Unit 8: Waves


Beetle Bailey
BACK UP, SARGE
GREG+ MORT WALKER
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WAVE!


Hagar the Horrible
WE'RE GOING TO ATTACK THE CASTLE IN WAVES!
A THIRD OF US IN THE FIRST WAVE
A THIRD OF US IN THE SECOND WAVE AND A THIRD OF US IN THE LAST WAVE!
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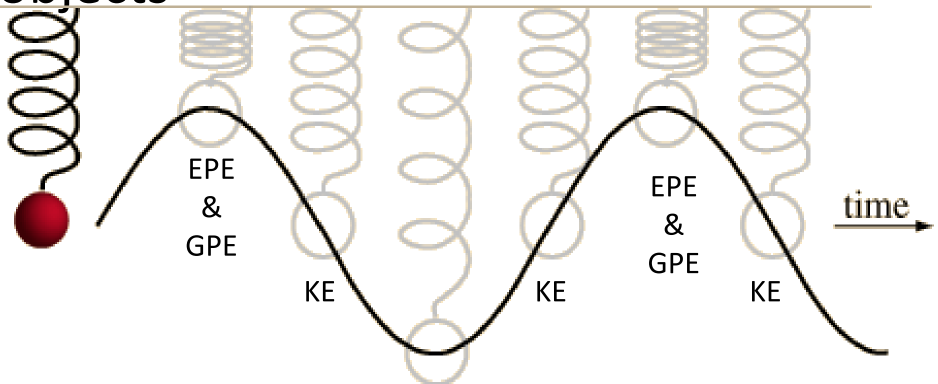
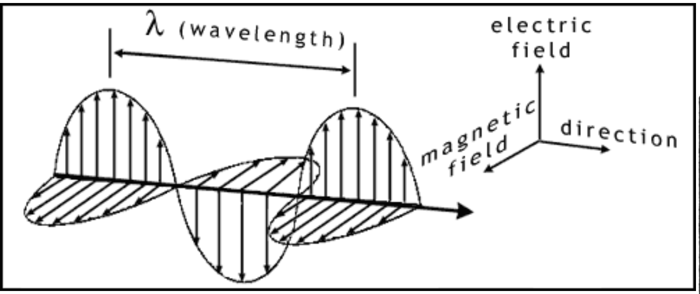
WHAT'S WRONG ?
I CAN'T GO— I THINK I'M SEASICK!
CHRIS BROWNE
6-20

Wave Basics

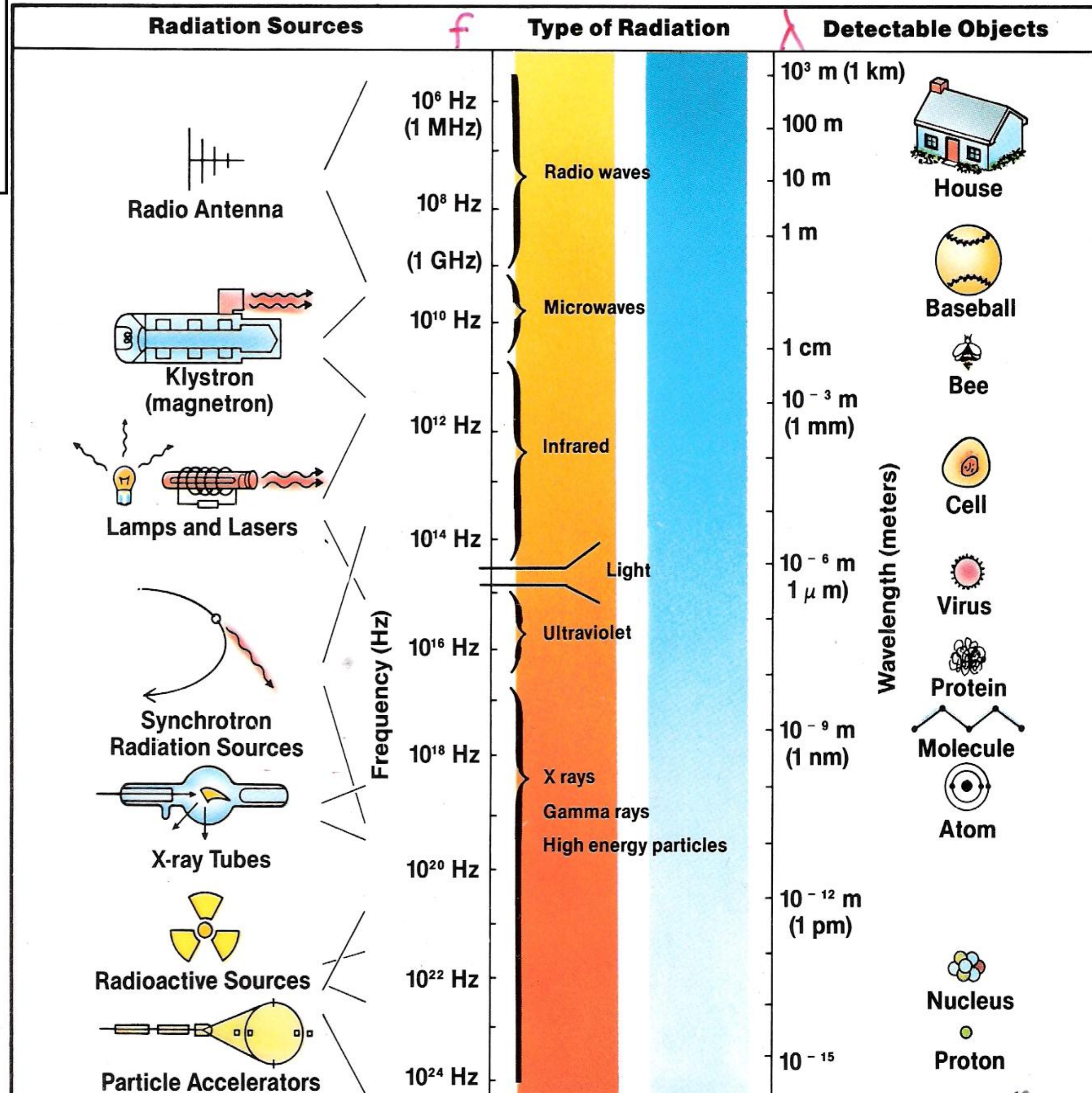
- **Waves** = disturbance that carries energy through matter or space.
  - As wave travels away from source, energy may spread out over a larger volume (ex. water ripples)
- **Medium** = matter through which wave travels (ex. wall, water, air, vacuum)
- **Mechanical wave**: requires a medium to travel through (sound, H_2Owaves)
- **Electromagnetic wave**= wave consisting of oscillating electrical & magnetic fields, which radiate outward at the speed of light = c (ex. on next slide)
- Most waves are caused by **vibrating** objects



- **Vibrating mass-spring system**
  - Mechanical energy changes form between PE (elastic & grav.) and KE
  - **simple harmonic motion** = periodic motion of an object where the net force is directly proportional to the displacement from the equilibrium position and acts in the opposite direction of the displacement.
  - **damped harmonic motion=** vibration that fades out as energy is transferred from one object to another (ex. series of masses on springs connected in a row-1^{st} mass slows quicker than if it were free)
- Wave particles move like masses on a string



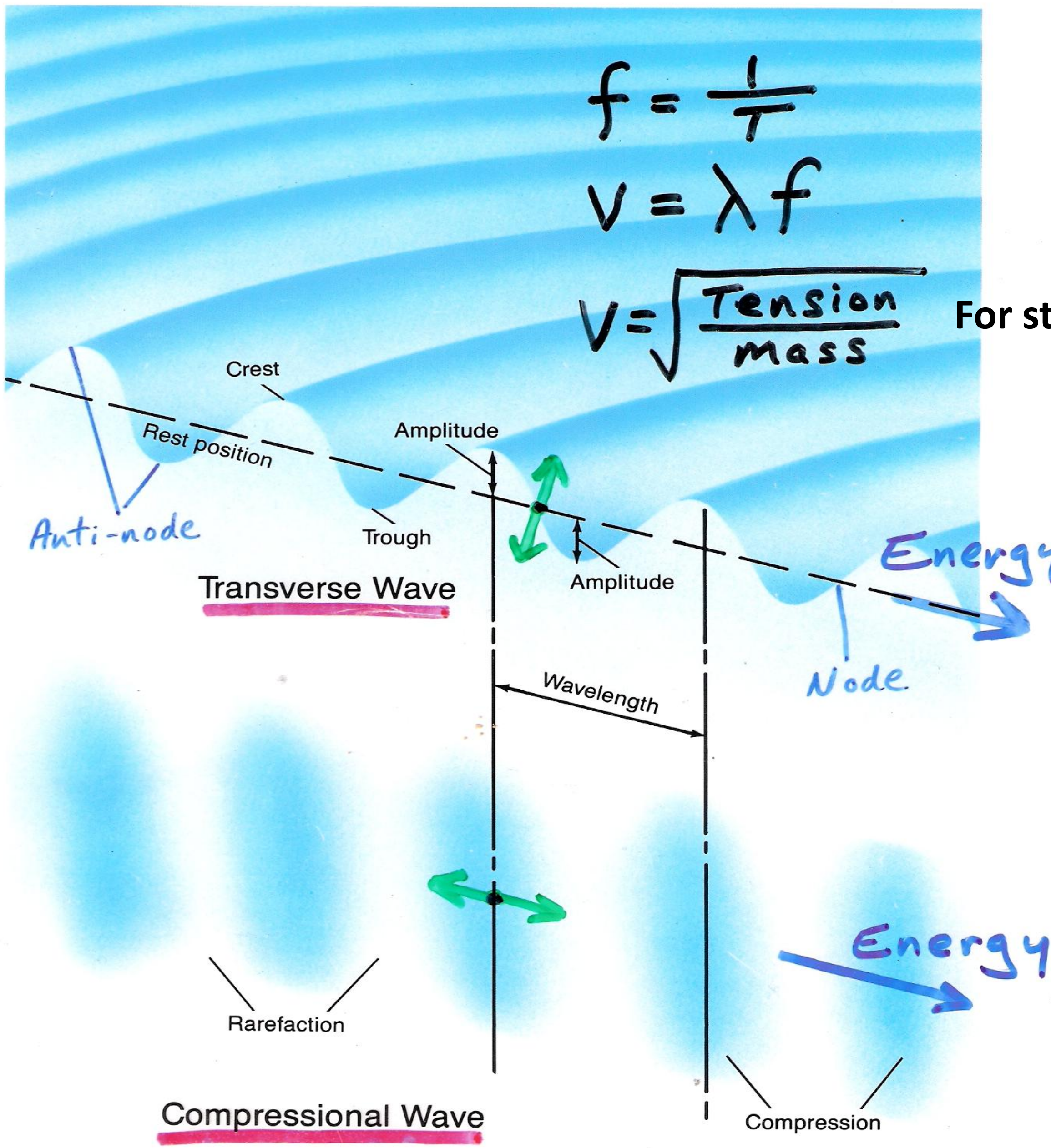
REPRESENTATIVE ELECTROMAGNETIC SPECTRUM



$c = \lambda f = 3 \times 10^8 \, m/s$ Vacuum

ROY G BIV

WAVE PROPERTIES



For string instruments

WAVE CATEGORIES

Longitudinal vs. Transverse:

