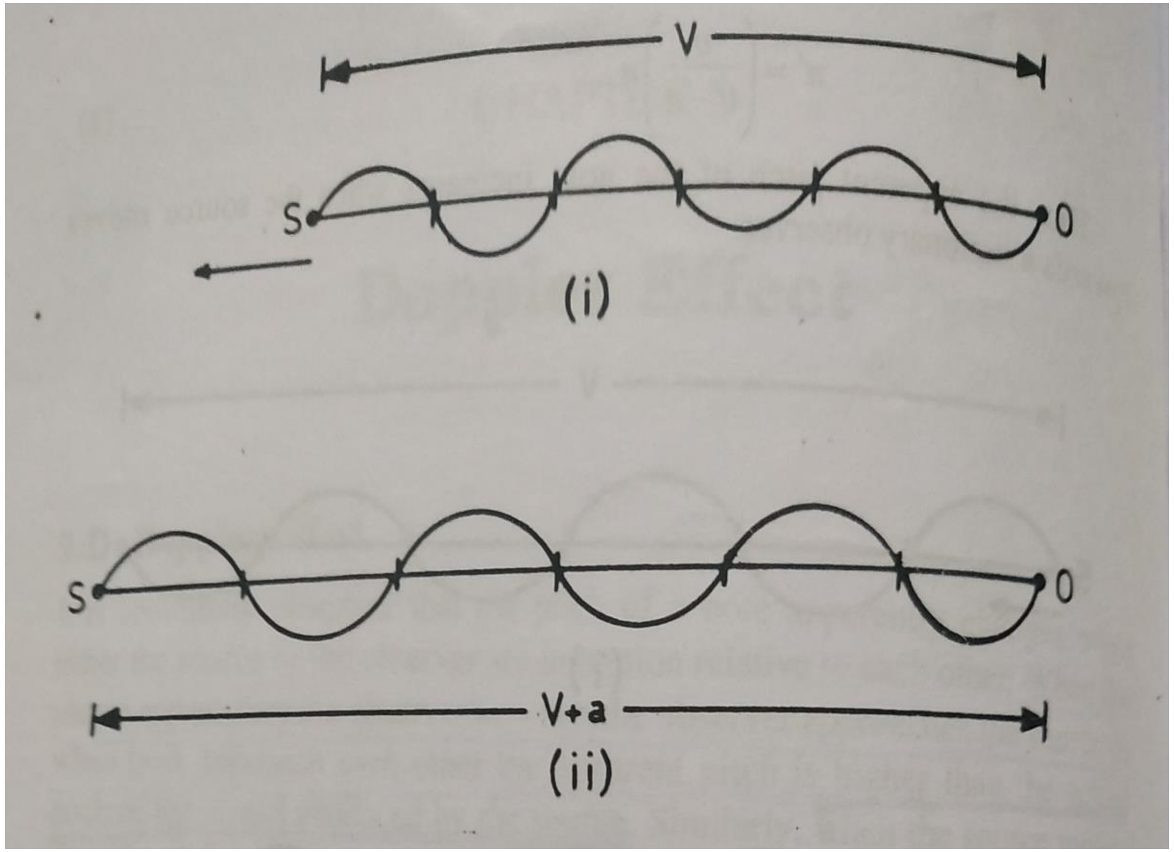
a= velocity of the source while moving away from the observer.

In one second n waves will be contained in the length (v+a) and the apparent wavelength,

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

Apparent frequency, $n' = \frac{v}{\lambda'}$

So, $n' = \left(\frac{v}{v+a}\right) n$ That is, $n' < n$



In the figure, S is the source and O is the observer.

❑ Source at rest and observer in motion:

