Physics Unit 7
• This Slideshow was developed to accompany the textbook
  • *OpenStax Physics*
    • Available for free at [https://openstaxcollege.org/textbooks/college-physics](https://openstaxcollege.org/textbooks/college-physics)
  • *By OpenStax College and Rice University*
  • *2013 edition*
• Some examples and diagrams are taken from the textbook.

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Waves
• A traveling disturbance
• Carries energy from place to place

• When a boat makes a wave,
  • the water itself does not get up and move
  • the water pushes a little, then moves back
  • energy is transferred in the wave and is what you feel

If the water moved in bulk, then there would be a hole in the water.
Demonstrate with a slinky

Transverse
- Up and down disturbance
- Wave travels left or right
- Disturbance is perpendicular to direction of travel

Examples:
- Radio waves, light waves, microwaves, stringed instruments
Demonstrate with a slinky
07-01 WAVES

• Other
  • Water waves are a combination
  • Water at the surface of a water wave travels in small circles
Put drawing on board and label the parts

The amplitude of a longitudinal wave is the amount of compression instead of a height
07-01 WAVES

• Period (T) → time it takes for one cycle
  • Unit: s
  • Frequency (f) → # of cycles per second
  • Unit: 1/s = 1 hertz (Hz)
  
  \[ f = \frac{1}{T} \]

  \[ v = \frac{\lambda}{T} = f \cdot \lambda \]
WAUS operates at a frequency of 90.7 MHz. These waves travel at $2.99 \times 10^8$ m/s. What is the wavelength and period of these radio waves?

- $\lambda = 3.30$ m
- $T = 1.10 \times 10^{-8}$ s

\[
\begin{align*}
\nu &= f\lambda \\
2.99 \times 10^8 \text{ m/s} &= 90.7 \times 10^6 \text{ Hz} \lambda \\
\lambda &= 3.30 \text{ m}
\end{align*}
\]

\[
\begin{align*}
f &= \frac{1}{T} \Rightarrow 90.7 \times 10^6 \text{ Hz} = \frac{1}{T} \Rightarrow T = \frac{1}{90.7 \times 10^6 \text{ Hz}} = 1.10 \times 10^{-8} \text{ s}
\end{align*}
\]
You are sitting on the beach and notice that a seagull floating on the water moves up and down 15 times in 1 minute. What is the frequency of the water waves?

- $f = 0.25$ Hz

Frequency is $\frac{\text{cycles}}{\text{seconds}}$

$$f = \frac{15}{60 \text{ s}} = 0.25 \text{ Hz}$$
07-01 HOMEWORK

• Wave hello to some exercises.

• Read 16.1, 16.3
07-02 LAB

• Do the 07-02 Simple Harmonic Motion Lab
• A mass is hung from a spring
• If it just hangs, it is at equilibrium position
• If stretched and released, it bounced up and down
07-02 HOOKE’S LAW AND SIMPLE HARMONIC MOTION

- Hooke’s Law
  \[ F = -kx \]
  - F = restoring force
  - x = distance displaced
  - k = spring constant

- Force will pull the mass back toward equilibrium
- As mass gets to equilibrium, it has momentum, so it continues past
Energy in Hooke’s Law

- Since a force acts over a distance, work is done

\[ PE_{el} = \frac{1}{2} kx^2 \]

Called elastic potential energy
A Nerf dart gun uses a spring to launch a dart. If it takes 24 N of force to compress the spring 6 cm, what is the spring constant? How much potential energy does it contain?

\[ F = -kx \]
\[ 24 \, N = -k(-0.06 \, m) \]
\[ k = 400 \frac{N}{m} \]

\[ PE_{el} = \frac{1}{2}kx^2 \]
\[ PE_{el} = \frac{1}{2} \left( 400 \frac{N}{m} \right) (0.06 \, m)^2 \]
\[ PE_{el} = 0.72 \, J \]
07-02 Hooke’s Law and Simple Harmonic Motion

- On a string, if one part of the string is pulled up (a wave pulse created),
  - Then the next piece of the string is pulled up
  - Then the next piece of the string is pulled up, etc.
- After the pulse passed the string moves back down to the equilibrium position due to Hooke’s Law
- The more force, the quicker the string accelerates back and the faster the wave travels.
Speed of a Wave on a String