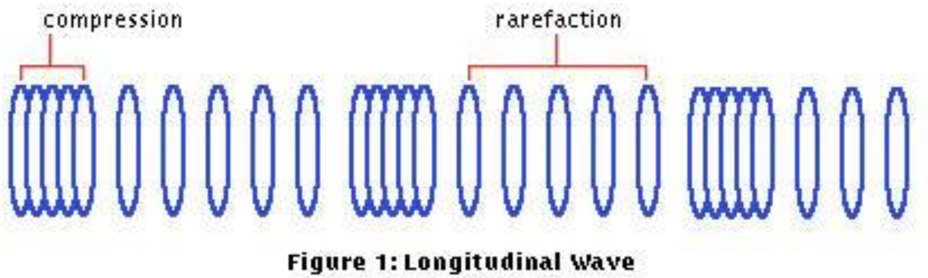


Figure 1: Longitudinal Wave

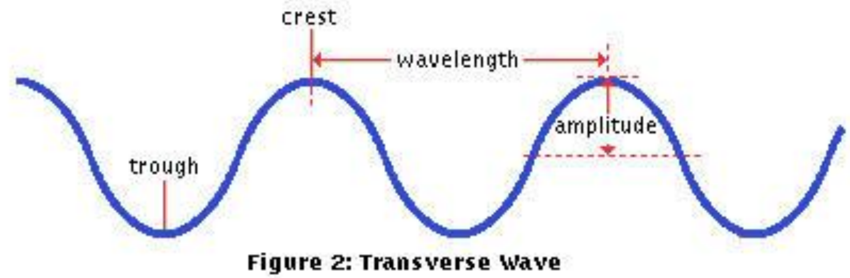


Figure 2: Transverse Wave

- oscillates parallel to energy flow
- oscillates ⊥ to energy flow

Mechanical vs. Electromagnetic

- Medium to pass through
- Usually observable
- Passes through vacuum
- Cannot see

Traveling vs. Standing:

- Appears to move
- Appears to stand still due to INTERFERENCE

Water wave: move perpendicular & parallel (ellipse) to energy

WAVE PROPERTIES

Longitudinal vs. Transverse

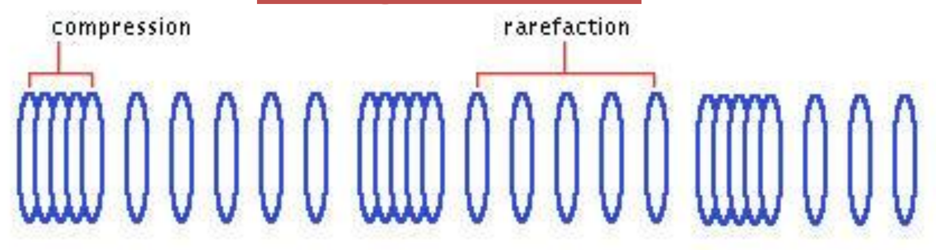


Figure 1: Longitudinal Wave

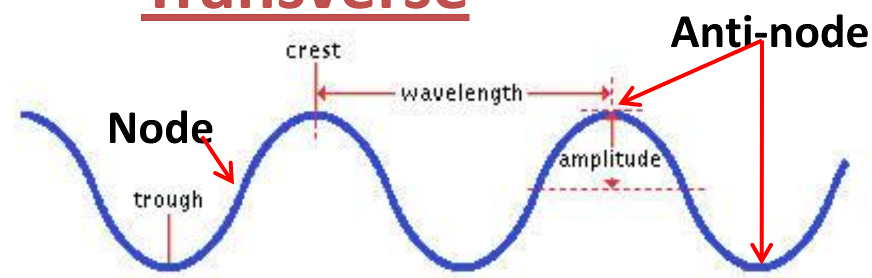


Figure 2: Transverse Wave

- **Compression**: wave/particles crowded
- **Rarefactions**: waves/particles spread-out

- **Node-** 0 pt, no amp./oscillation
- **Anti-node-** Maximum pt
- **Crest** – highest point
- **Trough**-lowest point

Amplitude: max distance wave particles move from rest, depends on energy

Wavelength (λ): distance (m) between any 2 successive identical points (Ex. crest-crest or compression-compression)

↑amplitude OR ↓wavelength = ↑Energy

Period (T): time (sec) it takes for a wave to pass a given point

Frequency(*f*):# of wavelengths that pass a point in a given time interval (Hz = 1 cycle/sec), determines pitch (high or low sound)

$$f = \frac{1}{T} \qquad v = f\lambda \qquad v = \sqrt{\text{tension/mass}}$$

WAVE SPEED

$$v = \frac{\lambda}{T} \quad \text{OR} \quad v = f \times \lambda$$

- Depends on the medium (↓ KE of medium= particles closer together = ↑ v) Solids > liquid > gas
- Is constant in a medium
- Does NOT depend on frequency!
- All electromagnetic waves have finite speed = speed of light ($c = 3 \times 10^8$ m/s)

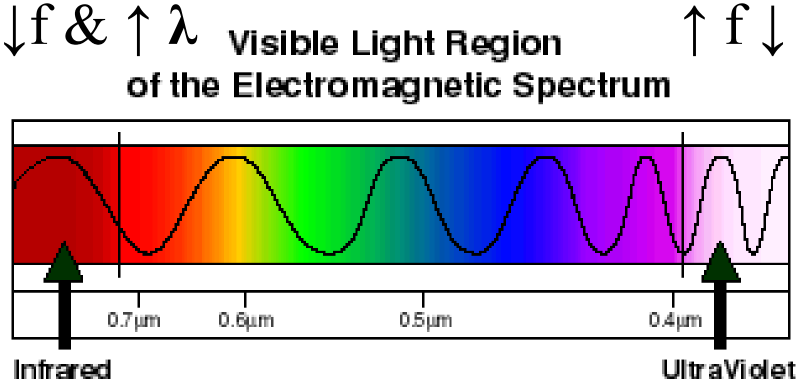
$$c = f \times \lambda$$

-Light travels slower in air or water

-Visible light = 4.3×10^{14} Hz to 7.5×10^{14} Hz

ROY G BIV

↓f & ↑ λ ↑ f ↓ λ



3 primary colors eyes can see = R G B

WAVE SPEED

$$v = \frac{\lambda}{T} \qquad \text{OR} \qquad v = f \times \lambda$$

1. If an ocean waves that are 5 meters apart hit the beach every 3seconds, what is the Frequency & speed of the waves?

$f = \frac{1}{T} = \frac{1}{3\ s}$ = **0.333 Hz or sec^{-1}**

$v = \frac{\lambda}{T} = \frac{5\ m}{3\ s}$ = **1.67 m/s** OR $v = f \times \lambda$ = (0.333 Hz)(5m) = **1.67m/s**

2. WSPT-AM on dial is 1010 which is the frequency in kHz (FM in MHz). What is the wavelength of this channel's frequency?

All EM radiation has speed = c = speed of light = 3 x10^8 m/s

$\lambda = \frac{v}{f} = \frac{3 \times 10^8\ m/s}{1{,}010{,}000\ Hz}$ = **297 m**

≈ 3 x football field or size of SPASH building

WAVE SPEED

$$v = \frac{\lambda}{T} \quad \text{OR} \quad v = f \times \lambda$$

3. If an ocean wave has a wavelength of 15m and a crest arrives at shore every 10 seconds, what is the frequency and speed of the waves?

$$f = \frac{1}{T} = \frac{1}{10\text{ s}} = 0.1\text{ Hz} \quad \text{or sec}^{-1}$$

$$v = \frac{\lambda}{T} = \frac{15\text{ m}}{10\text{ s}} = \mathbf{1.5\text{ m/s}} \quad \text{OR} \quad v = f \times \lambda = (0.1\text{ Hz})(15\text{m}) = \mathbf{1.5\text{m/s}}$$

4. Green light has a wavelength of 5.2×10^{-7} m. The speed of light c = 3×10^{8} m/s. Calculate frequency.

$$f = \frac{v}{\lambda} = \frac{3 \times 10^{8}\text{ m/s}}{5.2 \times 10^{-7}\text{ m}} = \mathbf{5.77 \times 10^{14}\text{ Hz}}$$

5. The speed of sound in air is about 340 m/s. What is the wavelength of the sound wave if its frequency is 220 Hz (on a piano, the A below middle C)?

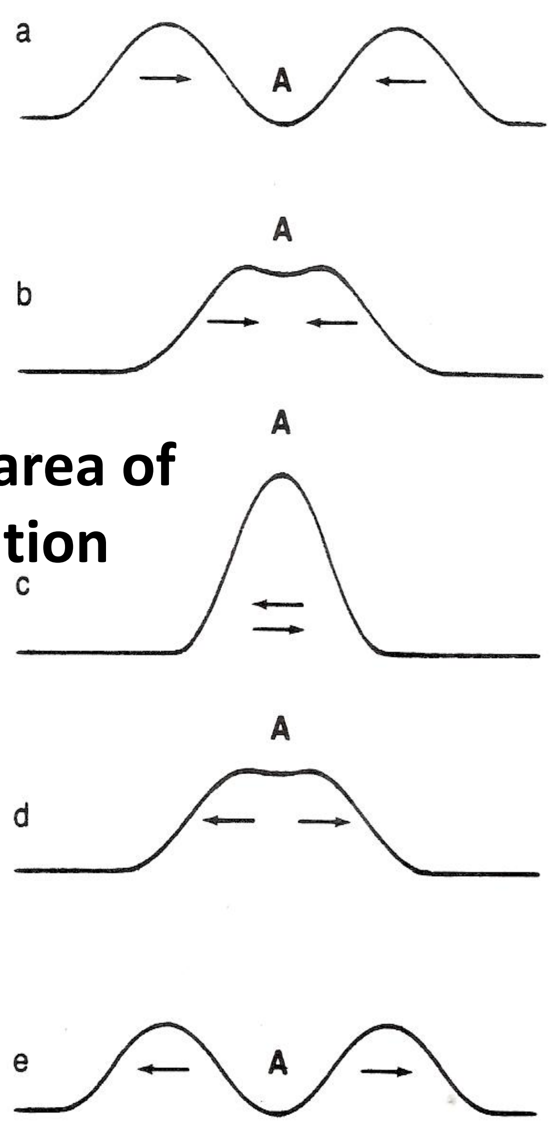
$$\lambda = \frac{v}{f} = \frac{340\text{ m/s}}{220\text{ Hz}} = \mathbf{1.5\text{ m}}$$

INTERFERENCE

- Occurs when several waves are in the same location and combine to produce a single, new wave that is different from the original waves
- **Constructive interference** increases amplitude when two like points (crests-crest) overlap creating an **anti-node** = area of max vibration
  - Ex. Tacoma Narrows Bridge = Galloping Gerdy (40mph winds)
- **Destructive interference** decreases amplitude when two unlike points overlap (crest-trough) creating a **node** = area of minimum vibration
  - Ex. Noise cancellation features
- White light traveling different distances through soap bubbles will interfere constructively & destructively due to waves being in & out of phase = swirling rainbow effect

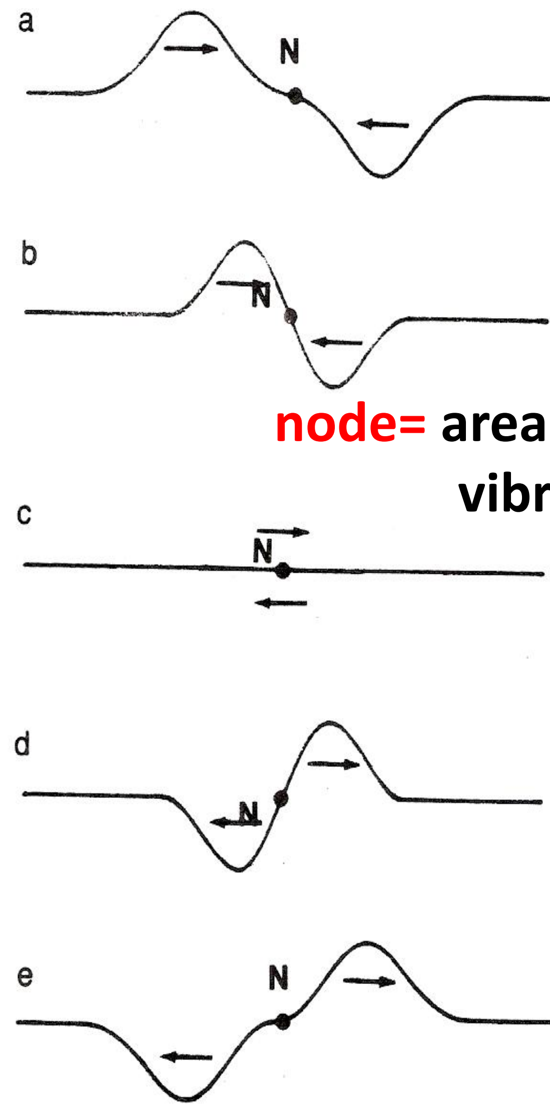
- Interference with sound waves of different frequencies produces **beats** = pattern alternating loud and soft

INTERFERENCE



Anti-node= area of max vibration

FIGURE 14–14. Constructive interference of two equal pulses. An antinode is a point of maximum displacement.

