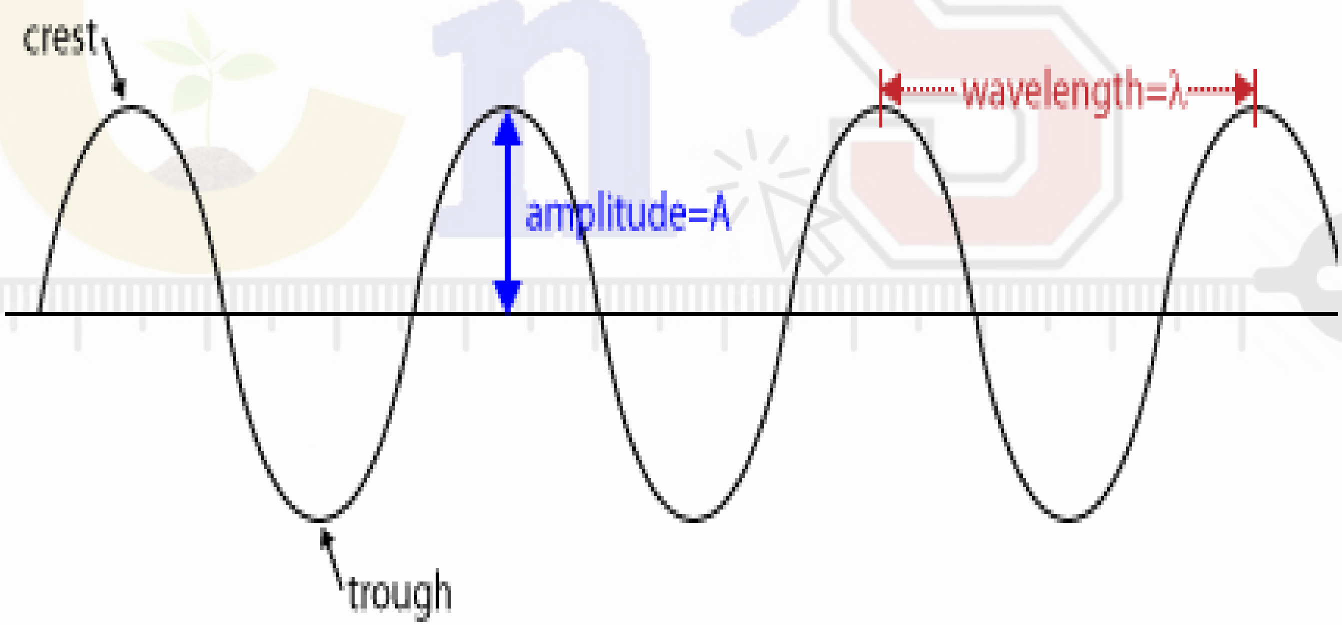
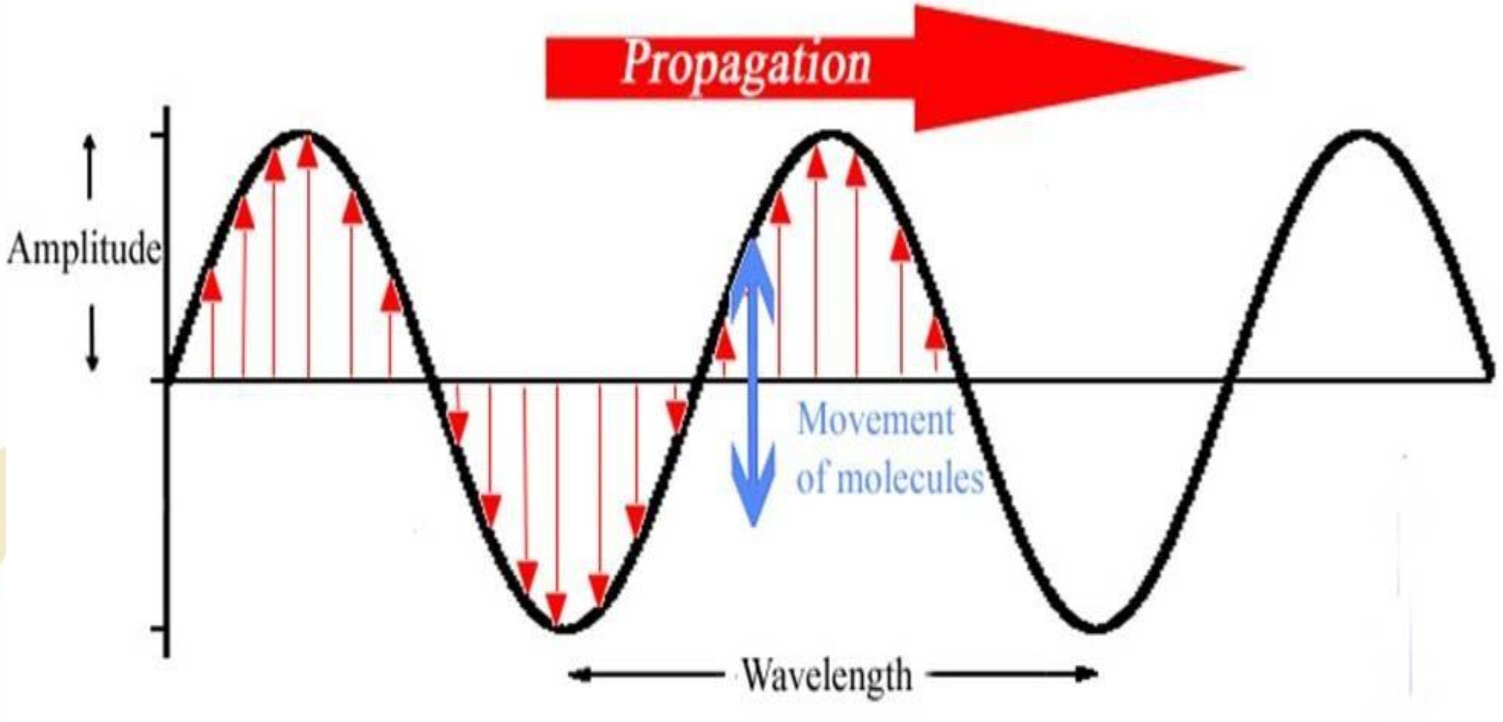
Transverse Waves

