vibration - an oscillation, or repeating back-and-forth motion, about an equilibrium position

- cannot exist in one instant....needs time to move back & forth

wave - a "wiggle in space and time"

- a disturbance that repeats regularly in space & time that is transmitted progressively from one place to the next with no actual transport of matter

- wave cannot exist in one place but must extend from one place to another

- light and sound forms of energy that move thru space as waves

25.1 Vibration of a Pendulum

period - time required for a pendulum to make one to-and-fro swing. symbol T

- the time to complete a single cycle

period of pendulum depends on 2 things: length of pendulum & acceleration due to gravity

length ~ period longer the length....the longer the period swing back & forth slowly
shorter the length...the shorter the period swinging back & forth quickly

the back and forth vibratory motion (oscillatory motion) of a swinging pendulum is called simple harmonic motion

simple harmonic motion - periodic motion in which acceleration is proportional to the distance from an equilibrium position & is directed toward that equilibrium position

sine curve - a curve whose shape represents the crests and troughs of a wave, as traced out by a swinging pendulum that drops a trail of sand over a moving conveyor belt

Fig. 25.3 sine curve is a pictorial representation of a wave

crest - one of the places in a wave where the wave is highest or the disturbance is greatest

trough - one of the places in a wave where the wave is lowest, or the disturbance is greatest, in the opposite direction from a crest

amplitude - the distance from the midpoint to the maximum (crest) of a wave or, equivalently, from the midpoint to the minimum (trough)

wavelength - the distance from the top of the crest of a wave to the top of the following crest, or equivalently, the distance between successive identical parts of the wave
how often a vibration or wave occurs is described by its frequency

a complete back-and-forth vibration is one cycle

**frequency**- the number of events (vibrations, oscillations, or any repeated event) per time;
- measured in hertz (or events per time) symbol - f unit - Hz (s⁻¹)
  - inverse of period f = 1/T

# waves / sec

**hertz**- the SI unit of frequency
- one hertz is one vibration per second (Hz)
  - measure higher frequencies in kilohertz and megahertz

AM radio waves broadcasted in kilohertz KHz 1 X 10³ Hz (thousands of hertz)
  970 AM broadcasts radio waves of frequency of 970 X 10³ vibrations per second (970,000 Hz)

FM radio waves broadcasted in megahertz MHz 1 X 10⁶ Hz (millions of hertz)
  107.3 FM broadcasts radio waves of frequency of 107.3 X 10⁶ vibrations per second (107,300,000 Hz)

radio wave frequencies are the frequencies at which electrons are force to vibrate in the antenna of a radio station’s transmitting tower

**source of all waves is something that vibrates**

**frequency of vibrating source and frequency of the wave it produces are the same**

**frequency and period are inverses of each other**

  frequency = 1 / period
  period = 1 / frequency

yellow ?’s
25.3 Wave Motion

as a wave travels through a medium, there is no transfer of matter (medium vibrates)

when energy is transferred by a wave from a vibrating source to a distant receiver, there is no transfer of matter between the two points

sound is a wave light, radio, & TV signals are electromagnetic waves

fig 25.5

the energy transferred from a vibrating source to a receiver is carried by a disturbance in a medium, not by matter moving from one place to another within the medium

25.4 Wave Speed

speed of a wave depends on the medium thru wh/ the wave moves

eg. sound moves in air at 340 m/s and 4X faster in water

wave speed = wavelength X frequency $v = \lambda f$

lambda ($\lambda$) (greek letter for wavelength)

calculate the wavelength of your favorite radio station. (the velocity of radio waves is $3 \times 10^8$m/s)

yellow ? p378

1. If water wave vibrates up & down two times each second & the distance between wave crests is 1.5m. what is the frequency of the wave?

what is its wavelength?

What is its speed?