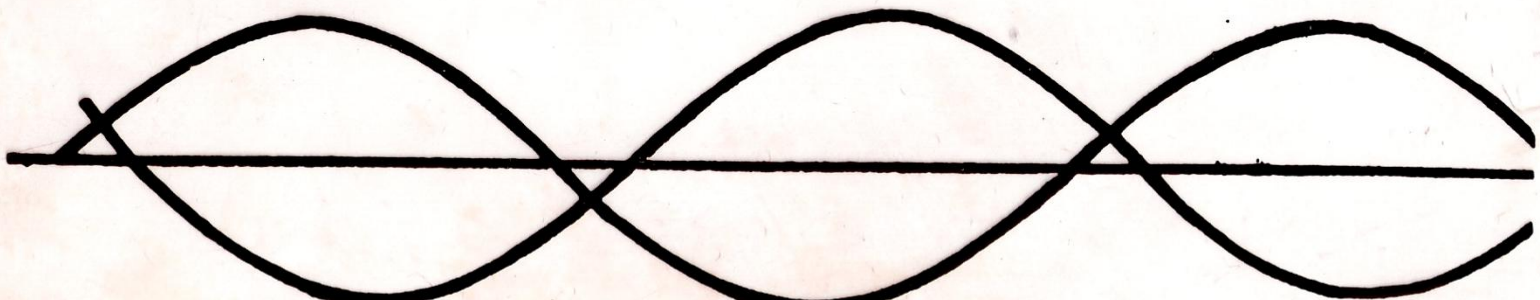


node= area of minimun vibration

FIGURE 14–15. Destructive interference of two equal pulses. A node is a point of the medium that remains undisturbed.

INTERFERENCE

CONSTRUCTIVE



DESTRUCTIVE

Sample Problem

WSPT-FM on dial is 97.9 which is the frequency in MHz . What is the wavelength of this channel's frequency?

All EM radiation has speed = c = speed of light = 3 x10^8 m/s

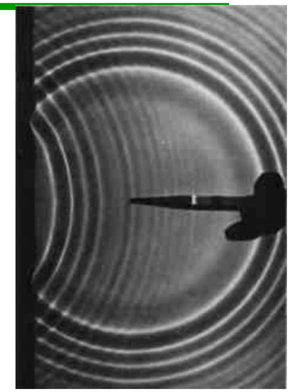
$$\lambda = \frac{v}{f} = \frac{3 \times 10^8 \text{ m/s}}{97.9 \times 10^6 \text{ Hz}} = \frac{3 \times 10^8 \text{ m/s}}{0.979 \times 10^8 \text{ Hz}} = \frac{3}{0.979 \text{ Hz}} \text{ m/s} = \mathbf{3.06 \text{ m}}$$

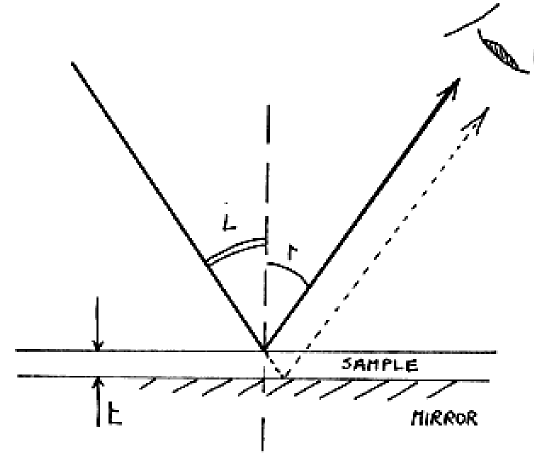
FM: better resolution but harder to pick up in buildings

AM: transmits further but ↓ quality, better at night because sun disrupts atmosphere

Wave Interactions

Reflection: when a wave meets a boundary & bounces back (ex. mirror = reflection of light)





Diffraction: abrupt change in the direction of a wave around an obstacle

-reason why shadows down have sharp edges

Refraction: bending of a wave as it passes between two different mediums which alters the speed of the wave

-reason pencil looks split in a glass of water

RESONANCE

2 or more waves pass through each other

↓

INTERFERENCE -- chaotic unless...

↓

- Same/multiple *f* and λ
- Match length of medium

↓

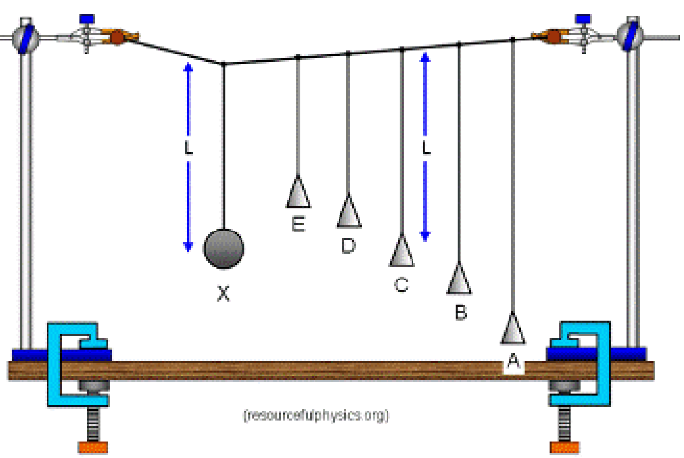
STANDING WAVE

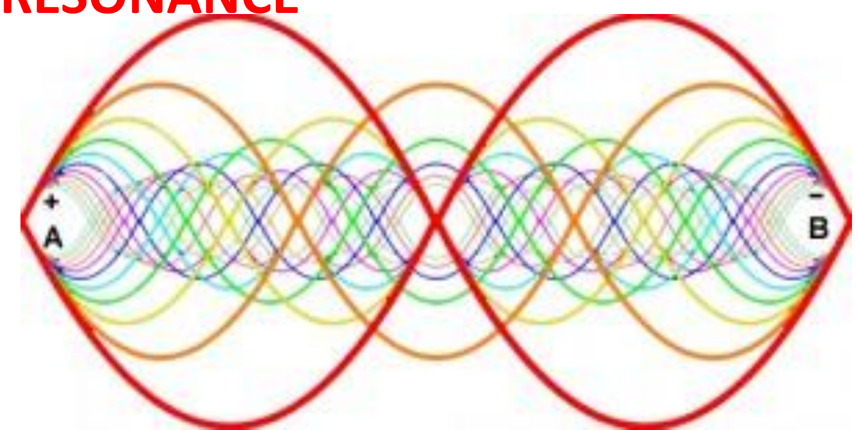
↓

- External force (person/wind) of similar *f* and λ
- Continuous amplification

↓

RESONANCE





EXAMPLES OF GOOD RESONANCE

- Musical instruments
- LASER(Light Amplification by Stimulated Emission of Radiation)
- Swing
- Car shocks
- Earthquake & wind architecture
- Singing glasses
- Electronics (tuned or resonant circuits)
- MRI
- Ear
- Loudspeaker
- Organic chemistry
- Quantum physics

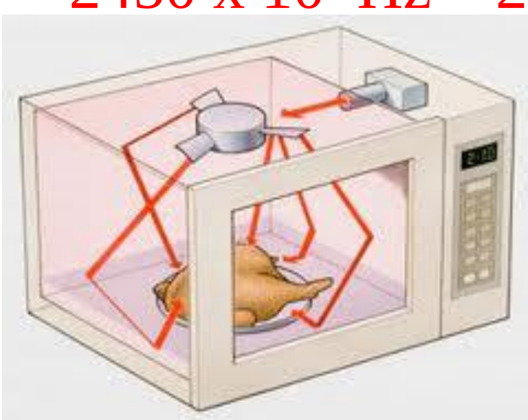
EXAMPLES OF BAD RESONANCE

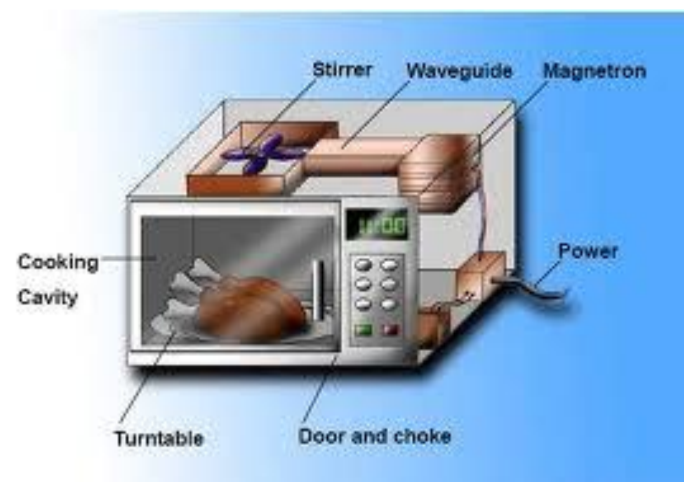
- Earthquake/wind damage to structures ("Galloping Gertie")
- Stereo feedback
- Breaking a glass
- Microwave oven
- Washboard road
- Ear damage from too many decibels

Microwave

- 1st proposed by Tesla
- **Capacitor:** stores 3000 V AC
- **How it works:** friction between molecules especially water causes heat; NOT size of wave that excites particles
- **Danger:** standing waves reflect waves back to source that resonates & amplifies = BLOWS UP
  - **Prevention:** fan or turn table to mix up waves so not make standing wave
- **Ex. A microwave has a frequency of 2450 MHz, what is its wavelength?**

$$\lambda = \frac{v}{f} = \frac{3 \times 10^8 \text{ m/s}}{2450 \times 10^6 \text{ Hz}} = \frac{3 \times 10^8 \text{ m/s}}{2.45 \times 10^9 \text{ Hz}} = \mathbf{0.122\ m} = \mathbf{12.2\ cm}$$

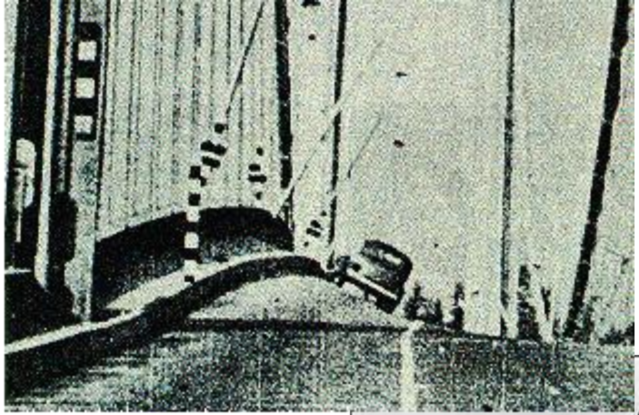




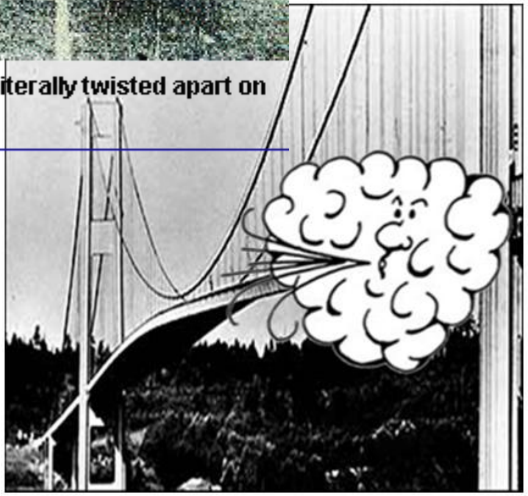
Tacoma Narrows Bridge

- aka "Galloping Gertie"
- In use less than 4 months
- **Cause:** **Resonance** = 40 mph winds keep pumping in energy to create standing wave that resonated & amplified to tear bridge apart
- **Prevention:** hydraulic plungers or counter weights to absorb energy of hurricanes & earthquakes

- Tacoma Bridge (00;4:14) https://gaggle.net/gaggleVideoProxy.do?op=view&v=6854a527a1134ab112581ee9a2147a6a766057cc0f85b0e4
- Tacoma Narrows Bridge (00:2:25) https://gaggle.net/gaggleVideoProxy.do?op=view&v=309e3e4e5cc2c7f051d8e2453da590c0a690c103467a0a0e



The Tacoma Narrows Bridge literally twisted apart on Nov. 7, 1940.