- **Transverse waves –** medium displacement is perpendicular to the direction of wave propagation.



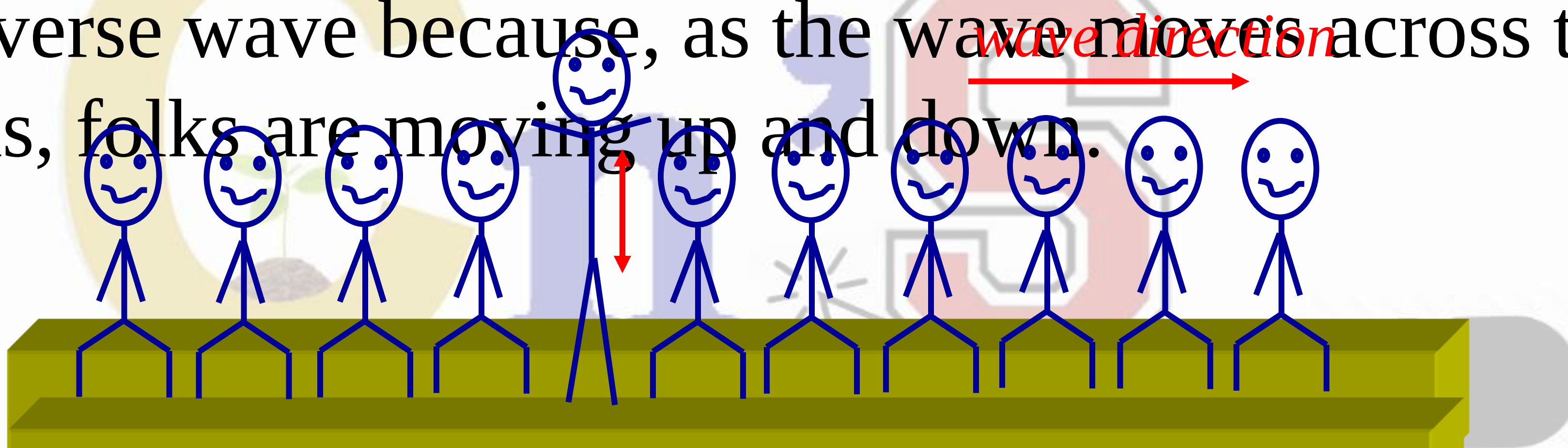


Light waves.
Radio waves.
Waves on a rope.
Water waves

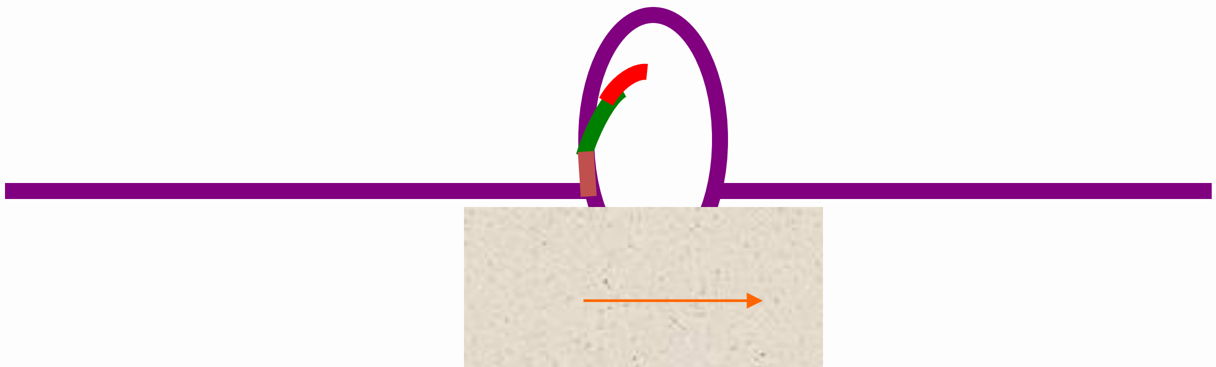
- The stadium wave is like a transverse wave.