• Speed of a wave depends on the medium
• For a string, the speed depends on
  • Tension
  • Linear density (m/L)

\[ v = \sqrt{\frac{F}{m/L}} \]
• Simple harmonic motion
  • Motion that regularly repeats
  • Frequency independent of amplitude

\[ T = 2\pi \sqrt{\frac{m}{k}} \]

\[ f = \frac{1}{2\pi} \sqrt{\frac{k}{m}} \]

• If a graph of position versus time of simple harmonic motion is made, a wave is formed
- Think of a point on a string some distance \( x \) from the origin
- We want to know the vertical displacement \( y \) of the particle at any given time

- If the wave repeats, then it will look like a sine (or cosine) graph

\[
y = A \cos \left( \frac{2\pi t}{T} \right)
\]

20
A wave has an amplitude of 1.5 cm, a speed of 20 m/s, and a frequency of 100 Hz. Write the equation of the wave position of the wave.

\[ y = 0.015 \cos(200\pi t) \]

\[
y = A \cos \left( \frac{2\pi t}{T} \right)
\]

\[
A = 0.015 \text{ m}
\]

\[
f = 100 \text{ Hz} \rightarrow T = \frac{1}{100 \text{ Hz}} = 0.01 \text{ s}
\]

\[
y = 0.015 \cos \left( \frac{2\pi t}{0.01 \text{ s}} \right)
\]

\[
y = 0.015 \cos(200\pi t)
\]
07-02 HOMEWORK

• These problems harmonize with the lesson

• Read 17.1, 17.2
07-03 LAB

• Do the 07-03 Properties of Sound Lab
How sound is made

- Some vibrating object like a speaker moves and compresses the air
- Air pressure rises called **Condensation**
- Condensation moves away at speed of sound
- Object moves back creating less air pressure called **Rarefaction**
- Rarefaction moves away at speed of sound
- Particles move back and forth

Maybe have big speaker with bouncing something on it
Distance between consecutive condensations or rarefactions is wavelength.

String or speaker makes air molecule vibrate.

That molecule pushes the next one to vibrate and so on.

When it hits the ear, the vibrations are interpreted as sound.
• 1 cycle = 1 condensation + 1 rarefaction
• Frequency = cycles / second
• 1000 Hz = 1000 cycles / second

• Each frequency has own tone
  • Sounds with 1 frequency called *Pure Tone*

• Healthy young people can hear frequencies of 20 to 20,000 Hz
Brain can interpret frequency as pitch
  • High freq = high pitch
  • Subjective because most people don’t have perfect pitch

Some electronic devices can produce and detect exact frequencies
Loudness is subjective, pressure is not. Measure pressure to see if damaging.
For all waves

\[ v_w = f \lambda \]

- Sound travels slowest in gases, faster in liquids, and fastest in solids
- Air at 20 °C → 343 m/s
- Fresh Water → 1482 m/s
- Steel → 5960 m/s
• Speed of sound depends on properties of medium

• In gases
  • Sound is transmitted only when molecules collide
  • So we derive formula from speed of molecules
    • And speed changes with temperature
For air

\[ \nu_w = \left(331 \frac{m}{s}\right) \sqrt{\frac{T}{273 \, K}} \]

where \( T \) is in Kelvin
What wavelength corresponds to a frequency of concert A which is 440 Hz if the air is 25 °C?

\[ \lambda = 0.786 \text{ m} \]
Sonar (Sound Navigation Ranging)

Sound is emitted from the hull of a ship.

It bounces off some object.

The echo returns to a receiver on the hull of the ship.

How far away is a ship if it takes 3.4 s to receive a return signal in seawater?

\[ d = 2618 \text{ m} \]

\[ v = 1540 \text{ m/s} \]

\[ x = vt \rightarrow x = \left(1540 \frac{m}{s}\right)(3.4 \text{ s}) \rightarrow x = 5236 \text{ m} \]

This the distance to the object and back again. So divide it by 2 \( \rightarrow x = 2618 \text{ m} \)
07-03 HOMEWORK

- These problems sound like you could speed right through them.