A. When the observer **moves towards** the stationary source

Let, n = frequency of the sound produced by source S

λ= wavelength of the sound

v=velocity of the sound

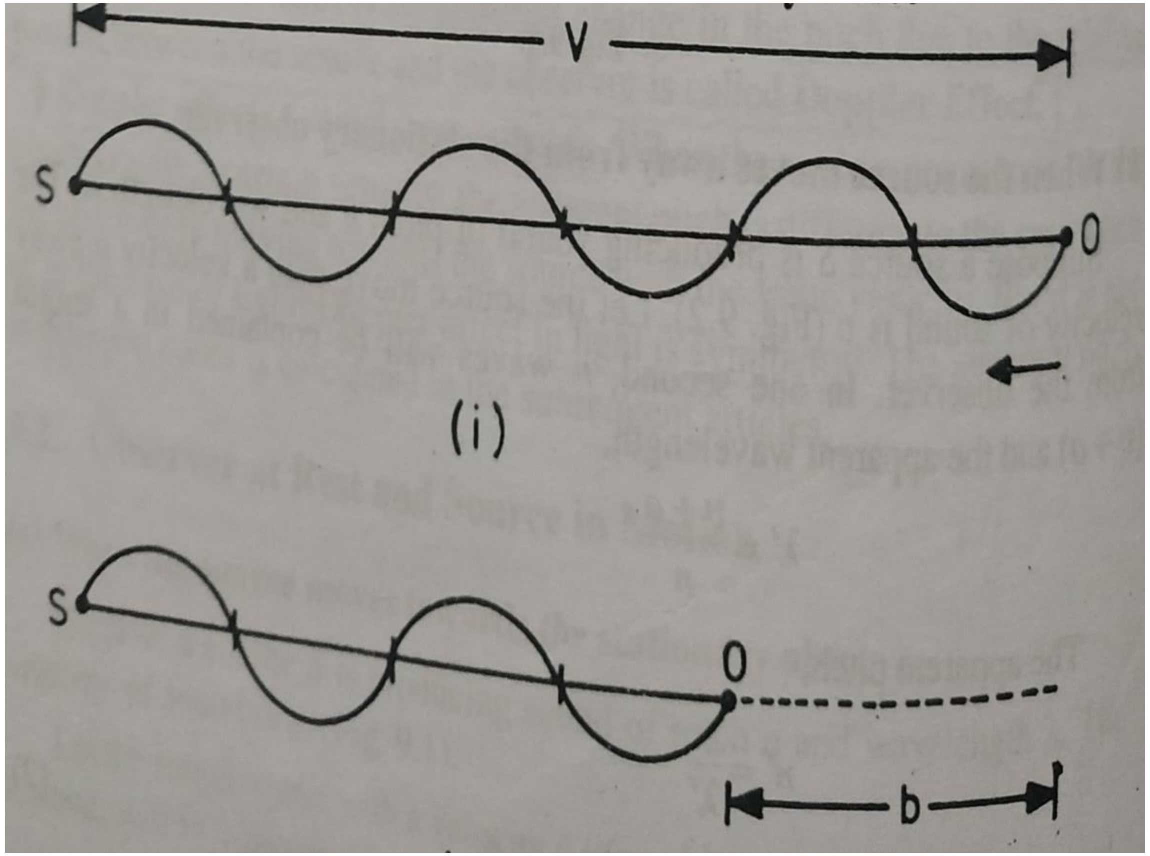
b= velocity of the observer while moving towards the source.

In this case observer receives more number of waves in one second. The apparent wavelength remains the same.

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

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

But, $\lambda = \frac{v}{n}$ $\quad\quad$ $\therefore n' = \left(\frac{v+b}{v}\right)n$ $\quad\quad$ That is, $n' > n$



In the figure, S is the source and O is the observer.

❑ Source at rest and observer in motion:

B. When the observer **moves away from** the stationary source

Let, n = frequency of the sound produced by source S

λ= wavelength of the sound

v=velocity of the sound

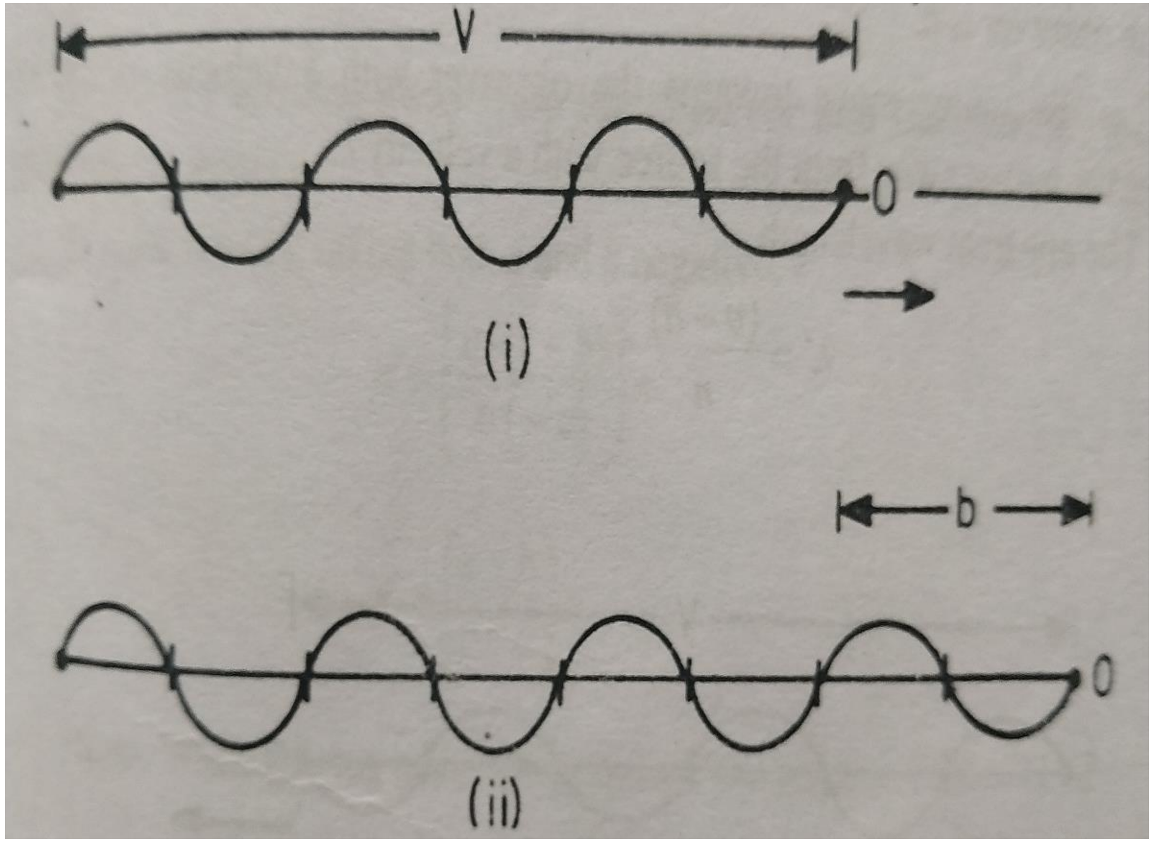
b= velocity of the observer while moving away from the source.