Transverse Waves

After a great performance at a *drum and bugle corps* contest, the audience decides to start a wave in the stands. Each person rises and sits at just the right time. People make up the wave medium here. This is a transverse wave because, as the wave moves across the stands, folks are moving up and down.



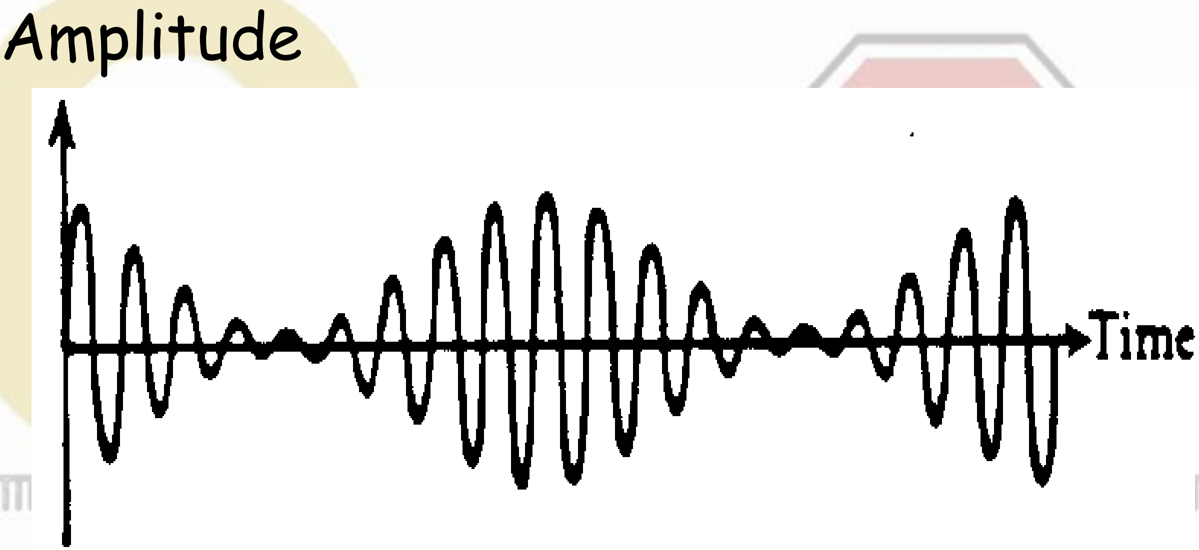
In a transverse wave, molecules aren’t being compressed and spread out as they are in a longitudinal wave. The reason a transverse wave can propagate is because of the attraction between adjacent molecules. Imagine if each person in the stands on the last slide were connected to the person on his left and right with giant rubber bands. As soon the person on one end stood up, the band stretches. The tension in the band pulls his neighbor up, who, in turn, lifts the next guy.



The tension in the rubber bands is analogous to the forces connecting particles of the medium to their neighbors.   The colored sections of rope tug on each other as the waves travels through them. If they didn't, it would be as if the rope were cut, and no wave could travel through it.

Beats

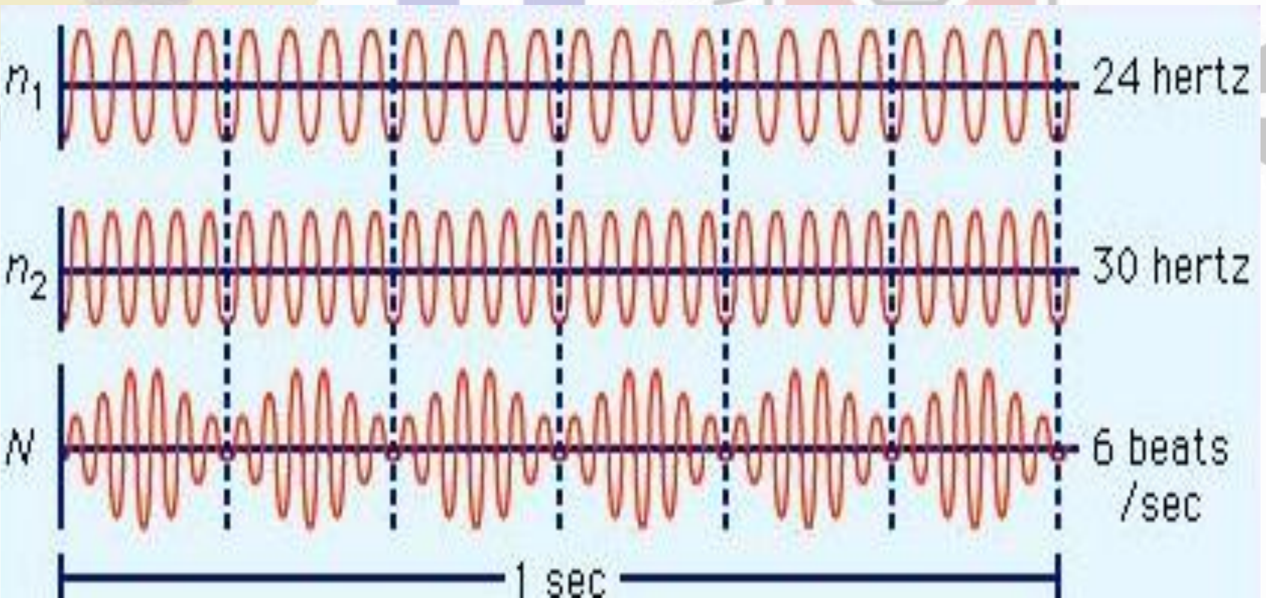
What word best describes this to physicists?