- Read 17.3
07-04 LAB

• Do the 07-04 Intensity vs Distance Lab
07-04 Sound Intensity and Sound Level

- Sound waves carry energy that can do work
- Amount of energy transported per second = power
- Units: J/s = W

Work example causing ear drum to vibrate
07-04 SOUND INTENSITY AND SOUND LEVEL

- As sound moves away from a source, it spreads out over a larger and larger area.
- As the areas get bigger, intensity at any 1 point is less.
- \[ I = \frac{P}{A} \]
- Units: W/m²
Notice that Intensity $\propto \frac{1}{r^2}$
As distance doubles, the intensity is divided by four
07-04 SOUND INTENSITY AND SOUND LEVEL

• Intensity is proportional to amplitude^2

\[ I = \frac{(\Delta p)^2}{2 \rho v_w} \]

• where
  • \( \Delta p \) = pressure amplitude
  • \( \rho \) = density of the medium
  • \( v_w \) = speed of the wave

Used lowercase p for Pressure to keep from confusing with Power
You and a friend are watching fireworks that are launching from the observatory. You are standing right in front of University Towers (150 m) and your friend is across campus at AA (700 m). The sound intensity at AA is 0.2 W/m². What is the sound intensity at your location, and how much power is the firework emitting?

- P = 1.23 × 10⁶ W
- I = 4.36 W/m²

\[ I = \frac{P}{A} \]

\[ 0.2 \frac{W}{m^2} = \frac{P}{4\pi(700 \text{ m})^2} \rightarrow P = 1.231504 \times 10^6 \text{ W} \]

\[ I = \frac{P}{A} \]

\[ I = \frac{1.23 \times 10^7 \text{ W}}{4\pi(150 \text{ m})^2} = 4.36 \text{ W/m}^2 \]

Sitting out by berman hall during the fireworks at the beginning of the school year. Some
07-04 SOUND INTENSITY AND SOUND LEVEL

Sound Level and Decibels
• Unit of measure to compare two sound intensities.

• Based on how human ear perceives loudness.

• If you double the intensity, I, the sound isn’t twice as loud.
• Use a logarithmic scale
I₀ is the threshold of hearing
07-04 SOUND INTENSITY AND SOUND LEVEL

• Intensity can be measured
• Loudness is simply how ear perceives
• Doubling intensity does not double loudness
• You double the intensity of sound coming from a stereo. What is the change in loudness?
• $\beta = 3 \, \text{dB}$

• Experiment shows that if the intensity level increases by 10 dB, the sound will seem twice as loud.
• See Table 17.2

$$\beta = (10 \, dB) \log \left( \frac{I}{I_0} \right)$$
$$\beta = (10 \, dB) \log \left( \frac{2I}{I} \right)$$
$$\beta = (10 \, dB) \log 2$$
$$\beta \approx 3 \, \text{dB}$$

Thus a 200 W stereo system will only sound twice as loud as a 20 W system.
07-04 SOUND INTENSITY AND SOUND LEVEL

• What is the intensity of a 20 dB sound?

• \( I = 10^{-10} \text{ W/m}^2 \)

\[
\begin{align*}
\beta &= (10 \text{ dB}) \log \left( \frac{I}{I_0} \right) \\
20 \text{ db} &= (10 \text{ dB}) \log \left( \frac{I}{10^{-12} \text{ W/m}^2} \right) \\
2 &= \log \left( \frac{I}{10^{-12} \text{ W/m}^2} \right) \\
10^2 &= \frac{I}{10^{-12} \text{ W/m}^2} \\
I &= 10^{-10} \text{ W/m}^2
\end{align*}
\]
07-04 HOMEWORK

• This is intense!

• Read 17.4
07-05 LAB

- Do the 07-05 Doppler Effect Lab
07-05 DOPPLER EFFECT

• Have you ever listened to a ambulance drive by quickly with their lights and sirens going?

• What did it sound like?

• High pitch as they were coming, low pitch as they were leaving.