Videos: Resonance

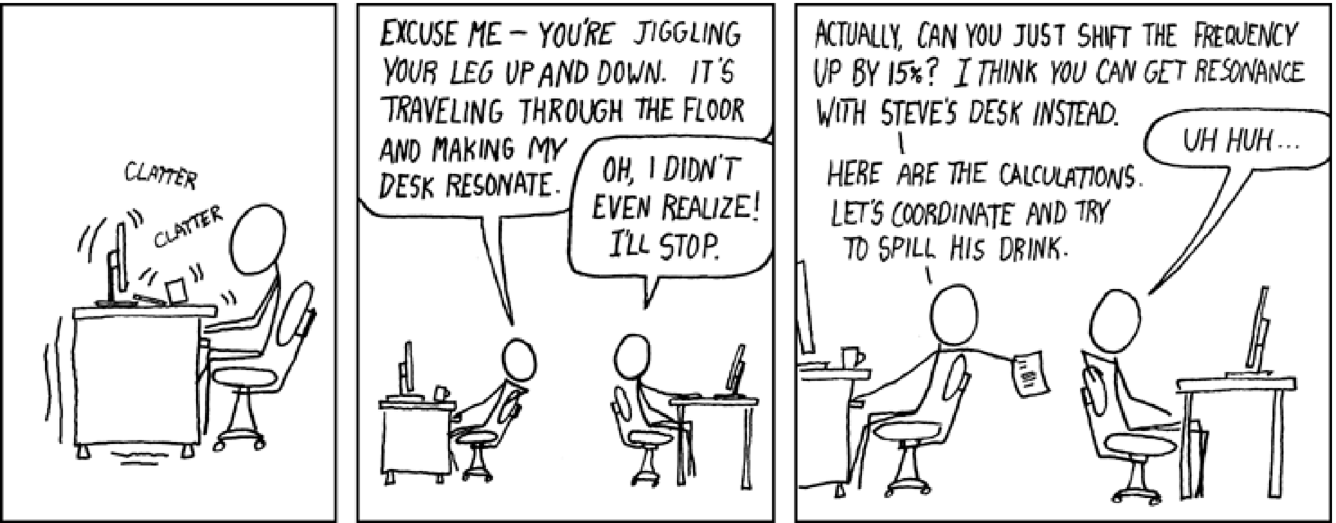
- Singing Glasses (00:1:53)
https://gaggle.net/gaggleVideoProxy.do?op=view&v=aff562c086dfe015fc06b834017

- Singing Glasses-Sway (00:3:11)
https://gaggle.net/gaggleVideoProxy.do?op=view&v=35dd0854fe6bd6fbb5da155474

- 2010 Lexus breaking glass (00:3:37)
https://gaggle.net/gaggleVideoProxy.do?op=view&v=695fb5de745172d3d29656a66

- Breaking Glass SLOW MOTION (00:1:05)
https://gaggle.net/gaggleVideoProxy.do?op=view&v=52e4701bc554c2c241be9420f0

- Mythbusthers breaking (4:37, 6:16, 5:37)
https://gaggle.net/gaggleVideoProxy.do?op=view&v=aaab72709ae462f5441073d68
https://gaggle.net/gaggleVideoProxy.do?op=view&v=ea374934850f0d68ca253c2a12
https://gaggle.net/gaggleVideoProxy.do?op=view&v=4fc966787364de1879d888fa42



SOUND

Sound Wave = longitudinal (compression) wave caused by vibrations that carries energy through a medium

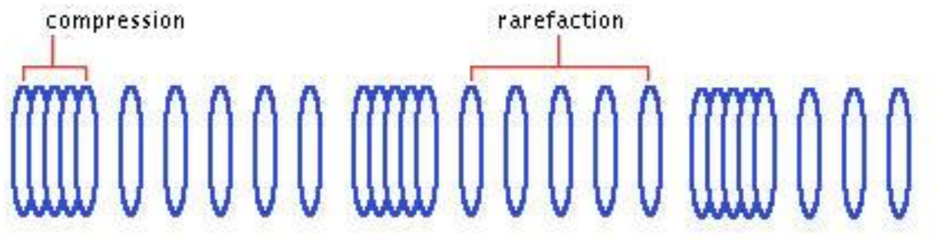
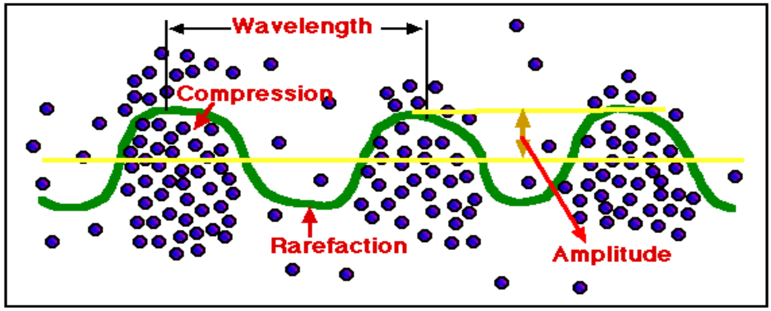


Figure 1: Longitudinal Wave



- *Speed depends on temperature & type of medium material*

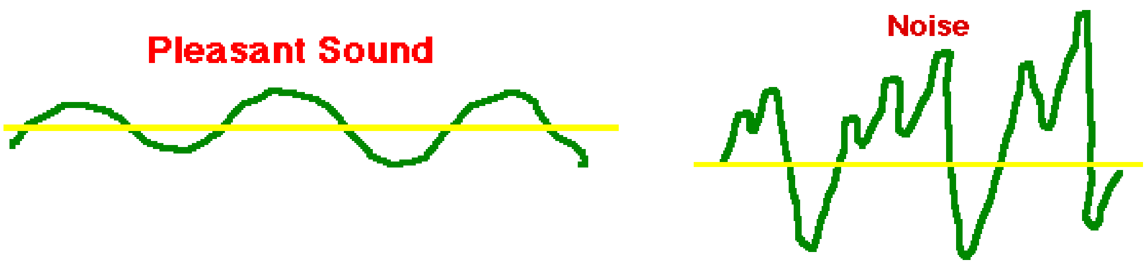
  *Temperature = measure of KE of the substance,

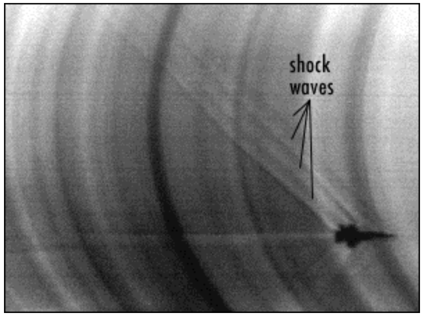
  *↑KE =↑temperature = molecules farther apart = ↓velocity wave

  *Speed in medium: Solid >liquid > gas & no sound in a vacuum

  (at room temperature v = 340 m/s)

  *Speed is constant in a particular medium





Shock wave: **produced when object travels faster than waves**

Mach # : ratio of aircraft speed to SOS in air

Mythbusters Fun with Gases (00:00:39)

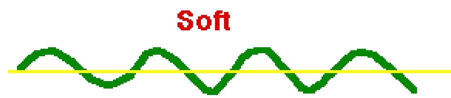
https://gaggle.net/gaggleVideoProxy.do?op=view&v=c072ed4b9293d76ed6e4c65b9002eb9328ccd5acf5ffad20

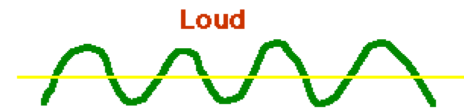
• *Loudness depends on intensity*

*__Intensity__ = rate at which wave transmits energy through medium which depends on <u>amplitude</u> (amount of energy) & distance from source, for sound- measured in decibels (dB)

↑amplitude = ↑intensity   ↑distance from source =↓intensity

0 dB = threshold of hearing   120 dB = threshold of pain

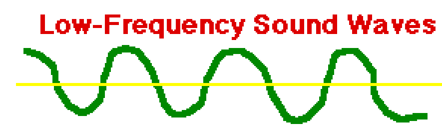




• *Pitch depends on frequency*

Pitch= highness or lowness of tone (musical term for <u>frequency</u>)

↑ pitch = ↑frequency =↓λ ↓ pitch = ↓ frequency = ↑ λ

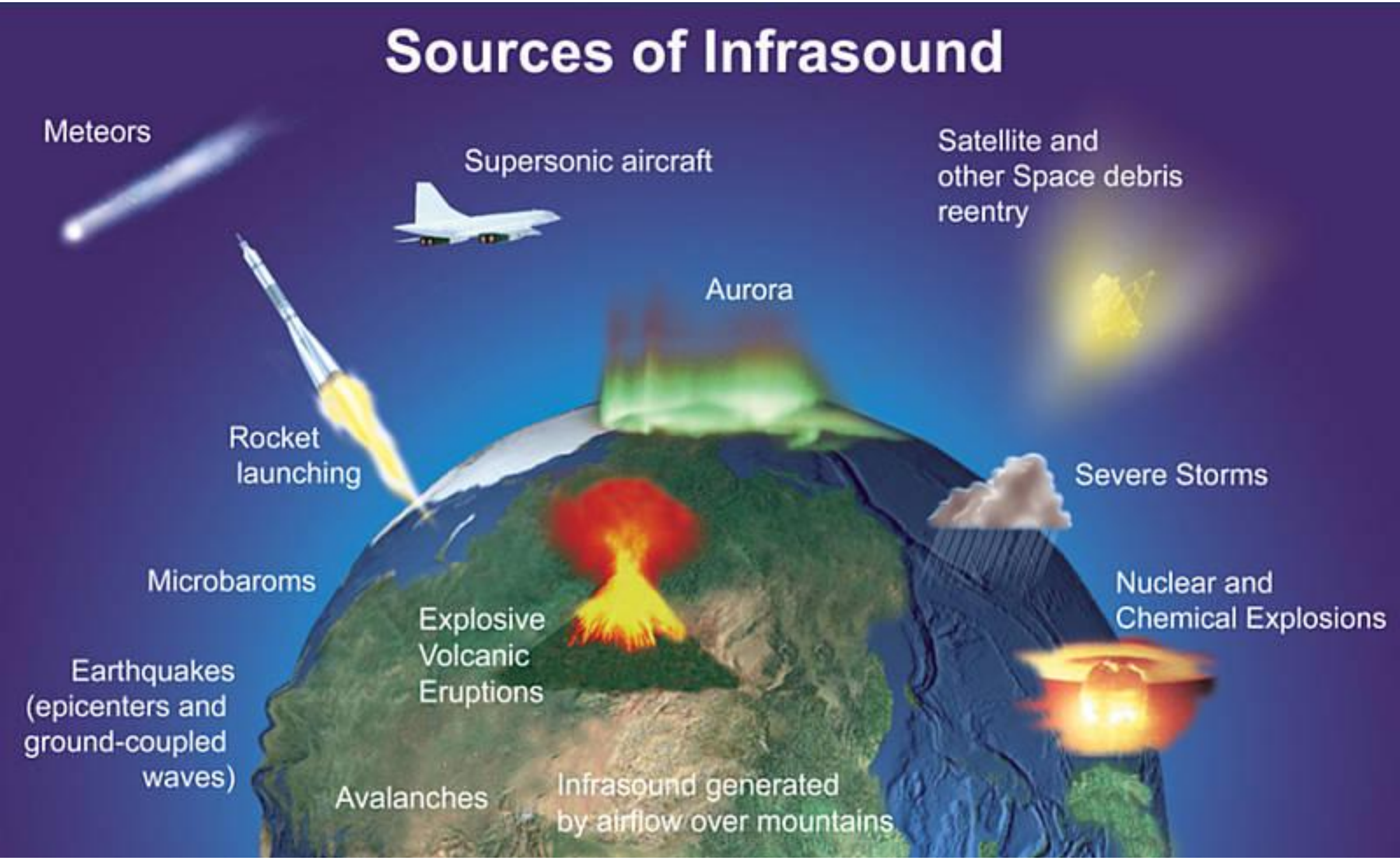


*__Infrasound__ = sound waves with slow vibrations of frequencies lower than 20Hz; below the frequency that humans can hear

