Waves Notes

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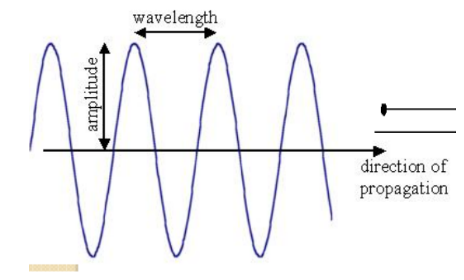
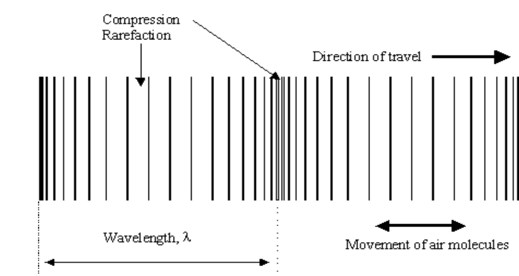
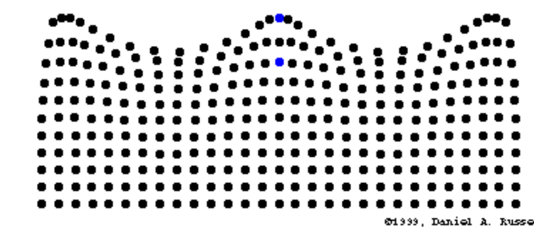
MECHANICAL WAVES :-
- disturbances in matter that carry energy from one point to another through a medium
- require some physical connection through which adjacent portions of the medium can influence each other
- require some source of disturbance
- require a medium that can be disturbed.

ELECTROMAGNETIC WAVES :- carry energy from one point to another without requiring a medium.







TYPES OF MECHANICAL WAVES :-

TRANSVERSE WAVES :- • a wave that causes the medium to vibrate at right angles to the direction of the wave

LONGITUDINAL WAVES :- • a wave that causes the medium to vibrate parallel to the direction the wave travels

COMBINATION OF TRANSVERSE & LONGITUDINAL WAVES :- • the motion of water molecules on the surface of water in which a wave is propagating is a combination of transverse and longitudinal displacements, with the result that molecules at the surface move in nearly circular paths. Each molecule is displaced both horizontally and vertically from its equilibrium position, causing the medium particles to be displaced.

LIGHT :-
- light is an electromagnetic transverse wave
- energy is ⊥ to direction of motion
- moving photon creates electric and magnetic field
- light has both electric and magnetic fields at right angles and ⊥ to direction of propagation of wave.

SOUND :-
- sound is a mechanical longitudinal wave
- sound travels at different speeds through different media. (solid > liquid > gas)
- the denser the medium, the faster the sound will travel
- the higher the temperature, the faster the particles of the medium will move, and the faster the particles will carry the sound.
- a healthy human ear can hear frequencies in the range 20Hz – 20000Hz
- sounds above 20,000Hz = ultrasonic, sounds below 20Hz = infrasonic

Medium	Velocity
air (20 C)	343
air (0 C)	331
water (25 C)	1493
seawater	1533
diamond	12000
iron	5130
copper	3560
glass	5640

FORMULAE FOR WAVE ON A STRING ELEMENT :-
- $f = \frac{\text{waves}}{\text{total time}}$

angular wave num

- $\underbrace{y(x,t)}_{\text{displacement}} = \underbrace{y_m}_{\text{amp}} \sin \underbrace{(kx - \omega t + \phi)}_{\text{phase}}$

phase :- as a wave sweeps through a string element at a particular position x, the phase changes linearly with time

- $k = \frac{2\pi}{\lambda}$
- $\omega = \frac{2\pi}{T}$
- $f = \frac{1}{T}$
- $v = \frac{\omega}{k} = \frac{\lambda}{T} = \lambda f$
- transverse velocity (along y axis) $\rightarrow u = -\omega y_m \cos(kx - \omega t)$
- transverse acceleration $\rightarrow a_y = -\omega^2 y_m \sin(kx - \omega t)$
  $a_y = -\omega^2 y$

TRANSVERSE VELOCITY :- rate at which displacement y of the element is changing.