• Called Doppler effect after Christian Doppler who first labeled it.
When the truck is still, the sound waves move outward in all the directions, the same speed.
When the truck is moving.
It produces a condensation, moves, produces another condensation, moves, etc.
Since it moves between condensations, they are closer together in front of the truck and farther apart behind the truck.
Higher freq (short \( \lambda \)) = higher pitch
Lower freq (long \( \lambda \)) = lower pitch
The perceived wavelength is shortened by the distance the source moves in one period. 
(Period is time between condensations)
07-05 DOPPLER EFFECT

- \( f_o = \frac{v_w}{\lambda'} = \frac{v_w}{\lambda - v_s T} \)
- \( \lambda = \frac{v_w}{f_s} \)
- \( f_o = f_s \left( \frac{v_w}{v_w - v_s} \right) \)

- \( \lambda' = \) perceived wavelength
- \( f_o = \) frequency observed
- \( f_s = \) frequency of source
- \( v_w = \) speed of wave
- \( v_s = \) speed of source
Notice the differences between the two formulas
07-05 DOPPLER EFFECT

- General Case
- Combine the two formulas
- Both observer and source can be moving

\[ f_o = f_s \left( \frac{v_w \pm v_o}{v_w \mp v_s} \right) \]

- WARNING!
  - \( v_w, v_o \), and \( v_s \) are signless
  - Use the top signs when that object is moving towards the other object
07-05 DOPPLER EFFECT

- You are driving down the road at 20 m/s when you approach a car going the other direction at 15 m/s with their radio playing loudly. If you hear a certain note at 600 Hz, what is the original frequency? (Assume speed of sound is 343 m/s)

\[
 f_o = f_s \left( \frac{v_w \pm v_o}{v_w \mp v_s} \right)
\]

\[
 600 \text{ Hz} = f_s \left( \frac{343 \frac{m}{s} + 20 \frac{m}{s}}{343 \frac{m}{s} - 15 \frac{m}{s}} \right)
\]

\[
 600 \text{ Hz} = f_s(1.1)
\]

\[
 f_s = 542 \text{ Hz}
\]
07-05 DOPPLER EFFECT

- A duck is flying overhead while you stand still. As it moves away, you hear its quack at 190 Hz. Because you are a brilliant naturalist, you know that this type of duck quacks at 200 Hz. How fast is the duck flying?

\[
f_o = f_s \left( \frac{v_w \pm v_o}{v_w \mp v_o} \right)
\]

\[
190 \text{ Hz} = 200 \text{ Hz} \left( \frac{343 \frac{m}{s} + 0}{343 \frac{m}{s} + v_s} \right)
\]

\[
65170 \frac{m}{s} + 190 v_s = 68600 \frac{m}{s}
\]

\[
190 v_s = 3430 \frac{m}{s}
\]

\[
v_s = 18.1 \frac{m}{s}
\]
Water on one side of tornado move away, water on other side move towards radar
07-05 HOMEWORK

• Move yourselves to do these exercises

• Read 16.10
07-06 LAB

- Do the 07-06 Superposition Lab
07-06 SUPERPOSITION AND INTERFERENCE

- Often two or more wave pulses move through the same space at once

- When two or more waves are present simultaneously at the same place, the resultant disturbance is the sum of the disturbances from individual waves
Try to demonstrate with spring or wave tank
Draw the result on the pull down graph

- After 2 seconds, what is the height of the resultant pulse at x = 2, 4, and 6 cm?
  - 0, -2, 2
At a point between the speakers where each of the sounds have moved full wavelengths
• Condensation meets condensation and rarefaction meets rarefaction all the time
• Linear superposition says the sound is twice as loud
• Called constructive interference (exactly in phase)
Now a condensation always meets a rarefaction, so cancel into nothing
Called Destructive interference (exactly out of phase)
Sound Wave Interference
A microphone hears the noise
The electronics invert the noise
A speaker plays the inverted noise and destructive interference results so you don’t hear much
Solid lines are condensations, dashed lines are rarefactions

2 fixed speakers

where two condensations or rarefactions meet = constructive interference (red dots)
Where a condensation and rarefaction meet = destructive interference (white dots)

So as you move throughout the room the noise intensities change depending on your position

Follows law of conservation of energy

- At constructive interference $\rightarrow$ twice as much energy
- At destructive interference $\rightarrow$ no energy
- Add it all up and you get constant energy ($1 + 1 = 2 + 0$)
07-06 SUPERPOSITION AND INTERFERECE

- Beats
  - When two frequencies are the same

- Constructive and Destructive Interference give twice the amplitude or no amplitude

- What if the two frequencies are just slightly different?
When the frequencies are slightly different, Constructive and destructive interference still happens
Where two condensations are at the same place, you get louder
Where 1 condensation and 1 rarefaction are at the same place, you get softer
You get some places with loud and some soft and in between
What the ear hears is the rising and falling of volume of the combined frequency. How often the loudness rises and falls is the **beat frequency**. Beat frequency obtained from subtracting the two frequencies of the sounds. In the picture, the number above each blue wave indicates the number of complete cycles.