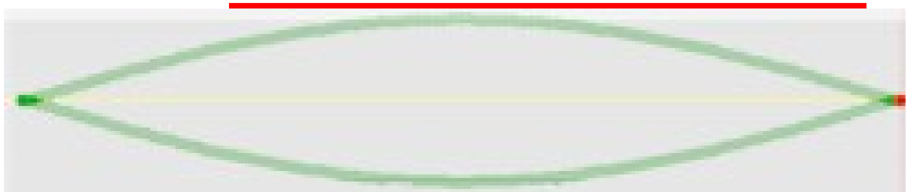
*__Ultrasound__ = sound waves with frequencies higher than 20,000 Hz; above the frequency that humans can hear

Mythbusters-Ultrasonic motion sensor (00:3:18)

https://gaggle.net/gaggleVideoProxy.do?op=view&v=1f4132162f8d9dfbcfc5b2e4a8b4e81b71325d0c1459b094

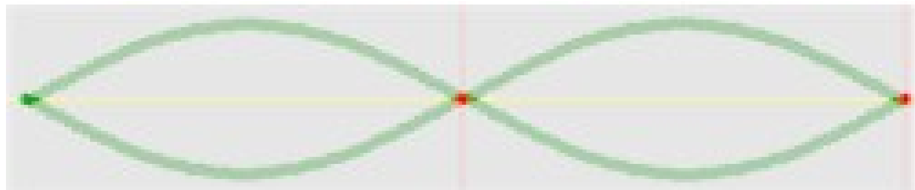

Sources of Infrasound
Meteors
Supersonic aircraft
Satellite and
other Space debris
reentry
Aurora
Rocket
launching
Severe Storms
Microbaroms
Nuclear and
Chemical Explosions
Explosive
Volcanic
Eruptions
Earthquakes
(epicenters and
ground-coupled
waves)
Avalanches
Infrasound generated
by airflow over mountains

STRING HARMONICS

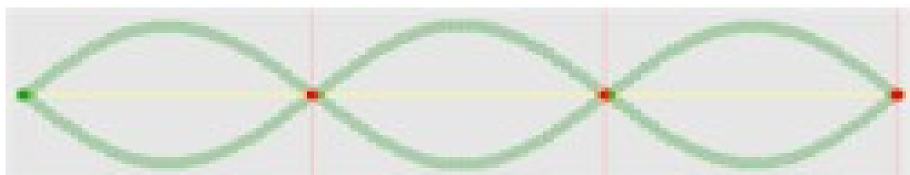


Lowest (f) & Loudest tone heard, Longest λ

Fundamental frequency (1st harmonic) = ½ wave



2nd Harmonic = 1 wave



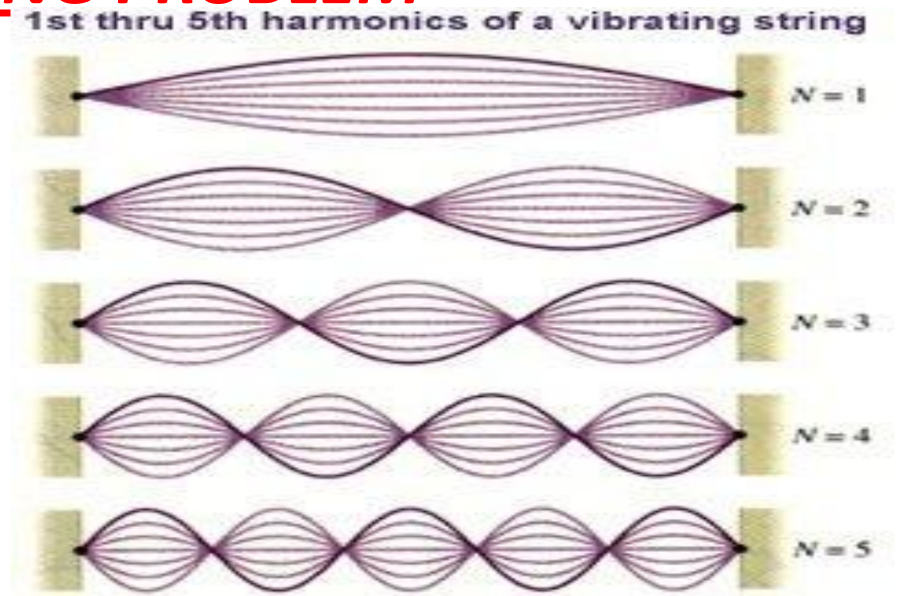
↑ harmonics =↓ hear them

3rd Harmonic = 3/2 wave

- String constrained to nodes at both ends
- All harmonics exist together to yield rich sound (timbre)
- Waves move at same speed along string regardless of harmonic =
  $v = \sqrt{Tension/mass}$
- Amplitude (n^{th} harmonic) = (1/n) x Amplitude (fundamental)
- See the pattern that develops:

$$L = \frac{1}{2} n\lambda \quad \text{where } n = 1, 2, 3, \ldots$$

SAMPLE STRING PROBLEM



Violin, 4 strings: G-D-A-E

D string: L = 33 cm f = 297 Hz
1st harmonic $\lambda_1 = 2L$

Calculate v for the first harmonic.
$v = \lambda f$
$\lambda_1 = 2L = 66$ cm
so v = 2Lf = (0.66m)(297 Hz) = 196.02 m/s

$L = \frac{1}{2}n\lambda$ where n = 1, 2, 3, . . .

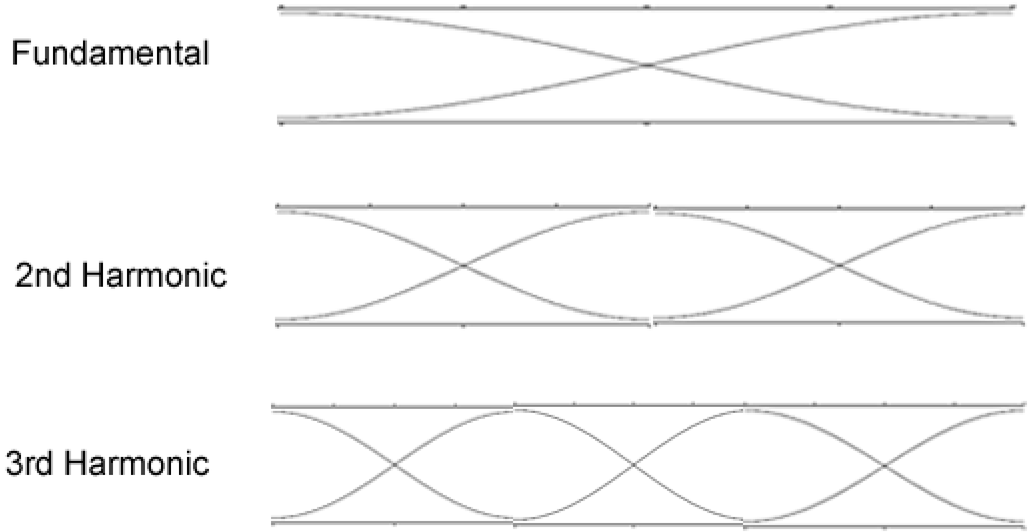
NOTE:

- **Higher harmonics on the string travel at same speed**
- **Higher frequency (f) means shorter wavelength (λ)**
- **λ_2 is half as long as λ_1 so f_2 is double f_1 (octave)**

λ_2 = L = 33 cm so v = Lf = (0.33m)(594 Hz) = 196.02 m/s
λ_3 = ⅔L = 22 cm so v = 2/3Lf = (0.22m)(891 Hz) = 196.02 m/s

WIND HARMONICS

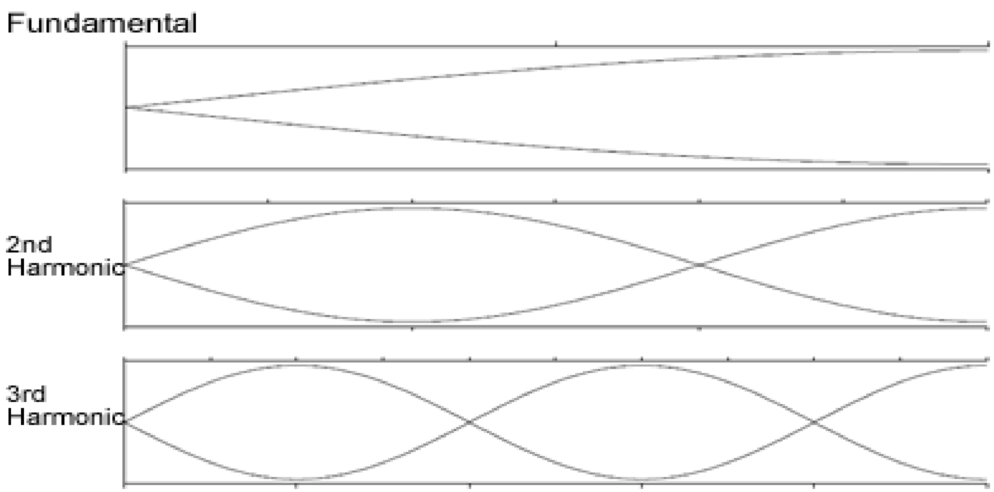
OPEN TUBES



- Same pattern as string
- Anti-nodes at ends
- Wave reflects same direction

The pattern: L = ½nλ where n = 1, 2, 3, . . .

