Section 6: Waves

The following maps the videos in this section to the Texas Essential Knowledge and Skills for Physics TAC §112.39(c).

6.01 Classifications of Waves

- Physics (7)(A)
- Physics (7)(B)

6.02 Properties Waves

Note: This section requires use of trigonometry.

- Physics (7)(A)
- Physics (7)(B)
- Physics (7)(D)

6.03 Sound Waves

- Physics (7)(C)

6.04 The Doppler Effect and Interference

- Physics (7)(D)

6.05 Applications of Waves

- Physics (7)(F)
- Physics (7)(D)

Note: Unless stated otherwise, any sample data is fictitious and used solely for the purpose of instruction.

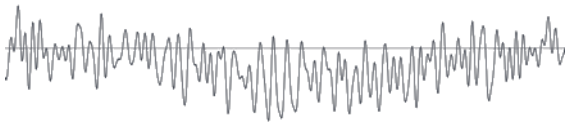
6.01

Classifications of Waves

Wave – a disturbance that carries energy through matter or space

Examples of Waves:

- ***Mechanical Wave*** – a type of wave that requires a medium to transmit energy
- ***Electromagnetic Wave*** – a type of wave that can transmit energy *without* a medium (in a vacuum)
- ***Periodic Wave*** – a type of wave that moves up and down (oscillates) at the same rate at every point in space and/or time

Periodic Wave	Aperiodic Wave
	

Types of Waves:

- ***Transverse Wave*** – a type of wave that oscillates _____ to the direction of the wave's motion
- ***Longitudinal Wave*** – a type of wave that oscillates _____ to the direction of the wave's motion

6.02

Properties of Waves

Amplitude – the _____ displacement of a periodic wave from its resting position

Trough – the _____ point of a periodic wave

Crest – the _____ point of a periodic wave

Period – the time elapsed for the motion of an oscillator to complete one _____

The letter T denotes the period of a wave.

Wave speed – the displacement of a wave peak, divided by the time over which the displacement took place

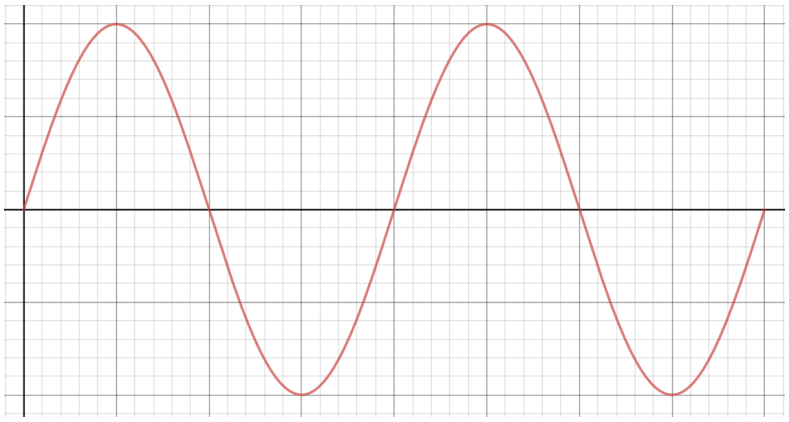
$$v = \frac{\Delta d}{\Delta t}$$

Frequency – the number of _____ oscillations a wave makes in one second

Frequency is the reciprocal of period: $f = \frac{1}{T}$

Wavelength – the _____ distance between successive crests or troughs

- Wavelength can be expressed in terms of period using the equation $\lambda = vT$.
- Using the equation for frequency, wavelength is expressed as $\lambda = \frac{v}{f}$.



6.03

Sound Waves

Sound wave – a pressure variation that is transmitted through matter

- Sound waves are _____ waves.
- Since these types of waves are difficult to draw, it is customary to look at the equivalent transverse wave representation in diagrams.

- Gas molecules found in the air are continuously compressed and rarified in the process of sound transmission.
  - This corresponds to changes in pressure between columns of air.
  - Rarefaction is the process of making a material *less* dense.
  - Compression is the process of making a material *more* dense.
- These oscillations propagate through three-dimensional space in a spherical manner.
- Since it is hard to draw in three dimensions, it is customary to only view sound waves in one dimension as a simple sine wave or in two dimensions as a circle.