The top wave is 10 Hz, the bottom is 12 Hz. The beat frequency is $12 - 10 = 2$ Hz as seen in the red wave.
07-06 SUPERPOSITION AND INTERFERENCE

• Beat Frequency = difference of the two source frequencies

• Beats = \(|f_1 - f_2|\)
07-06 SUPERPOSITION AND INTERFERENCE

• A simple way to tune musical instruments is with beats
• If the notes are out of tune, you hear beats
• Adjust the tuning and try again
• If the frequency of the beats is higher, adjust the other way
• Keep adjusting until there are no more beats
Two car horns have an average frequency of 420 Hz and a beat frequency of 40 Hz. What are the frequencies of both horns?

\[
f_{\text{ave}} = \frac{f_1 + f_2}{2}
\]
\[
f_B = f_1 - f_2
\]

\[
420 \, \text{Hz} = \frac{f_1 + f_2}{2}
\]
\[
40 \, \text{Hz} = f_1 - f_2
\]

\[
840 \, \text{Hz} = f_1 + f_2
\]
\[
40 \, \text{Hz} = f_1 - f_2
\]
\[
880 \, \text{Hz} = 2f_1
\]
\[
f_1 = 440 \, \text{Hz}
\]
\[
f_2 = 400 \, \text{Hz}
\]
07-06 HOMEWORK

• Don’t beat around the bush, start the problems now!

• Read 17.5
• One end of a string is attached to a fixed point.
• The other end is vibrated up and down.
• The standing wave is formed.
• Nodes – No move
• Antinodes – most movement
The wave travels along the string until it hits the other end.
The wave reflects off the other end and travels in the opposite direction, but upside down.
The returning wave hits the vibrating end and reflects again (this side the wave is right side up).
Unless the timing is just right the reflecting wave and the new wave will not coincide.
When they do coincide, the waves add due to constructive interference.
When they don’t coincide; destructive interference.

Why its reflected upside down. → the string pulls up on the wall, by Newton’s reaction force, the wall pulls down on the string.
07-07 SOUND INTERFERENCE AND RESONANCE

• Harmonics
  • When you vibrate the string faster, you can get standing waves with more nodes and antinodes
  • Standing waves are named by number of antinodes
    • 1 antinode → 1\textsuperscript{st} harmonic (fundamental freq)
    • 2 antinodes → 2\textsuperscript{nd} harmonic (1\textsuperscript{st} overtone)
    • 3 antinodes → 3\textsuperscript{rd} harmonic (2\textsuperscript{nd} overtone)
Multiply the fundamental frequency by an integer to obtain that integer’s harmonic.

- $f_1 =$ fundamental frequency ($1^{\text{st}}$ harmonic)
- $f_2 = 2f_1$ ($2^{\text{nd}}$ harmonic)
- $f_3 = 3f_1$ ($3^{\text{rd}}$ harmonic)

Harmonics Example
- If the fundamental is 440 Hz (concert A)
- $2^{\text{nd}}$ harmonic $= 2(440 \text{ Hz}) = 880 \text{ Hz (High A)}$
- $3^{\text{rd}}$ harmonic $= 3(440 \text{ Hz}) = 1320 \text{ Hz}$
07-07 SOUND INTERFERENCE AND RESONANCE

• To find the fundamental frequencies and harmonics of a string fixed at both ends

\[ f_n = n \left( \frac{v_w}{2L} \right) \]

• Where
  • \( f_n \) = frequency of the \( n^{th} \) harmonic
  • \( n \) = integer (harmonic #)
  • \( v_w \) = speed of wave
  • \( L \) = length of string
Demonstrate antinodes at the end by making standing waves in a string by dangling a string and shaking it.
07-07 SOUND INTERFERENCE AND RESONANCE

Fundamental
\[ \lambda_1 = 2L \]
\[ f_1 = \frac{v}{2L} \]

First overtone
\[ \lambda_2 = \frac{L}{2} \]
\[ f_2 = \frac{v}{L} \]

Tube open at both ends

Second overtone
\[ \lambda_3 = \frac{2L}{3} \]
\[ f_3 = \frac{3v}{2L} \]