CLOSED TUBES



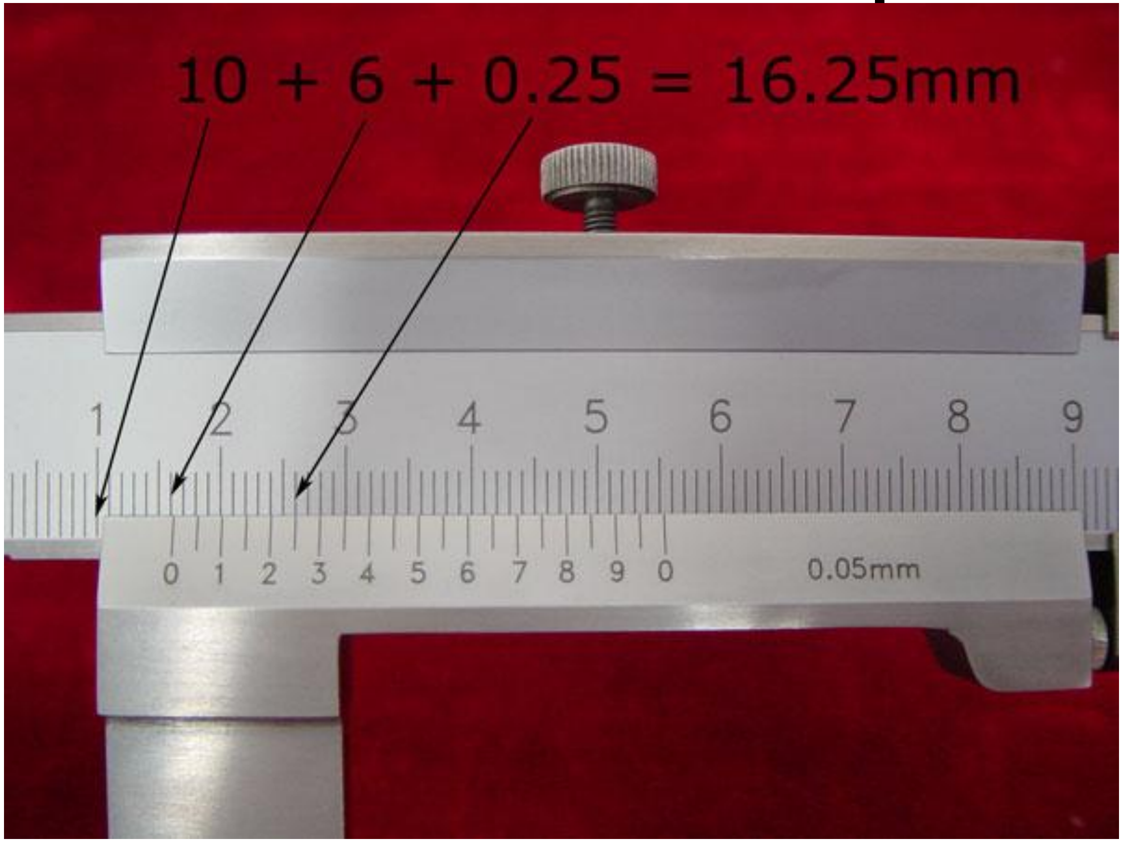
= ¼ wave

= ¾ wave

= 5/4 wave

The pattern: L = ¼nλ where n = 1, 3, 5, . . .

How to read Caliper?

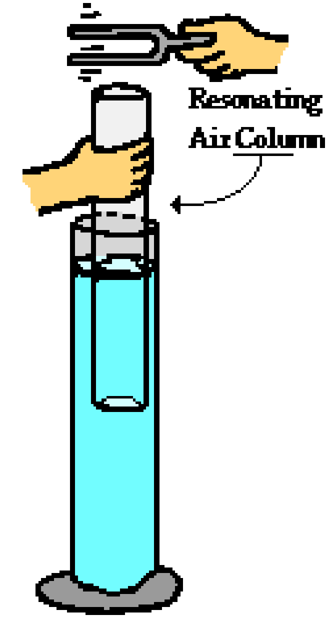


1.Find the centimeter & millimeter mark on the fixed scale that is just to the left of the 0 mark on the vernier scale. (1.6mm or 16mm on the fixed caliper)

2. Look along the ten marks on the vernier scale and the millimeter marks on the fixed scale above, until you find the two lines that align the best. (0.25mm on the vernier scale)

3.Write the entire reading as one measurement (ex. 1.625 cm or 16.25 mm) & convert into meters!!! **(0.01625 m)**

SOS LAB



Tuning fork forcing air coumn into resonance

Determine the speed of sound in air using resonance.

Resonance occurs when **L = ¼λ** (1st harmonic)

Trial	f(Hz)	L(m)	d(m)	T(°C)	λ(m)	SOS (m/s) Calc	SOS (m/s) Actual
1							
2							
3							
						Avg.	

Calculations:

$\lambda = 4L + 1.6d$

$v_{calc} = \lambda f$

$v_{actual} = 331.4 + (0.6)(°C)$

Error between SOS calculated avg and actual

Example Problem: Echo

In the SOS lab we found that the speed of sound in air is about 340 m/s. If an echo returns in 4 seconds, how wide is the canyon?

d = vt = (340m/s)(2sec) = **680 m/s** (Only 2 sec to go across once)

Example Problem: Thinking Problem

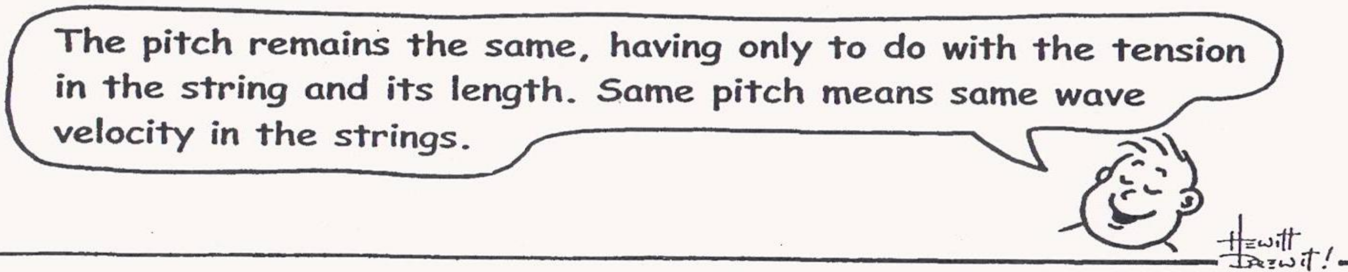
FIGURING PHYSICS

When playing a violin, the effect produced when the bow is drawn faster across the strings is

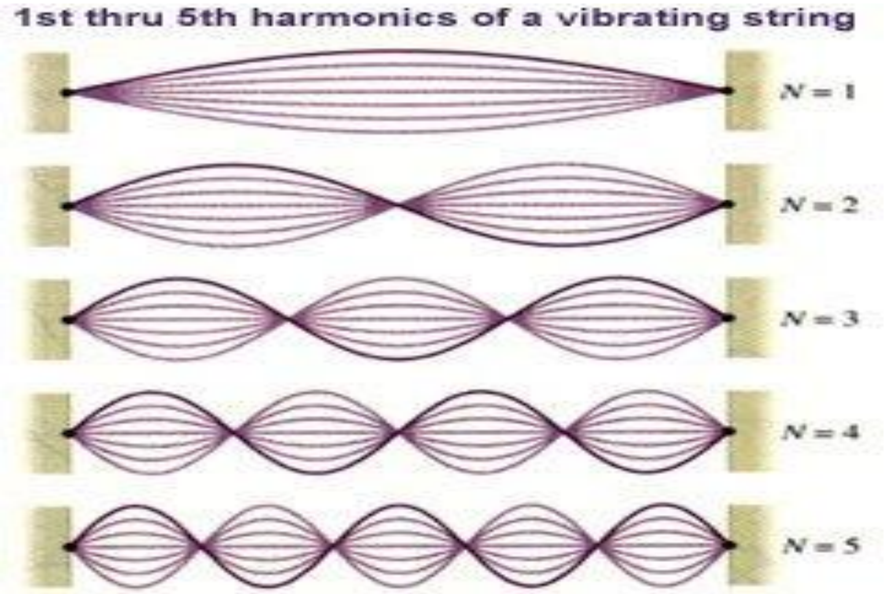
a) a higher pitch.
b) greater wave velocity in the strings.
c) a louder sound.
d) all of these.
e) none of these ... no discernable effect.

ANSWER: c, a louder sound.

Rosin on the bow ensures enough friction between the string and bow to tug the string sideways, where it snaps back to produce the vibration needed for sound. A faster-moving bow tugs the string farther, increasing the amplitude. This produces a louder sound.



STRING INSTRUMENTS



$L = \frac{1}{2} n\lambda$ where n = 1, 2, 3, . . .

All harmonics (½ wave increments) are present!

Amplitude (n^{th} harm.) = (1/n) x amplitude (1^{st} harm.)

Each string has one unique wave speed = $\sqrt{\text{Tension/mass}}$

Remember: wave speed $v = \lambda f$

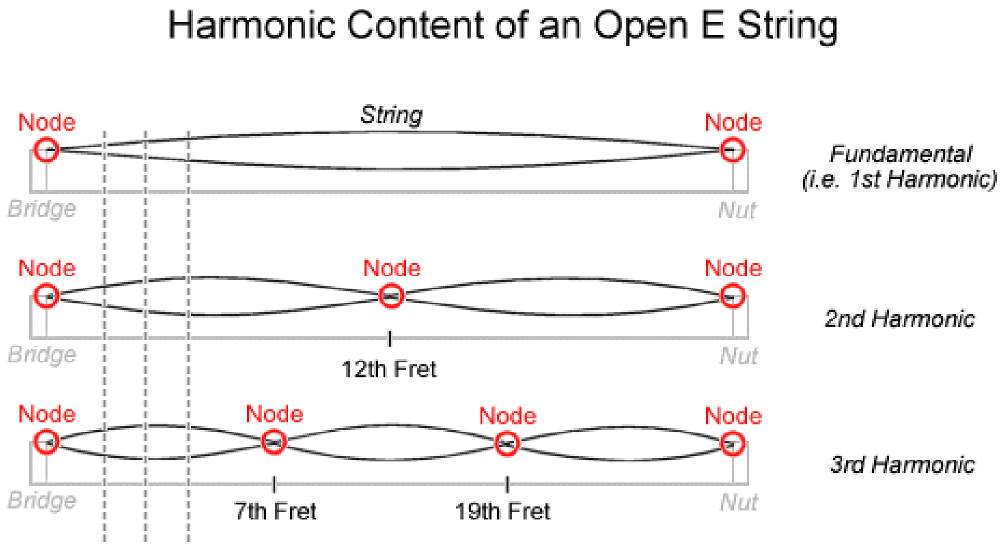
What do you see and hear?

1^{st} harmonic

SAMPLE STRING PROBLEM

Guitar, 6 strings: E-A-D-G-B-E

80 Hz **320 Hz**



High E: f = 320 Hz; L =72.5 cm

$L = \frac{1}{2} n\lambda$ where n = 1, 2, 3, . . .

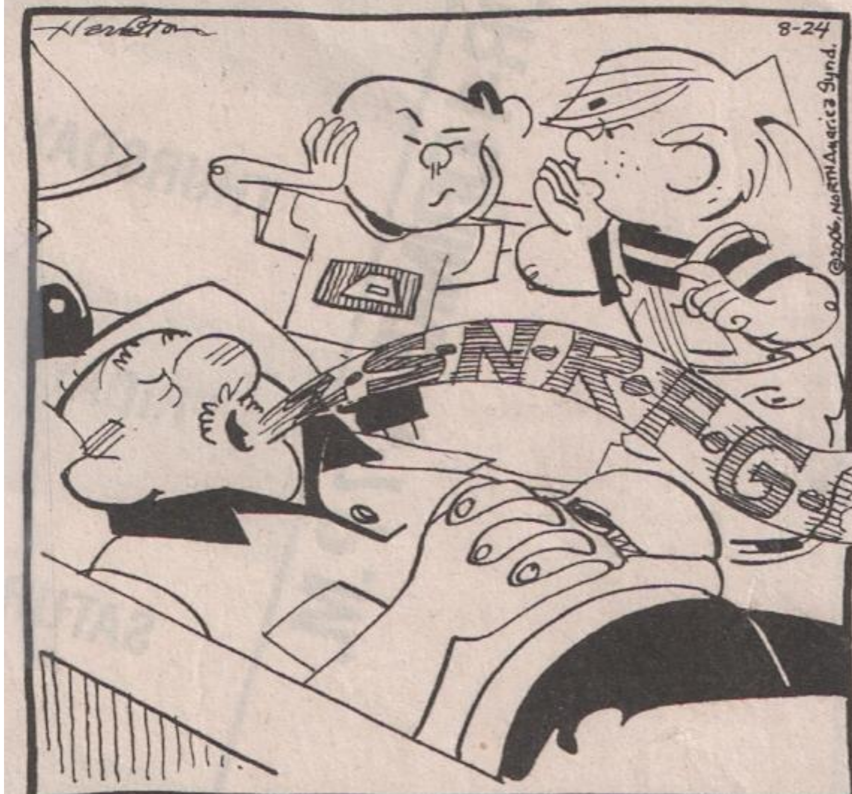
Calculate Hi E $v = \lambda f = 2Lf$ = 2 (320cycle/sec)(0.725m) = 464 m/s

$\lambda_1 = 2L = 145$ cm
$\lambda_2 = L = 72.5$ cm
$\lambda_3 = \frac{2}{3}L = 48.3$ cm

Low E string v = ¼ x high E string vel. = ¼(464m/s) = 116 m/s

Students Demo String instruments

Dennis the Menace



"MRS. WILSON WAS RIGHT WHEN SHE SAID MR. WILSON WAS A *SOUND* SLEEPER."