In this case observer receives less number of waves in one second. The apparent wavelength remains the same.

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

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

But, $\lambda = \frac{v}{n}$ $\therefore n' = \left(\frac{v-b}{v}\right)n$ That is, $n' < n$



In the figure, S is the source and O is the observer.

❑ Both the source and the observer are in motion:

When the source moves towards the observer and the observer moves away from the source

Let, n = frequency of the sound produced by source S

λ= wavelength of the sound

v=velocity of the sound

a= velocity of the source while moving towards the observer.

b= velocity of the observer while moving away from the source.

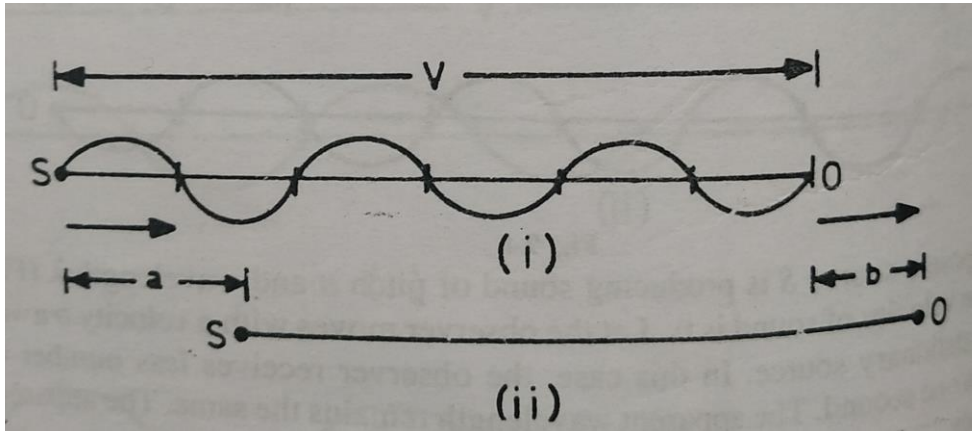
The apparent wavelength, $\lambda' = \frac{v-a}{n} \Rightarrow n\lambda' = v - a$

The apparent frequency, $n' = \frac{v-b}{\lambda} \Rightarrow n'\,\lambda = v - b$

So, $\frac{n'\,\lambda}{n\lambda'} = \frac{v-b}{v-a}$ Since, $\lambda \approx \lambda'$

$$\therefore n' = \left(\frac{v-b}{v-a}\right) n \qquad (12.18)$$

This is the general formula for solving numerical problems.



i. When the source and the observer move towards each other, in equation (12.18) the velocity "b" will be negative.

$$n' = \left[\frac{v-(-b)}{v-a}\right] n \qquad \Rightarrow n' = \left[\frac{v+b}{v-a}\right] n$$

ii. When the source and the observer move away from each other, in equation (12.18) the velocity "a" will be negative.

$$n' = \left[\frac{v-b}{v-(-a)}\right] n \qquad \Rightarrow n' = \left[\frac{v-b}{v+a}\right] n$$

iii. When the source moves away from the observer and the observer moves towards the source, in equation (12.18) both "a" and "b" will be negative.

$$n' = \left[\frac{v-(-b)}{v-(-a)}\right] n \qquad \Rightarrow n' = \left[\frac{v+b}{v+a}\right] n$$