Answer: beats

Beats

- **Beats** are produced by two waves of slightly different frequencies, but similar amplitudes. The resulting sound has a fluctuating amplitude that repeats regularly



- The periodic rise and fall in the amplitude of resultant wave due to superposition of two waves having slightly different frequencies but moving in the same direction.

- Musicians call this "being out of tune"

- Number of beats per second is equal to the difference between the frequencies of the tuning forks. When the difference between the frequencies of the two sounds is more than 10 Hz, then it becomes difficult to recognize the beats.

Characteristics of Beats:

- They are produced due to interference between the progressive waves which need not be traveling in opposite directions.
- Interfering waves must have slightly different frequencies.
- At a given point, amplitude changes with time.
- At a given point, the intensity of sound varies from a maximum to minimum.
- Waxing and waning of the sound of resulting intensity are produced.
- The resultant wave travels in the forward direction.

- How are the beats useful in tuning musical instruments?
- Ans. The number of beats produced per second is equal to the difference of frequencies of the two bodies. To tune a musical instrument to the required frequency, it is sounded together with an instrument of known frequency. Now the number of beats produce will tell the difference of their frequency. The frequency of the untuned instrument is adjusted till the number of beats become zero. At this stage, the two instruments will have the same frequencies. Thus the musical instrument is said to be tuned.
- When two notes of frequencies and are sounded together, beats are formed. What will be the frequency of the beats
- Ans. The Number of beats per second is equal to the difference between the frequencies of the notes.
- As a result of a distant explosion, an observer senses a ground tremor and then hears the explosion. Explain the time difference.
- Ans. The waves produced by the explosion reach the observer quickly through the ground as compared to the sound waves reaching through the air. This is due to the reason that sound travels faster in solid than gases.

Example – 1:

- Two sound waves having wavelengths of 87 cm and 88.5 cm when superimposed produce 10 beats per second. Find the velocity of sound.

- **Solution:**
- **Given:** Wavelength of first wave = λ_1 = 87 cm = 87×10^{-2} m, Wavelength of second wave = λ_2 = 88.5 cm = 88.5×10^{-2} m, No. of beats = 10 per second.
- **To Find:** Velocity of sound = v =?

We have v= n λ, Hence n = v/ λ

Now $n \propto 1/\lambda$ given $\lambda_2 > \lambda_1$ Hence $n_1 > n_2$

$$\therefore \quad n_1 - n_2 = 10$$

$$\therefore \quad \frac{v}{\lambda_1} - \frac{v}{\lambda_2} = 10$$

$$\therefore \quad v\left(\frac{1}{\lambda_1} - \frac{1}{\lambda_2}\right) = 10$$

$$\therefore \quad v\left(\frac{1}{87 \times 10^{-2}} - \frac{1}{88.5 \times 10^{-2}}\right) = 10$$

$$\therefore \quad v\left(\frac{1}{87} - \frac{1}{88.5}\right) \times 10^2 = 10$$

$$\therefore \quad v\left(\frac{88.5 - 87}{87 \times 88.5}\right) \times 10^2 = 10$$

$$v = \frac{10 \times 87 \times 88.5}{1.5 \times 10^2} = 513.3 \ \text{m/s}$$

Ans: Velocity of sound 513.3 m/s

Example – 2:

- Wavelengths of two sound waves in a gas are 2.0 m and 2.1m respectively. They produce 8 beats per second when sounded together. Calculate the velocity of sound in the gas and the frequencies of the two waves.

- **Solution:**
- **Given:** Wavelength of first wave = λ_1 = 2.0 m, Wavelength of second wave = λ_2 = 2.1m, No. of beats = 8 per second.
- **To Find:** Velocity of sound = v =? Frequencies of notes =?

We have v= n λ, Hence n = v/ λ

Now $n \propto 1/\lambda$ given $\lambda_2 > \lambda_1$ Hence $n_1 > n_2$

$$\therefore \quad n_1 - n_2 = 8$$
$$\therefore \quad \frac{v}{\lambda_1} - \frac{v}{\lambda_2} = 8$$
$$\therefore \quad v\left(\frac{1}{\lambda_1} - \frac{1}{\lambda_2}\right) = 8$$
$$\therefore \quad v\left(\frac{1}{2.0} - \frac{1}{2.1}\right) = 8$$
$$\therefore \quad v\left(\frac{2.1-2.0}{2.0\times 2.1}\right) = 8$$
$$v = \frac{8\times 2.0\times 2.1}{0.1} = 336 \text{ m/s}$$

Now $n_1 = v/\lambda_1$ = 336 /2.0 = 168 Hz and $n_2 = v/\lambda_2 = 336/2.1 = 160$ Hz

Ans: Velocity of sound 336 m/s, The frequencies of note are 168 Hz and 160 Hz.