"FIRST WE RE-ESTABLISH COMMUNICATION, THEN WE BRING DOWN THE DECIBELS."

MUSIC TERMS

- **Fundamental: lowest frequency in an instrument**
- **Harmonics: overtones above the fundamental**
- **Pitch: musical term for frequency**
- **Octave: doubling of frequency**
- **Timbre: rich sound from many harmonics**
- **Beats: interference of 2 close frequencies**
- **Decibel (dB): dB = 10 log (I/I_0)**

  dB doubles for 10-fold increase in sound energy
- **Resonance: amplification of a standing wave**
- **String harmonics: ½ waves**
- **Wind harmonics: open (½ waves), closed (¼ waves)**

A SIMPLE MUSICAL SCALE

C = 256 Hz

5:4 (major 3rd)

E = 320 Hz

6:5 (minor 3rd)

G = 384 Hz

3:2 (perfect 5th)

C = 256 Hz

4:3 (perfect 4th)

F = 341 Hz

5:4 (major 3rd)

A = 427 Hz

5:3 (6th)

D = 288 Hz

5:3 (6th)

B = 480 Hz

C = 256 Hz

6:5 (2nd)

D = 288 Hz

C (256 Hz) to C (512 Hz) = 2:1 (octave)

► This is a simple "just intonation" scale tuned to middle C. There are <u>many</u> complicated variations on this. Most tuning of pianos and orchestras is done to the key of A (440 Hz).

► Pythagoras developed the first musical scale based on mathematical intervals and harmonics around 500 BC (as far as we know!)

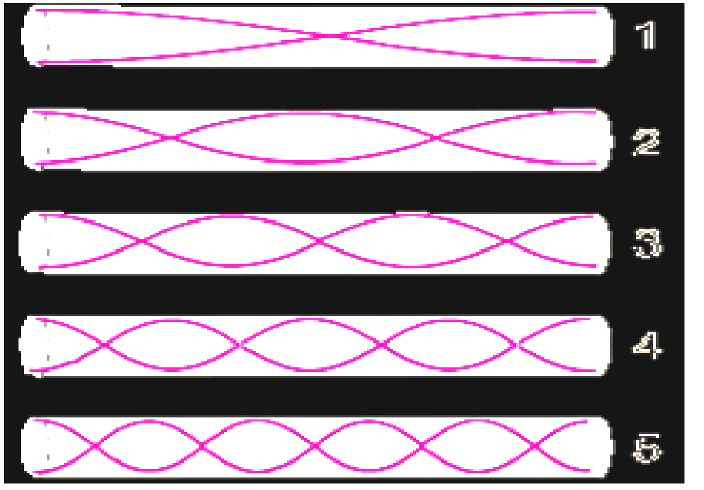
BC

Classic Peanuts

OPEN TUBES

Most wind instruments: $L = \frac{1}{2}n\lambda$ where n = 1, 2, 3, . . .

Each end of instrument is open (anti-node)



Sample problem: Bugle, L = 1.325 m

Calculate lowest possible frequency it can play:

$v = \lambda_1 f_1$ = 340 m/s (SOS in air)

So $f_1 = v/\lambda_1 = v/2L$ = (340m/s)/(2x 1.325m) = 128.3 Hz

This is the lowest possible note for the bugle!

All wind instruments have same speed (SOS)!!

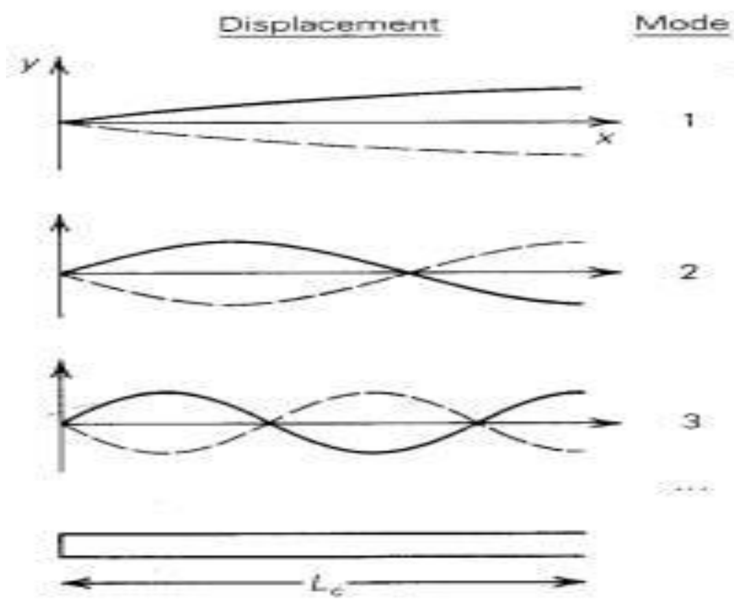
CLOSED TUBES

Organ, clarinet, ear, SOS lab:

$L = \frac{1}{4}n\lambda$ where n = 1, 3, 5, . . .

One end is open (anti-node), other end closed (node)

[Oboe, saxophone, bassoon are closed at reed end but behave as open tubes because of conical shape!]



Sample problem: **Organ pipe, L = 8.3 cm**

Calculate frequency it plays:

$v = \lambda_1 f_1$ = 340 m/s (SOS in air)

So $f_1 = v/\lambda_1 = v/4L$ = (340m/s)/(4 x 0.083m) = 1,024 Hz

Doppler Effect

Discovered by **Christian Doppler, Austrian physicist (1803-1853)**

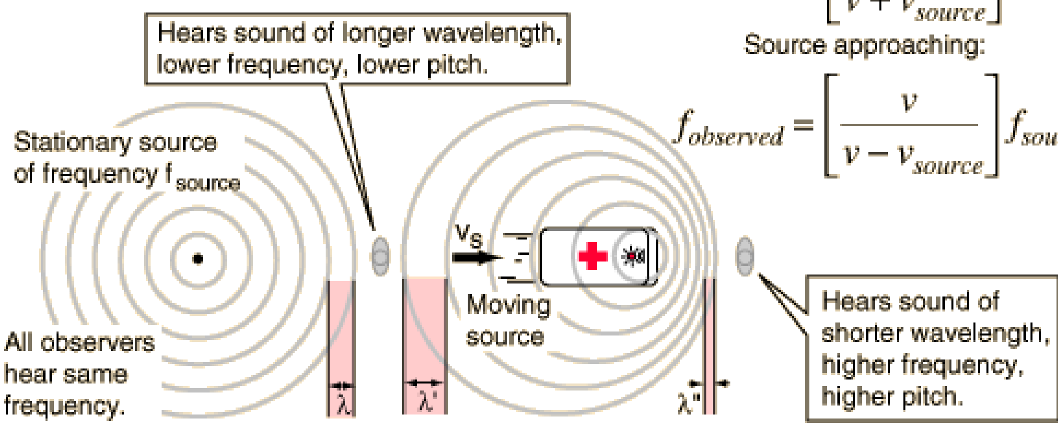
When object making noise passes you, a noticeable drop in the pitch of the sound will be observed as the source passes. An approaching source moves closer during period of the sound wave so the effective wavelength is shortened, giving a higher pitch since the velocity of the wave is unchanged. Similarly the pitch of a receding sound source will be lowered.

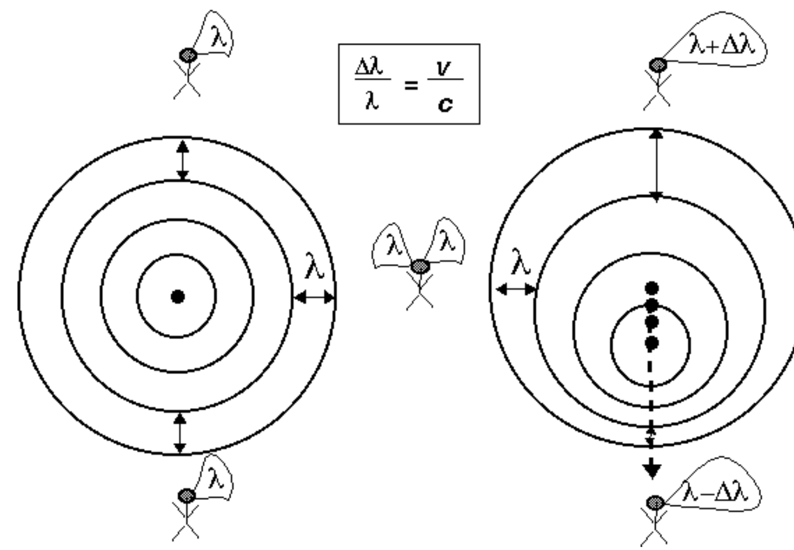
Source receding:

$$f_{observed} = \left[\frac{v}{v + v_{source}}\right] f_{source}$$

Source approaching:

$$f_{observed} = \left[\frac{v}{v - v_{source}}\right] f_{source}$$





DOPPLER USES

♣ RADAR
- Δ Military/ air control
- Δ Police
- Δ Baseball
- Δ Weather

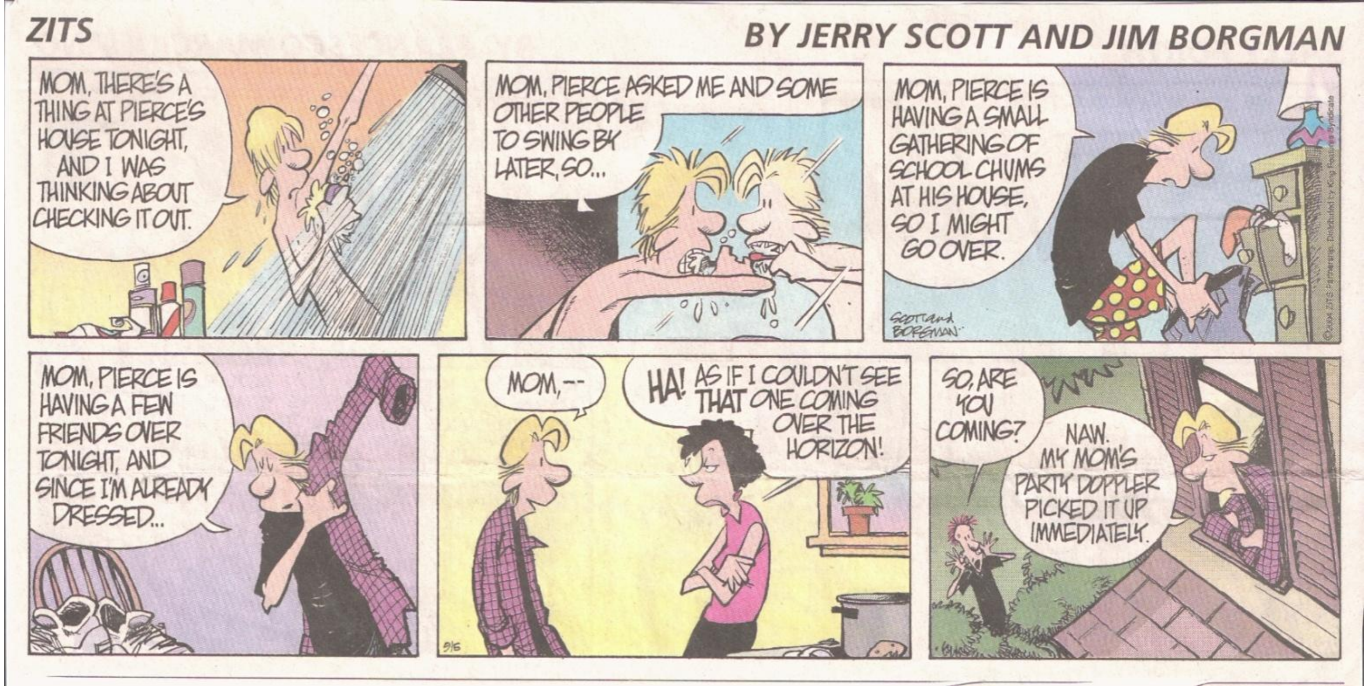
♠ Relativity

♦ Bats

♥ Medical ultrasound

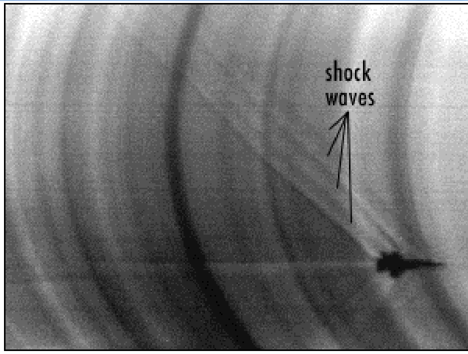
♦ Astronomy: detecting expansion of universe

