Physics Lecture 6 - Waves

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Definitions

Wave: transfer of momentum/energy from a point to another
Mechanical wave: physical displacement of medium
Transverse wave: displacement perpendicular to propagation direction
Longitudinal wave: displacement parallel to propagation direction
Surface wave: i.e. waves in ocean, gravity plays a role

Sine Function Waves

Describes most transverse/longitudinal waves
Wavelength λ: the distance between the wave's "repeats"
Frequency f: number of wavelengths that go through an imaginary line in 1 second (Hz)
Period T: number of seconds it takes for each wavelength to go through imaginary line
FORMULAS: $v = f\lambda$, $T = 1/f$
Amplitude A: how "strong" the wave is, equal to max displacement from zero
Velocity depends on the medium

- -> Heavier/denser medium (more inertia) = slower wave
- -> Stiffer medium (more elasticity) = faster wave
- -> In a gas, higher temperature = faster wave
- -> SURFACE WAVES: velocity doesn't depend on density, only depth

Intensity I: wave power, units are W/m^2. Depends on frequency^2 and amplitude^2

-> Decibels: $\beta = 10 \log \frac{I}{I_0}$ - always has to be relative to something

Increasing intensity by a factor of ten = +10 decibels
So if intensity is increased by 1000000x, it's only +60 decibels

Wave Effects

Waves can *interfere*, or boost each other/cancel each other out
Constructive interference: waves have displacement in same direction at certain points, increasing the total displacement
Destructive interference: waves have displacement in opposite direction at certain points, decreasing the total displacement
Beat frequency: when two waves of different frequencies are mixed together, will have constructive at some points and destructive at other points. $f_{beat} = |f_1 - f_2|$
Waves traveling between mediums: wavelength will change, FREQUENCY STAYS THE SAME
Wave reflection: next medium more dense = inverted, less dense = upright

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Standing wave: when wave doesn't look like it's moving, just going up and down
-> Some points will always have 0 amplitude = NODES
-> Some points will oscillate between max positive and min negative amplitudes = ANTI NODES

Usually only certain frequencies can have standing waves

String with both ends fixed/pipe closed or open at both ends:
-> Fundamental wavelength/first harmonic: 2 nodes at ends
-> Second harmonic: 3 nodes, third harmonic: 4 nodes, etc
-> $L = \frac{n\lambda_n}{2}, n = 1,2,3,...$

String with one end fixed/pipe open on one end, closed on other end:
-> Fundamental wavelength/first harmonic: 1 node at closed/tied end
-> Second harmonic: 2 nodes, third harmonic: 3 nodes, etc
-> $L = \frac{n\lambda_n}{4}, n = 1,3,5,...$

Standing waves will go up/down at the *resonant frequency* which is given by $f = \frac{v}{\lambda}$

<u>Simple Harmonic Motion</u>
CONSERVATION OF ENERGY
Max displacement: highest potential energy, zero kinetic energy
Min displacement: zero potential energy, highest kinetic energy

Mass on a spring: $T = 2\pi\sqrt{\frac{m}{k}}$, $\omega = 2\pi f = \sqrt{\frac{k}{m}}$, *m* is mass of object, *k* is spring constant

Pendulum: $T = 2\pi\sqrt{\frac{L}{g}}$, $\omega = 2\pi f = \sqrt{\frac{g}{L}}$, *L* is length of string, *g* is gravity

General principles:
-> Acceleration, displacement directly proportional but opposite in sign (highest displacement = highest acceleration in opposite direction)
-> Acceleration, frequency^2 directly proportional (2x frequency = 4x acceleration)

<u>Doppler Effect</u>
When source of waves is moving relative to observer

$\frac{\Delta f}{f_s} = \frac{v}{c}$, $\frac{\Delta\lambda}{\lambda_s} = \frac{v}{c}$ where v is how fast source, observer are moving towards each other