Example – 3:

- Two sound waves of lengths 1m and 1.01m produce 6 beats in two seconds when sounded together in the air. Find the velocity of sound in air.

- **Solution:**
- **Given:** Wavelength of first wave = λ_1 = 1 m, Wavelength of second wave = λ_2 = 1.01m, No. of beats = 6 per two second = 3 per second.
- **To Find:** Velocity of sound = v =?

We have $v = n\lambda$, Hence $n = v/\lambda$

Now $n \propto 1/\lambda$ given $\lambda_2 > \lambda_1$ Hence $n_1 > n_2$

$$\therefore \quad n_1 - n_2 = 3$$

$$\therefore \quad \frac{v}{\lambda_1} - \frac{v}{\lambda_2} = 3$$

$$\therefore \quad v\left(\frac{1}{\lambda_1} - \frac{1}{\lambda_2}\right) = 3$$

$$\therefore \quad v\left(\frac{1}{1.0} - \frac{1}{1.01}\right) = 3$$

$$\therefore \quad v\left(\frac{1.01 - 1.0}{1.0 \times 1.01}\right) = 3$$

$$v = \frac{3 \times 1.0 \times 1.01}{0.01} = 303 \text{ m/s}$$

Example – 4:

- Two tuning forks of frequencies 320 Hz and 340 Hz produce sound waves of lengths differing by 6cm in a medium. Find the velocity of sound in the medium.

- **Solution:**
- **Given:** Frequency of first wave = n_1 = 320 Hz, Frequency of second wave = n_2 = 340 Hz, Difference in wavelengths = 6 cm = 6×10^{-2} m
- **To Find:** Velocity of sound = v =?

We have v= n λ, Hence λ = v/ n

Now $\lambda \propto 1/n$ given $n_2 > n_1$ Hence $\lambda_1 > \lambda_2$

$$\therefore \quad \lambda_1 - \lambda_2 = 6\times10^{-2}$$

$$\therefore \quad \frac{v}{n_1} - \frac{v}{n_2} = 6\times10^{-2}$$

$$\therefore \quad v\left(\frac{1}{n_1} - \frac{1}{n_2}\right) = 6\times10^{-2}$$

$$\therefore \quad v\left(\frac{1}{320} - \frac{1}{340}\right) = 6\times10^{-2}$$

$$\therefore \quad v\left(\frac{340-320}{340\times320}\right) = 6\times10^{-2}$$

$$v = \frac{6\times10^{-2}\times340\times320}{20} = 326.4 \text{ m/s}$$

Ans: Velocity of sound 326.4 m/s

Example – 5:

- Wavelengths of two sound waves in air are 81/174m and 81/175 m. When these waves meet at a point simultaneously, they produce 4 beats per second. Calculate the velocity of sound in air.

- **Solution:**
- **Given:** Wavelength of first wave = λ_1 = 81/174 m, Wavelength of second wave = λ_2 = 81/175 m, No. of beats = 4 per second.
- **To Find:** Velocity of sound = v =?

We have v= n λ, Hence n = v/ λ

Now $n \propto 1/\lambda$ given $\lambda_1 > \lambda_2$ Hence $n_2 > n_1$

$$\therefore \quad n_2 - n_1 = 4$$

$$\therefore \quad \frac{v}{\lambda_2} - \frac{v}{\lambda_1} = 4$$

$$\therefore \quad v\left(\frac{1}{\lambda_2} - \frac{1}{\lambda_1}\right) = 4$$

$$\therefore \quad v\left(\frac{175}{81} - \frac{174}{81}\right) = 4$$

$$\therefore \quad v\left(\frac{175-174}{81}\right) = 4$$

$$v = \frac{4 \times 81}{1} = 324 \text{ m/s}$$

Ans: Velocity of sound 324 m/s

Example – 6:

- Wavelengths of two sound waves in air are 81/173m and 81/170 m. When these waves meet at a point simultaneously, they produce 10 beats per second. Calculate the velocity of sound in air.

- **Solution:**
- **Given:** Wavelength of first wave = λ_1 = 81/173 m, Wavelength of second wave = λ_2 = 81/170m, No. of beats = 10 per second.
- **To Find:** Velocity of sound = v =?

We have v= n λ, Hence n = v/ λ

Now n $\propto$ 1/ λ given $\lambda_2 > \lambda_1$ Hence $n_1 > n_2$

$$\therefore \quad n_1 - n_2 = 10$$

$$\therefore \quad \frac{v}{\lambda_1} - \frac{v}{\lambda_2} = 10$$

$$\therefore \quad v\left(\frac{1}{\lambda_1} - \frac{1}{\lambda_2}\right) = 10$$

$$\therefore \quad v\left(\frac{173}{81} - \frac{170}{81}\right) = 10$$

$$\therefore \quad v\left(\frac{173-170}{81}\right) = 10$$

$$v = \frac{10 \times 81}{3} = 270 \ \text{m/s}$$

Ans: Velocity of sound 270 m/s

Example - 7:

- Wavelengths of two notes in the air are 70/153 m and 70 /157 m. Each of these notes produces 8 beats per second with the third note of fixed frequency. What are the velocity of sound in air and the frequency of the third note?