2. What is the wavelength of a 340-Hz sound wave when the speed of sound in air is 340 m/s?
25.5 Transverse Waves

Motion of the medium (such as a rope or slinky) is at right angles to the direction in which the wave travels. Fig. 25.8

**Transverse wave** - A wave with vibration at right angles to the direction the wave is traveling

*eg. waves in the strings of instruments and waves on surfaces of liquids light waves radio waves*

25.6 Longitudinal Waves

When particles of the medium move back and forth in the same direction in which the wave travels, the wave is a longitudinal wave. Fig. 25.8

*Particles move along the direction of the wave*

**Longitudinal wave** - A wave in which the vibration is in the same direction as that in which the wave is traveling, rather than at right angles to it. Fig. 25.9

Medium vibrates parallel to the direction of energy transfer

*eg. sound waves are longitudinal waves*

25.7 Interference

Interference is a characteristic of all wave patterns (sound, light, water)

Interference can increase, decrease, or neutralize waves. Fig. 25.10

**Interference pattern** - A pattern formed by the overlapping of two or more waves that arrive in a region at the same time

**Constructive interference** - Addition of two or more waves when wave crests overlap to produce a resulting wave of increased amplitude. Aka: REINFORCEMENT

**Destructive interference** - Combination of waves where crests of one wave overlap troughs of another, resulting in a wave of decreased amplitude. Aka: CANCELLATION

**Combined waveform**

<table>
<thead>
<tr>
<th>wave 1</th>
<th>wave 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Two waves in phase</td>
<td>Two waves 180° out of phase</td>
</tr>
</tbody>
</table>
25.7 Interference

*fig. 25.11 interference pattern of 2 overlapping water waves
  gray “spokes” regions are areas of destructive interference - waves are out of phase
  dark & light “striped” regions are areas of constructive interference-waves are in phase

out of phase- term applied to two waves for wh/ the crest of one wave arrives at a point at the same time
  that a trough of the second wave arrives: their effects cancel each other

in phase- term applied to two or more waves whose crests (& troughs) arrive at a place at the same time
  : their effects reinforce each other

25.8 Standing Waves

standing waves are the result of interference  fig. 25.13, 25.14

made of 2 waves: incident wave (original) & reflected wave interfering with each other

standing wave- wave in wh/ parts of the wave remain stationary & the wave appears not to be traveling

nodes- any part of a standing wave that remains stationary

antinodes- the positions on a standing wave where the largest amplitudes occur

when 2 waves of equal amplitude & wavelength pass thru ea. oth. in opp. dir., the waves are always out of
  phase at the nodes...nodes are stable regions of destructive interference

yellow ?’s pg 382
1. Is it possible for one wave to cancel another wave so that the combined amplitude is zero?

2. Suppose you set up a standing wave of three segments, as shown in fig. 25.14 bottom.
   If you shake with twice the frequency, how many wave segments will occur in your new standing wave?

   How many wavelengths will there be?
25.9 The Doppler Effect

**fig 25.15**
bug is stationary
bug bobs in water at constant frequency
crests of waves make concentric circles
wavelengths are equal for each wave
waves hit points A & B at same time

**fig 25.16**
bobbing bug swims across water
bug bobs in water at constant frequency
bug’s speed is less than wave’s speed
center of outer crest made w/ bug in center of the circle
center of next smaller crest made when bug was in center of that circle
centers of circular crests move in dir. of swimming bug
pt B encounters waves of higher frequency
  bcs ea. successive crest has shorter dist. so they arrive at B more frequently
pt A encounters waves of lower frequency
  bcs ea. crest has to travel farther than one ahead of it due to motion of the bug

Doppler effect- the change in frequency of a wave due to the motion of the source or of the receiver

doppler wave- a wave that is the result of the motion of the source

*water waves spread out over water surface in 2 dimensions
*light and sound waves travel in 3-dimensional space, move in all directions

**Doppler effect with sound waves**
ex. fig 25.17 hearing the changing pitch of a car horn or siren as the vehicle passes you
  as vehicle approaches....pitch sounds higher than normal....bcs increase frequency
  as vehicle passes you....pitch sounds lower than normal....bcs decrease in frequency