TRANSVERSE ACCELERATION :- rate at which transverse velocity of the element is changing.

THE WAVE EQUATION :-
- a travelling wave is always in the following form $\rightarrow y(x,t) = f(x \pm vt)$
- $\frac{\partial^2 y}{\partial x^2} = \frac{1}{v^2} \frac{\partial^2 y}{\partial t^2}$

e.g $\rightarrow y(x,t) = A \sin\left(\frac{2\pi}{\lambda}x \pm \frac{2\pi}{T}t + \phi\right)$
+ for left
− for right

THE SUPERPOSITION OF WAVES :-
- overlapping waves algebraically add to produce a resultant / net wave
- they interfere but do not interact
- $y'(x,t) = y_1(x,t) + y_2(x,t)$
- principle of linear superposition is valid only when the amp is small

When two waves overlap, we see the resultant wave, not the individual waves.

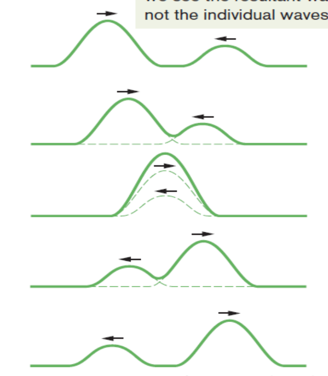


Fig. 16-11 A series of snapshots that show two pulses traveling in opposite directions along a stretched string. The superposition principle applies as the pulses move through each other.

INTERFERENCE OF WAVES :-
- if two sinusoidal waves of the same amp and λ travel in the same direction along a stretched string, they interfere to produce a resultant sinusoidal wave travelling in that direction.
- $y_1(x,t) = y_m \sin(kx - \omega t)$
  $y_2(x,t) = y_m \sin(kx - \omega t + \phi)$

$\longrightarrow y'(x,t) = y_1(x,t) + y_2(x,t)$

$y'(x,t) = y_m \sin(kx - \omega t) + y_m \sin(kx - \omega t + \phi)$

$\underbrace{y'(x,t)}_{\text{displacement}} = \underbrace{\left[2y_m \cos\tfrac{1}{2}\phi\right]}_{\text{amp}} \underbrace{\sin(kx - \omega t + \tfrac{1}{2}\phi)}_{\text{oscillating term}}$

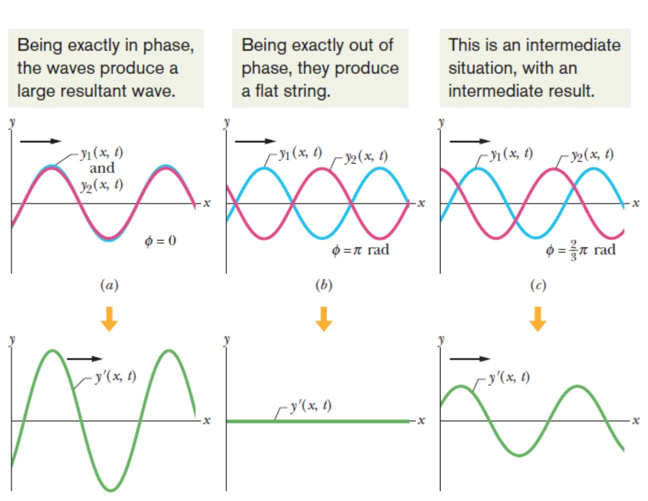


Table 16-1

Phase Difference and Resulting Interference Types[a]

Phase Difference, in Degrees	Radians	Wavelengths	Amplitude of Resultant Wave	Type of Interference
0	0	0	$2y_m$	Fully constructive
120	$\frac{2}{3}\pi$	0.33	y_m	Intermediate
180	π	0.50	0	Fully destructive
240	$\frac{4}{3}\pi$	0.67	y_m	Intermediate
360	2π	1.00	$2y_m$	Fully constructive
865	15.1	2.40	$0.60y_m$	Intermediate

[a] The phase difference is between two otherwise identical waves, with amplitude y_m, moving in the same direction.