- **Solution:**
- **Given:** Wavelength of first wave = λ_1 = 70/153 m, Wavelength of the second wave = λ_2 = 70/157 m, No. of beats with the third note = 8 per second.
- **To Find:** Velocity of sound = v =? The frequency of the third note =?

We have $v = n\lambda$, Hence $n = v/\lambda$

Now $n \propto 1/\lambda$ given $\lambda_1 > \lambda_2$ Hence $n_2 > n_1$

Let n be the frequency of the third note, such that $n_2 > n > n_1$

Given $n_2 - n = 8$ .... (1)

and $n - n_1 = 8$ .... (2)

Adding equations (1) and (2) we get

$$\therefore \quad n_2 - n_1 = 16$$

$$\therefore \quad \frac{v}{\lambda_2} - \frac{v}{\lambda_1} = 16$$

$$\therefore \quad v\left(\frac{1}{\lambda_2} - \frac{1}{\lambda_1}\right) = 16$$

$$\therefore \quad v\left(\frac{157}{70} - \frac{153}{70}\right) = 16$$

$$\therefore \quad v\left(\frac{157 - 153}{70}\right) = 16$$

$$v = \frac{16 \times 70}{4} = 280 \text{ m/s}$$

Now $n_1 = v/\lambda_1 = 280/(70/153) = 4 \times 153 = 612$ Hz

and $n = n_1 + 8 = 512 + 8 = 520$ Hz

Ans: Velocity of sound 280 m/s and frequency of the third note is 620 Hz.

Example - 8:

- Wavelengths of two notes in air are 80/179 m and 80/177 m. Each note produces 4 beats per second with a third note of fixed frequency. Calculate the velocity of sound in air. Ans : (320 m/s)
- **Solution:**
- **Given:** Wavelength of first wave = λ_1 =80/179 m, Wavelength of the second wave = λ_2 = 80/177 m, No. of beats with the third note = 4 per second.
- **To Find:** Velocity of sound = v =?

We have v= n λ, Hence $n = v/\lambda$

Now $n \propto 1/\lambda$ given $\lambda_1 < \lambda_2$ Hence $n_1 > n_2$

Let n be the frequency of the third note, such that $n_1 > n > n_2$

Given $n_1 - n = 4$ .... (1)

and $n - n_2 = 4$ .... (2)

