Longitudinal and Transverse waves.

a) Transverse wave:

- Crest
- Trough
- The particles of the medium oscillate in the direction perpendicular to the direction of propagation of the wave.

*Example:*

i) Waves on surface of fluids → surface of water
ii) Waves of disturbance in a string
(iii) Electromagnetic waves

\[ E(t) = E_0 \sin (kx - \omega t) \hat{y} \]
\[ B(t) = B_0 \sin (kx - \omega t) \hat{z} \]

Waves of the electric field and magnetic field.

Transverse waves can be polarized.

What is polarization?

b) Longitudinal wave:

- The particles of the medium oscillate in the direction of propagation of the wave.

Compression

Rarefaction

Layers of the medium

Example:

i) Sound wave in air
ii) Disturbance within a fluid (water)
Reflection and Transmission

End is fixed to a support.

End is movable.

Mixed case:

Light cord

Heavy cord.

\[
\frac{v_1}{\lambda_1} = \frac{v_2}{\lambda_2} \rightarrow v_2 \neq v_1, \quad \text{but} \quad \frac{v_2}{\lambda_2} = \frac{v_1}{\lambda_1} = (2v_T = v_R)
\]
Principle of Superposition

Consider the point A.

- Displacement of a particle at point A due to disturbance from wave 1 is
  \[ y_1(x, t) = y_{1m} \cos(k_1x - \omega_1t + \phi_1) \]

- Displacement of a particle at point A due to disturbance from wave 2 is
  \[ y_2(x, t) = y_{2m} \cos(k_2x - \omega_2t + \phi_2) \]

Total superposition:

\[ y(x, t) = y_1(x, t) + y_2(x, t) = y_{1m} \cos(k_1x - \omega_1t + \phi_1) + y_{2m} \cos(k_2x - \omega_2t + \phi_2) \]

**Interference**

- \( y_1(x, t) \) \& \( y_2(x, t) \) may produce effects that have similar effect and sum up, i.e. in phase and the superposition is bigger.
  * Constructive interference.

- \( y_1(x, t) \) \& \( y_2(x, t) \) may nullify the effects, i.e. out of phase.
  * Destructive interference.
Coherent waves cause perfect constructive & destructive interference.

\[ y_1(x,t) = y_0 \cos(kx + \omega t) \] for some \( \omega \neq k \).

\[ y_2(x,t) = y_0 \cos(kx + \omega t + \phi) \]

\[ y = y_1 + y_2 = 2y_0 \cos(kx + \omega t) \] Constructive interference if \( \phi = 0 \) or \( 2\pi \)

\[ y = y_1 + y_2 = y_0 \cos(kx + \omega t) + y_0 \cos(kx + \omega t + \pi) \]

\[ = y_0 \cos(kx + \omega t) - y_0 \cos(kx + \omega t) \]

\[ y(x,t) = 0 \] if \( \phi = \pi \) or \( \pi \)...

\( (2n+1)\pi \) even

\( \frac{2n\pi}{n} \) odd
Standing Waves

1. Simplest example:

The ends are fixed.

2. Superposition of a travelling wave and its reflected wave:

If two sinusoidal waves of the same amplitude and wavelength travel in opposite directions along a stretched string, their interference with each other produces a standing wave.

\[ y = y_1 + y_2 = y_m \sin (kx - wt) + y_m \sin (kx + wt) \]

\[ = y_m [\sin (kx - wt) + \sin (kx + wt)] = 2y_m \sin (kx) \cos (wt) \]

The position of nodes and antinodes are fixed (stationary.)
To obtain the position of the nodes:

\[ \sin kx = 0 \quad \text{at nodes, i.e. Amplitude at nodes is zero.} \]

\[ kx = n\pi \quad \text{for } n = 0, 1, 2, \ldots \]

Now, \[ k = \frac{2\pi}{\lambda} \]

\[ x = \frac{n\pi \lambda}{k} = \frac{n\pi}{2\pi} \frac{\lambda}{k} = \frac{n\lambda}{2} \]

\[ x = \frac{n\lambda}{2} \quad \text{for } n = 0, 1, 2, \ldots \]

The zero amplitudes, i.e. the nodes occur at x values separated by \( \frac{\lambda}{2} \)

\[ L = \frac{m(\lambda)}{2} \quad \text{must be true because only integer number of half waves can fit in a string length} \]

\[ L = 2\frac{\lambda}{2} \quad \text{fundamental mode} \]

\[ L = 2\left(2\frac{\lambda}{2}\right) = \lambda \quad \text{first harmonic} \]

\[ L = 3\left(2\frac{\lambda}{2}\right) \quad \text{second harmonic} \]
SOUND WAVES.

Longitudinal waves.

* Speed of sound?
  yesterday: \( v^2 = \frac{F}{M} = \sqrt{\frac{\text{elastic property}}{\text{inertial property}}} \)
  for sound, \( V_{\text{sound}} = \sqrt{\frac{B}{\rho}} \)

\( B = \text{bulk modulus} = -\frac{\partial P}{\partial V/N} \)
\( \rho = \text{density of medium} \)
\( \nu_{\text{air}} = 331 \text{ m/s} \)

Wave eqn for sound:
\[
\frac{\partial^2 D}{\partial x^2} = \frac{1}{v^2} \frac{\partial^2 D}{\partial t^2}
\]

The displacement causes pressure fluctuations
and is equivalent to a pressure wave

\[
D(x,t) = D_m \cos(\omega x - \omega t)
\]
\[
\Delta p(x,t) = \Delta p_m \sin(\omega x - \omega t)
\]

Intensity of sound,

\[
I = \frac{P_s}{4\pi r^2} = \frac{1}{2} P_m \omega^2 r^2
\]

decibel scale:
\[
\beta = (10 \text{ dB}) \log \left( \frac{I}{I_0} \right)
\]
\( I_0 = 10^{-12} \text{ W/m}^2 \) standard
The Doppler Effect

\[ f' = f \frac{v + v_d}{v - v_s} \]

\( v \) = speed of sound through air
\( v_s \) = source speed
\( v_d \) = detector speed.