# Chapter #3

Sound and waves

# We will discuss :-

- The definition of wave .
- Types of wave .
- Speed of sound.
- Amplitude , wavelength ,period and frequency .
- Speed of wave.
- Doppler shift .
- Shock wave
- Medical application.

# Wave

- Wave: propagation of disturbances from place to place in a regular and organized way.
- Properties of wave:

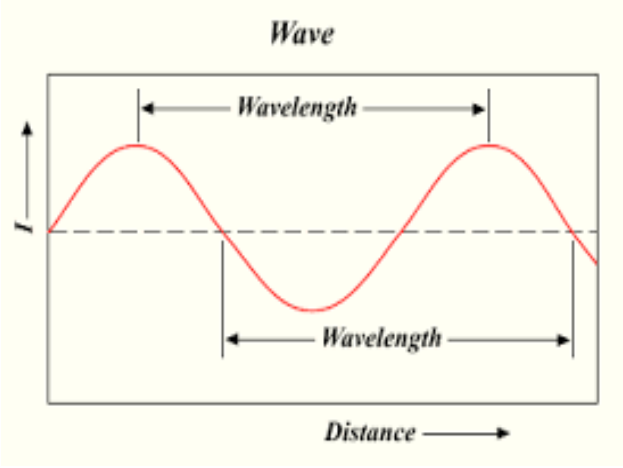
I. Waves carry energy

II. No net movement of matter

III. Waves can be wave pulses or continuous wave (oscillations)

IV. Some waves require medium some don't

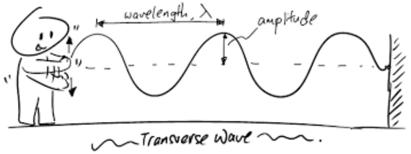
e.g. sound waves require medium while light waves don't.

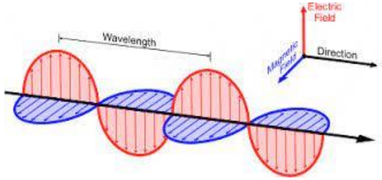


# Types of waves

- Transverse wave :the motion of particles in the medium is perpendicular to the direction of propagation of the wave.

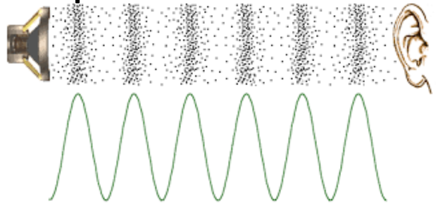
Example : *wave on a rope - *electromagnetic waves

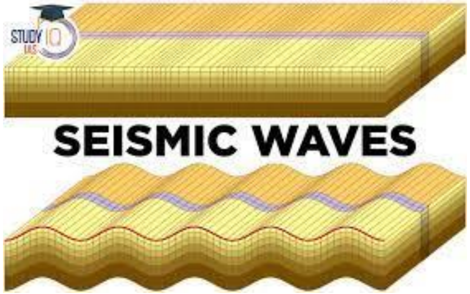



- Longitudinal wave : motion of particles in the medium is along the same line as the direction of propagation of wave.

Example : *Sound waves - *Seismic waves





# Speed of sound

- Depends on the temperature and the type of material

$$v = 331 + 0.606\,T_c$$

$T_c$: is the air temperature in degrees Celsius

$v$: is the speed in m/s

- Example : for T = 20 °C

$$v = 331 + 0.606 \times 20$$
$$= 343.12 \text{ m/s}$$

# Speed of sound

**Table 12.1** Speed of Sound in Various Materials (at 0°C and 1 atm Unless Otherwise Noted)

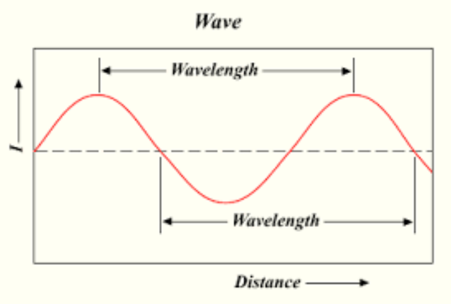
| Medium | Speed (m/s) | Medium | Speed (m/s) |
|---|---|---|---|
| Carbon dioxide | 259 | Seawater (25°C) | 1533 |
| Air (dry) | 331 | Blood (37°C) | 1570 |
| Nitrogen | 334 | Muscle (37°C) | 1580 |
| Air (dry, 20°C) | 343 | Concrete | 3100 |
| Helium | 972 | Copper | 3560 |
| Hydrogen | 1284 | Bone (37°C) | 4000 |
| Lead | 1322 | Aluminum | 5100 |
| Mercury (25°C) | 1450 | Pyrex glass | 5640 |
| Fat (37°C) | 1450 | Steel | 5790 |
| Water (25°C) | 1493 | Granite | 6500 |

