

3.7 DOPPLER EFFECT

Definition:

The apparent change in frequency (or) pitch either due to the motion of source (or) observer (or) both is known as Doppler Effect.

Example:

We can observe this effect, when we walk towards a loud speaker producing sound in streets i.e: when we go towards the loud speaker we will hear high pitch(sound) and when we go away from the loud speaker pitch becomes lower. This apparent change in pitch due to relative motion between the observer (human) and the source(loud speaker) is known as Doppler Effect.

Types:

Doppler Effect is found to exist in both sound as well as in light.

Doppler Effect in Sound:

Definition : (in Sound)

The apparent change in pitch of sound due to the relative motion of source of sound (or) observer is called Doppler effect in sound.

Symmetric Property:

Doppler Effect in Sound is **Asymmetric**.

Reason:

In the case of sound, a material medium is necessary for the sound to propagate. There exists a change in pitch or frequency and hence the apparent frequency will be different in both the following cases viz,

- i) When a source moves towards a stationary observer.
- ii) When the observer moves towards a stationary source.

thus, the Doppler effect in Sound is Asymmetric.

Mathematical Relations:

Let us consider a source 's' producing a sound of pitch ' n '. Let ' a ' be the velocity of the source, ' b ' be the velocity of the observer and ' v ' be the velocity

of the sound .Then we can write the apparent pitch (n') for both the cases as follows.

case i:

When the source is moving towards the stationary observer,the apparent pitch (n') is given by

$$n' = \left[\frac{v}{v-a} \right] n$$

case ii:

When the observer is moving towards the stationary source with same velocity,the apparent pitch (n') is given by

$$n' = \left[\frac{v+b}{v} \right] n$$

Applications of Doppler effect in sound:

- 1) Doppler effect in sound is used to find the velocity of liquids using Acoustic Doppler Velocimeter.
- 2) Doppler shift is used to convert an acoustic horn to a loud speaker.
- 3) Ultrasonic Doppler Velocimetry (UDV) is used to measure the blood flow rate.
- 4) Echo Cardiogram is used to assess the velocity of cardiac tissues.
- 5) SONAR [Sound Navigation and Ranging] is used to determine the speed of submarines and to navigate the objects under the sea,using Doppler effect.

Definition : (in light)

The apparent change in frequency of light radiation when the source of light (or) observer move relative to each other is known as **Doppler Effect in Light**.

Symmetric Property:

Doppler Effect in Sound is **symmetric**.

Reason:

In the case of light ,no material medium is required for the light to propagate.So the appaerent frequency will be same

- i)When either the source moves towards a stationary observer or when the observer move towards a stationary source .
- ii) When the source move away from the observer or when the observer move away from the source.

thus, the Doppler effect in light is symmetric.

Mathematical Relations:

case i:

When a source is moving with velocity 'v' towards a stationary observer or when the observer moving towards the stationary source.

In both case no material medium is required.There fore the observer will receive more waves due to the motion of the source.

When a source is moves with velocity 'v' comparable with the velocity of light (c) then

The apparent frequency $\gamma' = \gamma + \frac{v}{\lambda}$

$$\gamma' = \gamma \left[1 + \frac{v}{c} \right] \text{-----(1)}$$

we know $v = \frac{c}{\lambda} \text{ (or) } \lambda = \frac{c}{\gamma} \text{-----(2)}$

sub (2) in (1)

$$\gamma' = \gamma \left[1 + \frac{1}{\frac{c}{\gamma}} \right]$$

$$\gamma' = \gamma \left[1 + \frac{v}{c} \right] \text{-----(3)}$$

eqn (3) represents the apparent change in frequency for the source moving towards the observer (or)the observer moving towards the source.

Case :ii

When the source moves away from the stationary observer or the observer moves away from the stationary source with velocity 'v' then the apparent frequency

$$\gamma' = \gamma \left[1 + \frac{v}{c} \right] \text{-----(4)}$$

Applications of Doppler effect in light:

- 1) Doppler effect in light is used to estimate the velocity of liquid flow using Laser Doppler Velicimeter.
- 2) It is used to find the velocity and rotation of the sun.
- 3) Doppler effect is used in navigation systems of marine, radar surveillance, speed of automobiles etc.