Third overtone
\[ \lambda_4 = \frac{1}{2}L \]
\[ f_4 = \frac{2v}{L} \]
Demonstrate with tube

07-07 SOUND INTERFERENCE AND RESONANCE

• Formula for Tube Open at Both Ends
  • Distance between antinodes = \( \frac{1}{2} \lambda \)
  • Tube must be integer number of \( \frac{1}{2} \lambda \)
  • \( L = n \left( \frac{1}{2} \lambda_n \right) \) or \( \lambda_n = \frac{2L}{n} \)
  • \( f_n = \frac{v_w}{\lambda_n} \)

\[ f_n = n \left( \frac{v_w}{2L} \right) \]
• What is the lowest frequency playable by a flute that is 0.60 m long if that air is 20 °C.

• $f = 285.8 \text{ Hz}$

$$f = 1 \left( \frac{343 \text{ m/s}}{2 \times 0.6 \text{ m}} \right) = 285.8 \text{ Hz}$$
07-07 SOUND INTERFERENCE AND RESONANCE

Fundamental
\[ \lambda_1 = \frac{4L}{v} \]
\[ f_1 = \frac{v}{4L} \]

First overtone
\[ \lambda_2 = \frac{4L}{3} \]
\[ f_2 = \frac{3v}{4L} \]

Second overtone
\[ \lambda_3 = \frac{4L}{5} \]
\[ f_3 = \frac{5v}{4L} \]

Third overtone
\[ \lambda_4 = \frac{4L}{7} \]
\[ f_4 = \frac{7v}{4L} \]

Tube open at one end
• Tube Open at One End
  • Node at the closed end
  • Antinode at the open end
  • At fundamental frequency $L = \frac{1}{4} \lambda$
  • The 2$\text{nd}$ harmonic adds one more node or $\frac{1}{2} \lambda$
  • Thus the lengths are odd integer multiples of $\frac{1}{4} \lambda$

\[ f_n = n \left( \frac{v_w}{4L} \right) \]

• Only odd harmonics

Where $n$ is odd integers
07-07 HOMEWORK

• Try blowing your way through these problems

• Read 17.6, 17.7
07-08 HEARING AND ULTRASOUND

- Hearing
  - Pitch
    - Perception of frequency
    - 20 Hz – 20000 Hz
    - Most sensitive to 2000 – 5000 Hz
    - Can distinguish between pitches that vary by at least 0.3 %

- Loudness
  - Perception of intensity
  - Range $10^{-12}\, \text{W/m}^2 – 10^{12}\, \text{W/m}^2$
  - Most people can discern an intensity level difference of 3 dB
• Phons measure loudness
• The graph shows the sensitivity of the average human ear
Ultrasound

- Used in obstetrics to examine a fetus, used to examine some organs, and blood flow

- High frequency sound aimed at target

- Sound reflects at boundary of tissues with different acoustic impedances

- Computer compiles picture from where echoes come from

- Acoustic impedance
  \[ Z = \rho v \]

  - See table 17.5

- Intensity reflection coefficient
  \[ a = \frac{(Z_2 - Z_1)^2}{(Z_1 + Z_2)^2} \]

  - Higher coefficient, more reflection

- Can’t see detail smaller than \( \lambda \)

- Can only penetrate to depth of 500\( \lambda \)
Calculate the intensity reflection coefficient of ultrasound when going from water to fat tissue (like a baby in the womb).

\[ a = 0.00317 \]

This means 0.317\% of the sound is reflected.
Cavitron Ultra Surgical Aspirator
• Used to remove inoperable brain tumors

• Tip of instrument vibrates at 23 kHz

• Shatters tumor tissue that comes in contact

• Better precision than a knife
High-Intensity Focused Ultrasound

- Sound is focused on a region of the body.
- The waves entering the body don’t do damage.
- Only damage done where focused (like sun and magnifying glass).
- The focused energy at target causes heating which kills abnormal cells.
Doppler Flow Meter
- Transmitter and receiver placed on skin
- High frequency sound emitted
- Sound reflects off of blood cells
- Since cells are moving, Doppler effect exists
- Computer can find rate of flow by counting the returned frequency
- Used to find areas of narrowed blood vessels
- Narrowest area $\rightarrow$ fastest flow
• Applying science is called engineering.