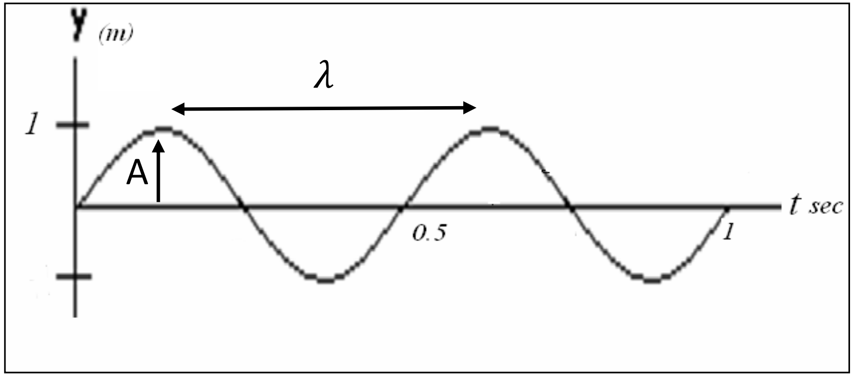
# Definitions

- Amplitude (A): the maximum displacement of points on a wave, measured from the equilibrium position.
- Wavelength($\lambda$): the distance between two successive like points on a wave.
- Period (T): the time needed to complete one full cycle (or one wavelength)
- Frequency ( $f$ ): the number of cycles passing a point per unit time (or the inverse of the period).

# Definitions

- Amplitude (A)= 1 m
- Wavelength($\lambda$)
- Period (T)= 0.5 s
- Frequency ( $f$ ): 2 Hz



# The speed of Wave

- A wave travels a distance λ (one wavelength) in time T (the period)

- $$v = \frac{distance}{time} = \frac{\lambda}{T} = \lambda f$$

- Example 1 :Sound waves travel in air with a speed of 344 m/s. The lowest frequency sound we can hear is 20 Hz. Find the wavelength of sound at this frequency?

# The speed of Wave

Example 2:

How long does it take for a sound wave of frequency 2 kHz and a wavelength of 35 cm to travel a distance of 1.5 km?

# The speed of Wave

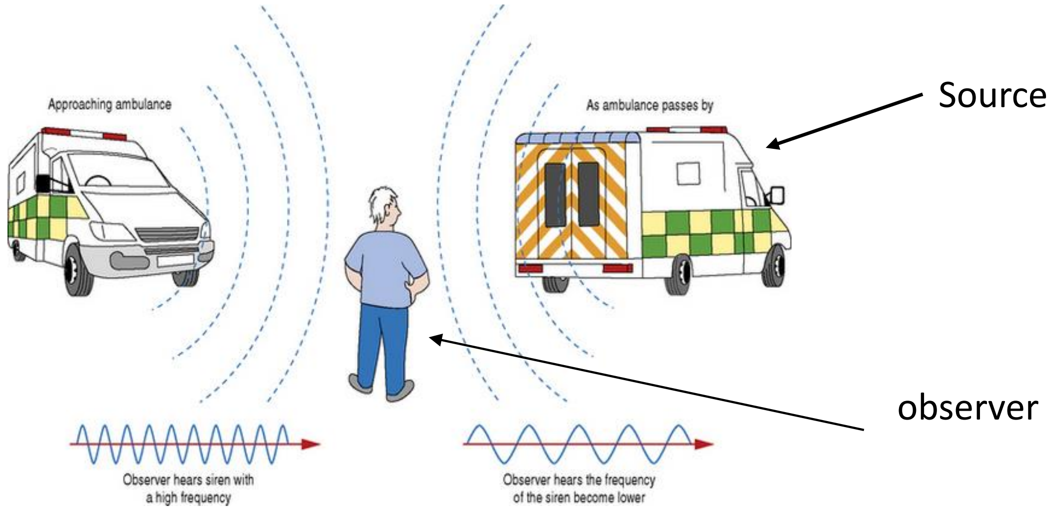
Example 3:

Playing middle C on the piano keyboard produces a sound with a frequency of 256 Hz. Assuming the speed of sound in air is 345 m/s, determine the wavelength of the sound corresponding to the note of middle C.

# Doppler shift

Doppler shift or Effect refers to the change in sound frequency during the relative motion between a sound source and its observer.