- The speed of sound depends on the *temperature* of the air that it travels through.
  - For each $1^{\circ}\mathrm{C}$ increase in temperature, the speed increases by roughly $0.6\,\frac{\mathrm{m}}{\mathrm{s}}$.
  - At room temperature ($20^{\circ}\mathrm{C}$) and at sea level, sound travels at $343\ \mathrm{m/s}$.

Speed of Sound in Various Media

Medium	Air ($0^{\circ}\mathrm{C}$)	Air ($20^{\circ}\mathrm{C}$)	Water ($25^{\circ}\mathrm{C}$)	Copper ($25^{\circ}\mathrm{C}$)	Iron ($25^{\circ}\mathrm{C}$)
$\mathbf{m/s}$	331	343	1493	3560	5130

1. Calculate the wavelength of a $20\ \text{Hz}$ sound wave. Assume the wave is traveling in air at $20°\text{C}$.

2. Find the frequency of a sound wave moving through copper at $25°\text{C}$ with a wavelength of $2\ \text{m}$.

3. Suppose you're in the Palo Duro Canyon and you shout to the other side. You hear the echo from your voice 1.2 seconds later. How wide is the canyon?

6.04

The Doppler Effect

Perception of Sound

- Humans perceive sound through two main parameters: pitch and loudness.
- ***Pitch*** describes the human perception of frequency.
  The pitch that one hears depends on how slow (low pitch) or fast (high pitch) the frequency is.
- ***Loudness*** describes the human perception of amplitude.
  Loudness is ***not*** directly proportional to pressure variations in a sound wave.
- ***Psychoacoustics*** is the study of how humans perceive sound.

Physical Characteristic	Perceived Characteristic
Frequency	Pitch
Amplitude	Loudness

The Doppler Effect

- As an observer moves *relative to a source* of sound waves, the observer hears a change in the pitch of the source.
- It is easiest to understand this phenomenon if one isolates two cases.
  - Case 1: The sound source moves *closer* to the observer.
    - As the sound source moves closer, the number of wave crests from the source to the listener increases, becoming more crowded in a smaller space.
    - This increase in the crowding of wave crests means that the frequency of the received sound increases.
  - Case 2: The sound source moves *farther* from the observer.
    - As the sound source moves farther away, the number of wave crests from the source to the listener decreases, becoming less crowded in a larger space.
    - This decrease in the crowding of wave crests means that the frequency of the received sound increases.
- The situation can become slightly more complicated when both the source and the receiver are moving simultaneously.

- The equation relating the source frequency (f_s) and the observed frequency (f_o) is given by

$$f_o = f_s\left(\frac{v - v_o}{v - v_s}\right)$$

where

$v =$ velocity of the sound wave

$v_o =$ velocity of the observer, and

$v_s =$ velocity of the source.

Tips for Solving Problems Involving the Doppler Effect

- Draw a picture.
- Make sure that the positive direction of your axes points from the source to the observer.
- Draw vector arrows that show the directions of the source and observer velocities.

1. Suppose a motorcycle in the Houston Bike Rally parade has an engine that emits a frequency of $250\ \text{Hz}$ while traveling at $20\ \text{m/s}$ toward a person watching the parade. Find the frequency at which a stationary observer hears the motorcycle engine.

2. Suppose Priya is traveling in a car at $25\ \text{m/s}$ as she approaches an ambulance traveling toward her at $30\ \text{m/s}$. The ambulance has its siren on, which emits a frequency $400\ \text{Hz}$. Assuming the speed of sound is $343\ \text{m/s}$, what frequency does Priya hear?

6.05

Applications of Sound Waves

Biology

- Bats use the Doppler effect to find insects to eat.
- Dolphins use the Doppler effect to locate objects in their path.

Music

- Musical instruments
- Sound synthesis

Robotics

- Voice recognition software
- Self-driving cars parallel parking and sonar