Adding equations (1) and (2) we get

$$\therefore \quad n_1 - n_2 = 8$$

$$\therefore \quad \frac{v}{\lambda_1} - \frac{v}{\lambda_2} = 8$$

$$\therefore \quad v\left(\frac{1}{\lambda_1} - \frac{1}{\lambda_2}\right) = 8$$

$$\therefore \quad v\left(\frac{179}{80} - \frac{177}{80}\right) = 8$$

$$\therefore \quad v\left(\frac{179 - 177}{80}\right) = 8$$

$$v = \frac{8 \times 80}{2} = 320 \text{ m/s}$$

POLARIZATION

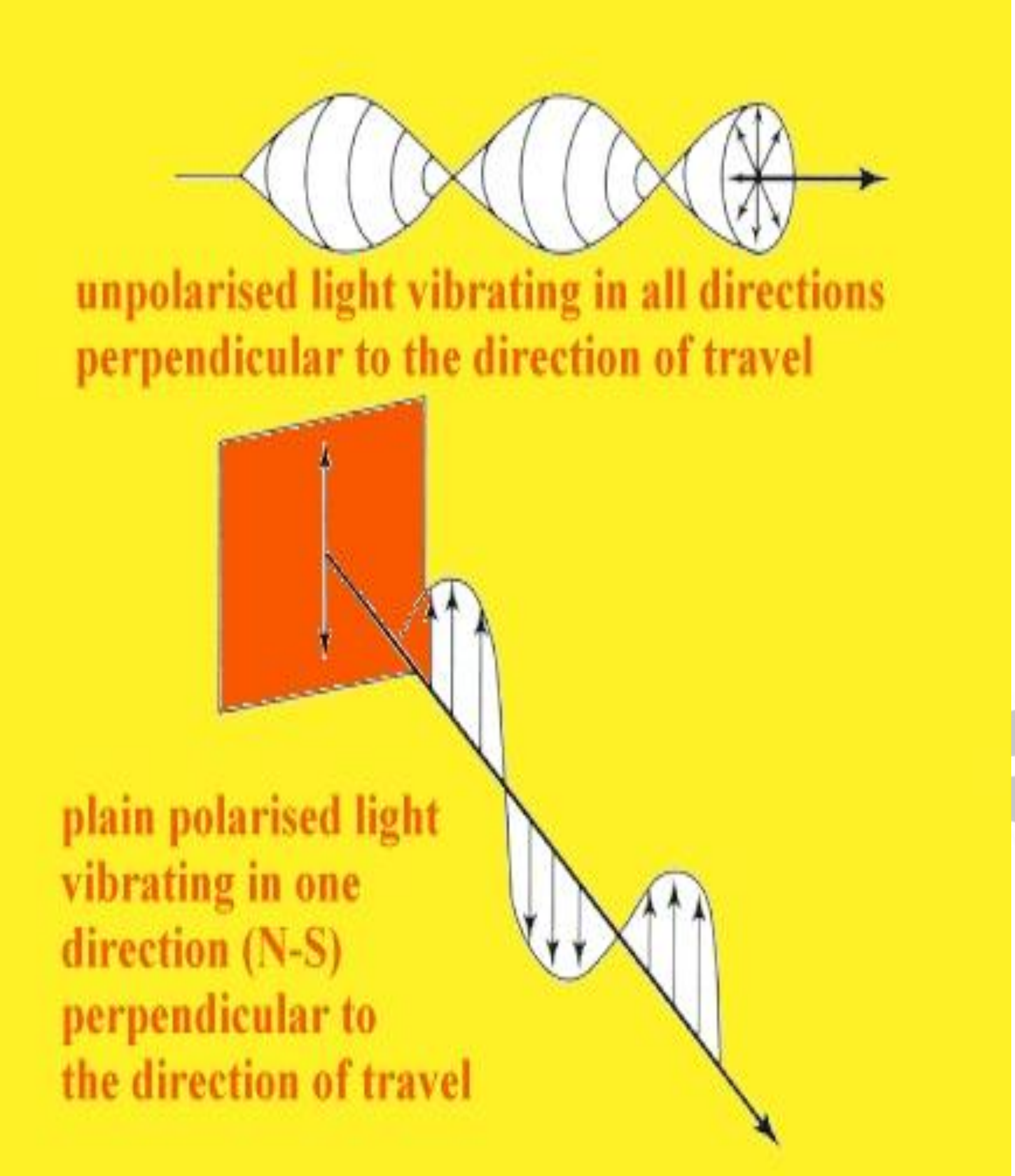
Polarisation

Only **TRANSVERSE** waves can be polarised.

To polarise a wave means to make it vibrate in one plane only

– **horizontally** plane polarised or

– **vertically** plane polarised


unpolarised light vibrating in all directions
perpendicular to the direction of travel
plain polarised light
vibrating in one
direction (N-S)
perpendicular to
the direction of travel

Unpolarized Light---A beam of ordinary light consisting of large number of planes of vibrations, vibrates in all directions in all possible directions perpendicular to the direction of propagation. Such a beam is called unpolarized light. For example, the light emitted by an ordinary incandescent bulb (and also by the sun) is unpolarized because its (electrical) vibrations are randomly oriented in space.

- Plane Polarized Light If the vibrations of

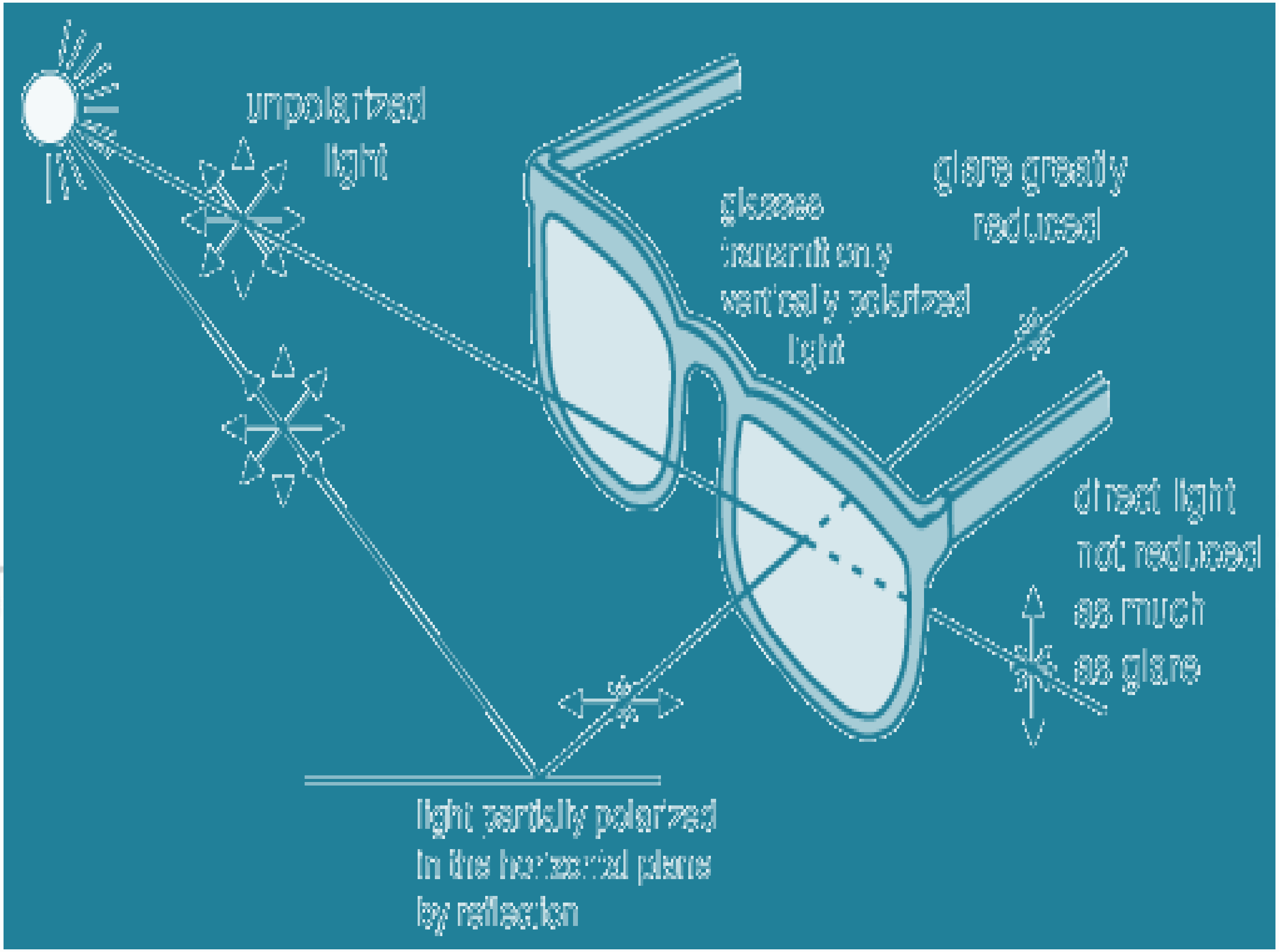
Polarisation is said to occur when oscillations are in one direction in a plane, {NOT just "in one direction"} normal to the direction of propagation.