♠ SONAR = SOund NAvigation and Ranging



Shock wave: produced when object travels faster than waves

Mach # : ratio of aircraft speed to SOS in air



Chuck Yeager 1st to break sound barrier, war hero: ACE in 1 day shot down 5 enemy planes

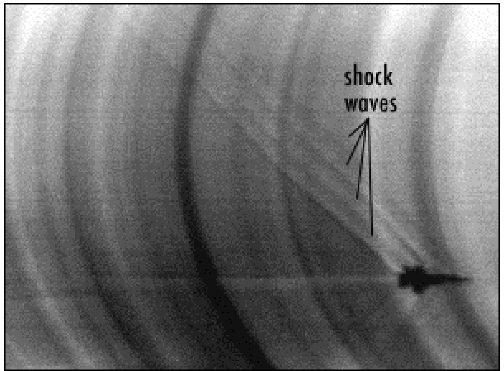
Concord Plane: taken out of commision too $$$ for citizens

SR-71 Blackbird = fastest plane in world

Standing still

Mach 0.7

Mach 1



Mach 1.4 supersonic

Videos: Doppler & Sonic Boom

Doppler Effect & SHOCK WAVE

Animation

https://gaggle.net/gaggleVideoProxy.do?op=view&v=e060b1c69b5f7d5cd882649a2d19d6ce4b90dad6cd8cf266

SHOCK WAVE

Mythbusters metal fusion

https://gaggle.net/gaggleVideoProxy.do?op=view&v=becb95dfc73eeae7d18a1e82eb7b1322b125351b27a3918b

Sonic boom-Crazy up close (00:00:21)

https://gaggle.net/gaggleVideoProxy.do?op=view&v=1ee600f4c9323832035163bae83a60d0

- Fighter Jet 619 (00:00:14)

https://gaggle.net/gaggleVideoProxy.do?op=view&v=9186a2e49f5e967cd12f4a9eabc37b88

Sonic Booms (00:1:01)

https://gaggle.net/gaggleVideoProxy.do?op=view&v=dff5483578544ca3e875c2a725375ead

Sonic Boom Jets Amazing (00:1:46)

https://gaggle.net/gaggleVideoProxy.do?op=view&v=e69e0ac3f383ccc4c4f7b29498b25b858b962d8316484412

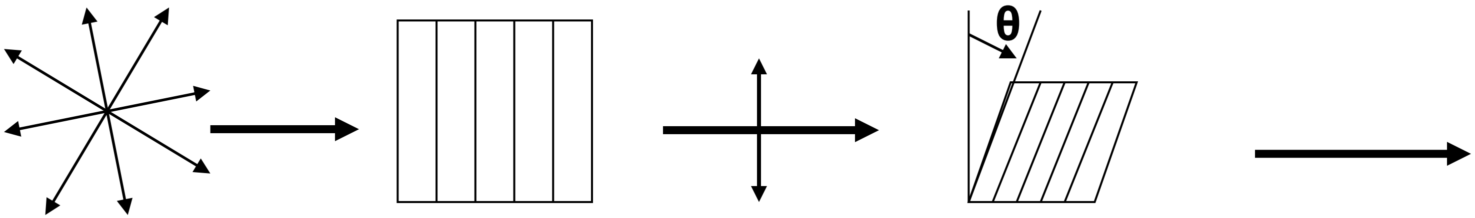
How to make supersonic shock wave (00:2:23)

https://gaggle.net/gaggleVideoProxy.do?op=view&v=9dfc664313386f55ddcde67d92fa8125

4 WAYS TO POLARIZE LIGHT

1. SELECTIVE ABSORPTION

Polaroid filters invented by Edwin Land to reduce glare for pilots

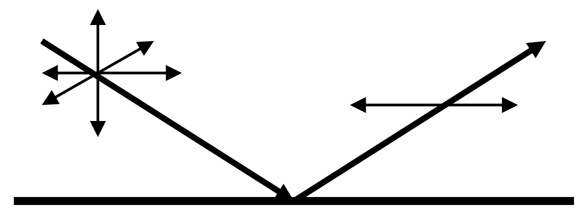


I_0 Polarizer $I_1 = .5I_0$ Analyzer $I_2 = I_1 \cos^2 \theta$

Law of Malus (1809)

Film stretch so molecules align & only let light oscillating in one direction through. 2 filters $\perp$ to each other blocks all light

2. SCATTERING: blue skies



3. REFLECTION: Ex. glare

oscillates one direction after reflection

4. DOUBLE REFRACTION (Birefringence): light goes in unpolarized follows, 2 different paths through a crystal by wave bending & comes out polarized creating double image

unpolarized **polarized**

POLARIZATION USES

← Sunglasses
↑ LCD's (calculator, watch, etc)
→ Antennas/satellite dishes
↓ Astronomy: cosmic dust, Saturn's rings, makeup of stars/planets
↔ X-ray crystallography: mineral ID
↕ Stress analysis: manufacturing
← Animation
↑ Medicine: virus ID
→ Structure of atoms/nuclei
↓ Animal navigation
↔ Photography filters

Beetle Bailey

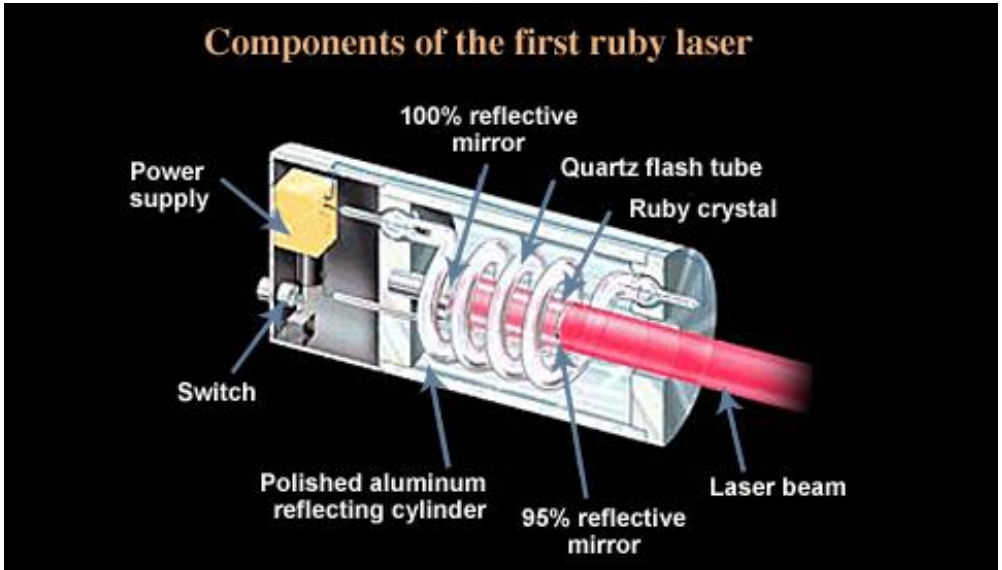
LASER

Light **A**mplification by **S**timulated **E**mission of **R**adiation

Theorized: Albert Einstein, 1916

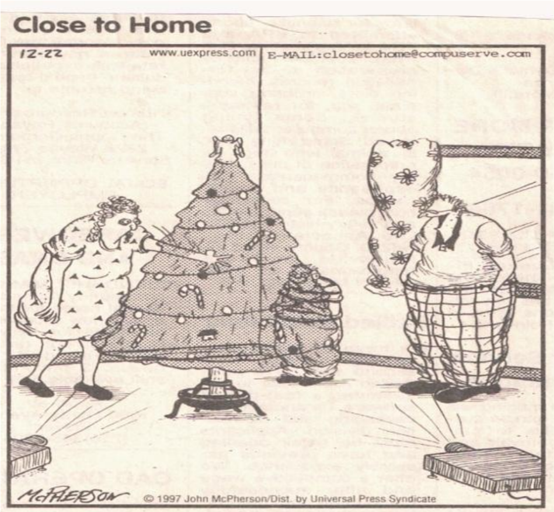
Invented: MASER, 1953, Townes-Basov-Prokhorov (Nobel, 1964)
LASER, 1958-60, Townes-Schawlow (Nobel, 1981)

Characteristics:
- ► Bright/intense
- ► Narrow/directional
- ► Monochromatic (single color/λ)
- ► Coherent – waves in phase

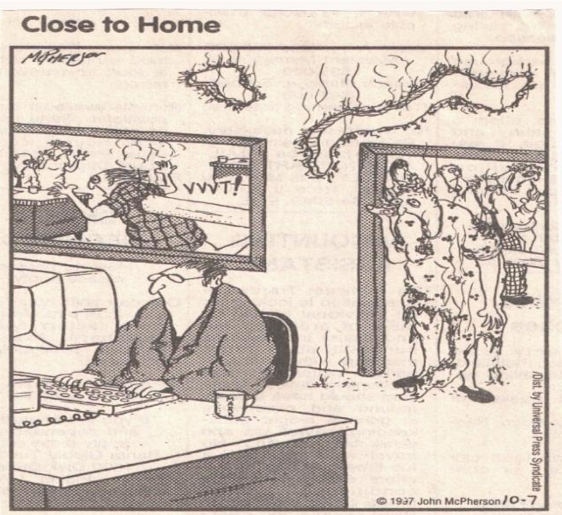


LASER USES

- ☼ Research: time measurement, spectroscopy
- ☼ Medicine/dentistry: surgery & diagnostics
- ☼ Material working/cutting
- ☼ Optical communications: fiber optics
- ☼ Measuring/inspecting: laser guns, surveying, construction, machinery alignment
- ☼ Thermonuclear fusion
- ☼ Information processing: CD's, DVD's, checkout scanner, computer memory
- ☼ Military: rangefinders, target designation, weapons
- ☼ Holography



"See, you thought it was real! I tell ya, hologram Christmas trees are the way to go!"



"Mr. Hopkins! We're having a bit of trouble with the new laser printer."

HOLOGRAPHY: 3D image on special film

Greek for "complete writing"

Invented: 1947, Dennis Gabor (Nobel prize, 1971)

What's needed: Coherent light source (laser)
Stability (no light or vibrations)
Special holographic film