**Doppler effect with radar waves**
ex. fig. 25.18 police calculate car’s speed by measuring Doppler effect of radar waves
  radar waves sent out by radar gun at a constant frequency....hit approaching car...
  radar is reflected off car back to radar gun...but car is moving towards radar gun...
  therefore wavelength is smaller and frequency is higher...computer in radar gun compares frequency of radar emitted by antenna w/ freq. of reflected radar wave of car
**Doppler effect with light waves**

when a light source approaches...there is an increase in its measured frequency
when a light source recedes...there is a decrease in its measured frequency

*electromagnetic spectrum:* fig 27.4 pg 408

radio   micro   Infra-red   visible light (ROYGBIV)   Ultra-violet   x-ray   gamma

**blue shift**- an increase in the measured frequency of light from an approaching source

- called the blue shift because the apparent increase is toward the high-frequency, or blue, end of the color spectrum

- also occurs when an observer approaches a source

**red shift**- a decrease in the measured frequency of light (or other radiation) from a receding source

- called the red shift because the decrease is toward the low-frequency, or red, end of the color spectrum

yellow ?’s p384  When a source moves toward you, do you measure an increase or decrease in wave speed?

**25.10 Bow Waves**

occurs in water are 2-dimensional
produced by overlapping circular waves that form a V

bow wave is example of constructive interference...with big increase in amplitude

occurs when speed of source in a medium is as great as the speed of the wave it produces
....the crests pile up or superimpose on one another directly in front of source

**bow wave**- a V shape wave produced by an object moving on a liquid surface faster than the wave speed

bow wave appears to be dragging behind the object producing the wave

ex. speedboat moving through water quickly will produce (many overlapping circular wave crests)....
a bow wave ...a V shaped wave

bow wave continues to spread out until it hits shore (sort of a “water boom” like sonic boom of shock wave)

fig. 25.19 bow wave made by obj moving at wave speed

fig 25.20 bow wave made by obj. moving faster than the wave speed

fig. 25.21 bow waves made by obj. moving at successively greater speeds

*overlapping at edges occurs only when the source travels faster than wave speed
the greater the speed of source....the narrower the V shaped pattern
25.11 Shock Waves

**subsonic** - slower than speed of sound
- speed of sound = 340 m/s
- each wave hits ear...hear a hum
- spherical waves do not overlap to form a cone....sound wave crests reach our ears one at a time
- hear continuous tone

**supersonic** - faster than speed of sound

**shock wave** - a cone-shape wave produced by an object moving
- at supersonic speed through a fluid
- shock wave produced by overlapping spheres that form a cone
- fig 25.22 fig 25.23
- conical shock wave continues to spread out until it hits the ground
- **source must be moving faster than speed of sound to get the overlapping spheres that form cone**
- (of compressed air)

**sonic boom** - the sharp crack heard when the shock wave that sweeps behind a supersonic aircraft reaches the listener

**sonic boom is a continuous front of high pressure generated by faster-than-sound sources**

- supersonic object (aircraft) is not source of sound but as it travels at supersonic speeds it produces its own sound as waves of air are generated to sides of moving obj.
- these waves move out in 3-dimensional pattern behind plane forming a cone of high pressure continuously behind plane
- when this front of high-pressure air reaches ground to a listener....they hear sonic boom
- this burst of high-pressure air (sonic boom) is similar to burst of high-pressure air from an explosion....ear can’t distinguish between them ....they sound the same
- it is not necessary for moving source to emit a sound for it to produce a shock wave.....once it is moving faster than the speed of sound....it will make a sound

eg. supersonic bullet passing overhead produces a crack
- cracking a whip.....tip of whip is traveling faster than the speed of sound produces crack
- snapping a towel....end of towel is traveling faster than the speed of sound

* these aren’t sources of sound …when traveling faster than speed of sound (supersonic speeds) they produce their own sound as waves of air are generated to sides of moving object.(forming cone of high-pressure