- Polarizers are used to achieve polarized light.
- Polarization may occur from reflections off of shiny surfaces.

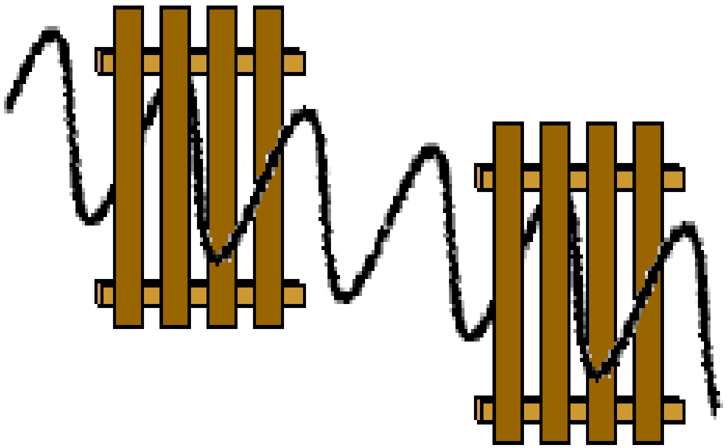
- Why the Polaroid sun-glasses are better than ordinary sun-glasses?
- Ans. The Polaroid sunglasses reduce the intensity of light passing through them, due to which the glare of light is decreased. That is why, they are better than ordinary sunglasses.

- How would you distinguish between un-polarized and plane-polarized light?
- Ans. A Polaroid is placed in the path of light and slowly rotated. If the light become dimmer and dimmer and then vanishes then the incident light was plane polarized. And if the light keeps on coming on the other side then it was un-polarized.

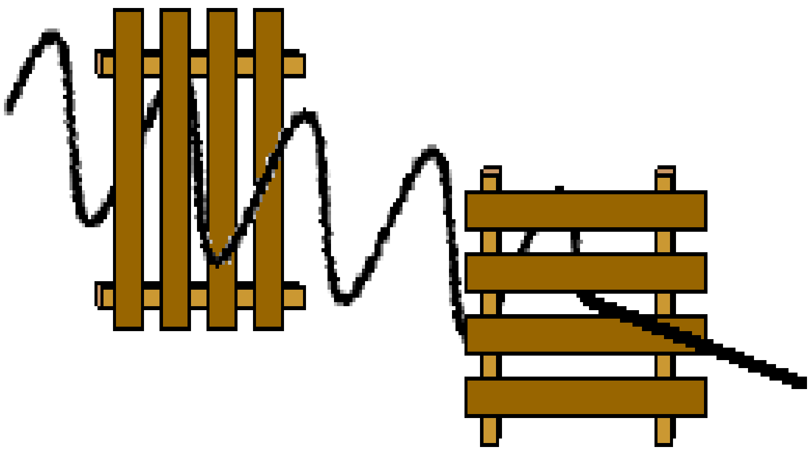
Polarised sunglasses



The Picket Fence Analogy



When the pickets of both fences are aligned in the vertical direction, a vertical vibration can make it through both fences.



When the pickets of the second fence are horizontal, vertical vibrations which make it through the first fence will be blocked.