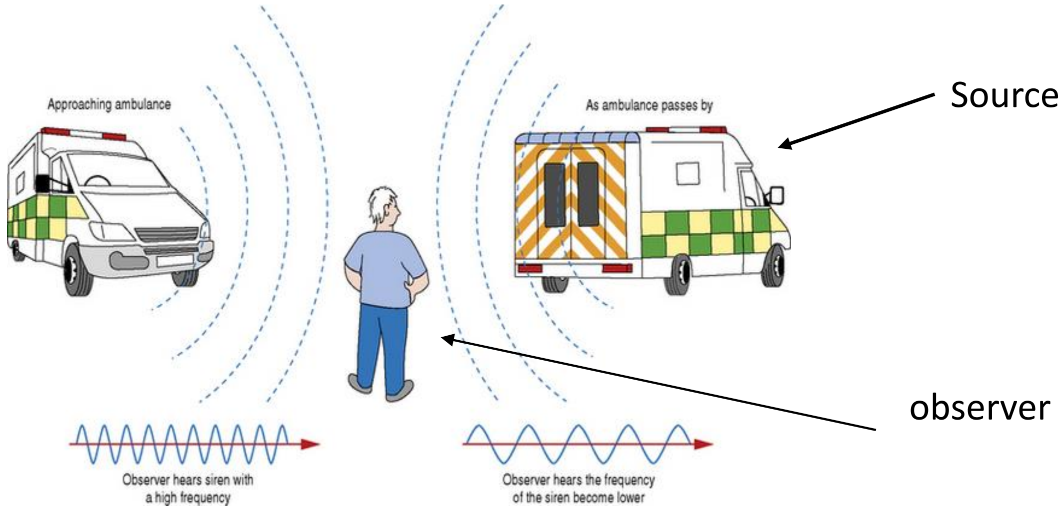
- A police car races by, its sirens screaming. As it passes, we hear the pitch change from higher to lower. The frequency change is called the Doppler shift or effect.



# Doppler shift

## Doppler shift or Effect

- https://youtu.be/ffg4TOpXZyg?si=w4_PE9WnlgzUcE_F



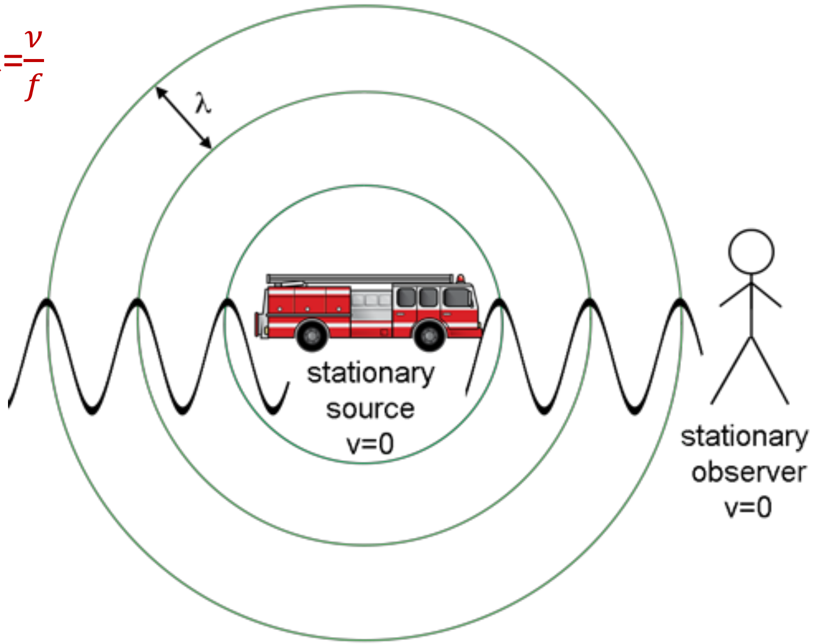
# Doppler shift formula

- $\upsilon = \lambda f$ where $\upsilon$=speed of the wave, $\lambda$=wavelength
- $\nu' = \lambda f'$ where $\nu'$=$\upsilon + u$ → $f'=\frac{\nu'}{\lambda}=\frac{\upsilon+u}{\lambda}$ , $\lambda=\frac{\nu}{f}$

→ $$f'=\left(1+\frac{U}{v}\right) f$$

f= actual frequency

$f'$=observed frequency



# Doppler shift formula

- Depending on the source and the observer we have two cases :-

1) when the source is stationary and the observer is moving with speed $u$ then:

$f' = \left(1 + \frac{U}{v}\right) f$ approaching observer

$f' = \left(1 - \frac{U}{v}\right) f$ receding observer

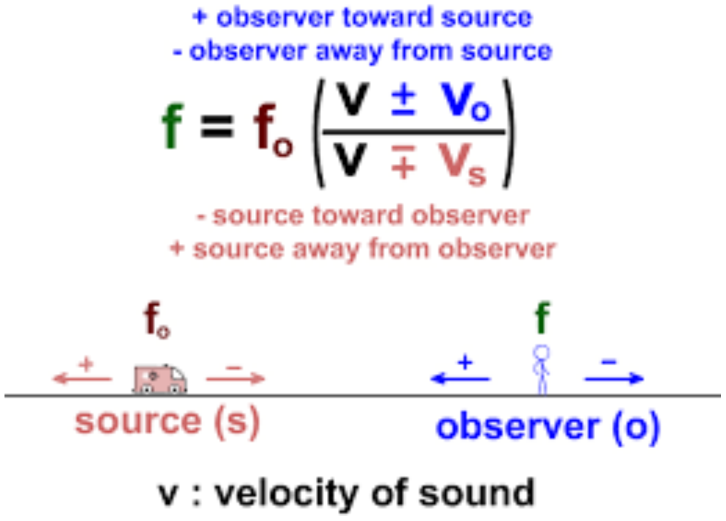
2) when the observer is stationary and the source is moving with speed $u$ then:

$f' = \left(\frac{1}{1 - \frac{u}{v}}\right) f$ approaching source

$f' = \left(\frac{1}{1 + \frac{u}{v}}\right) f$ receding source

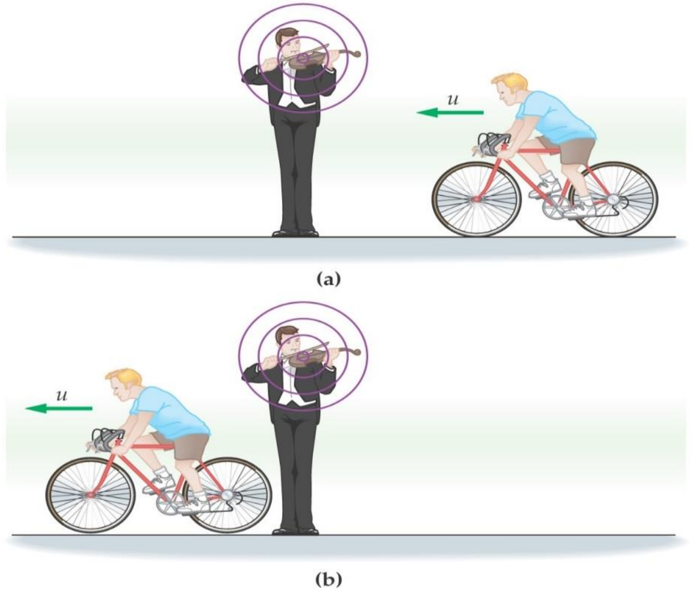
# Doppler shift formula

- Depending on the source and the observer we have two cases :-



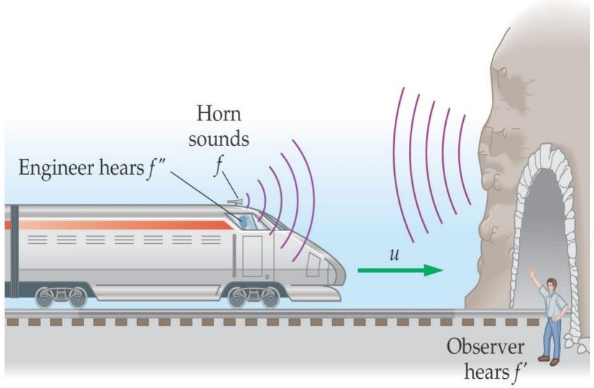
# Example 4

- A street musician sounds the `A' string of his violin, producing a tone of 440 Hz. What frequency does a bicyclist hear as he recedes from and approaches the musician with speed of 11m/s?



# Example 5

- A train sounds its whistle as it approaches a tunnel in a cliff. The whistle produces a tone of 650 Hz and the train travels with a speed of 21.2 m/s. Find the frequency heard by an observer standing near the tunnel entrance?

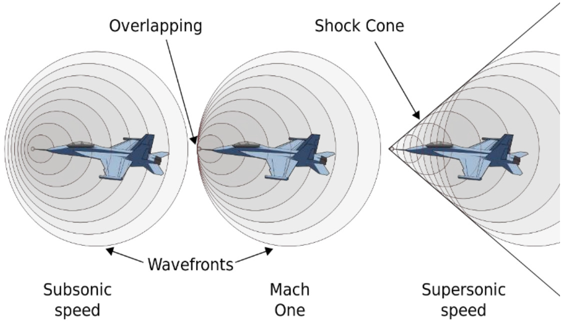


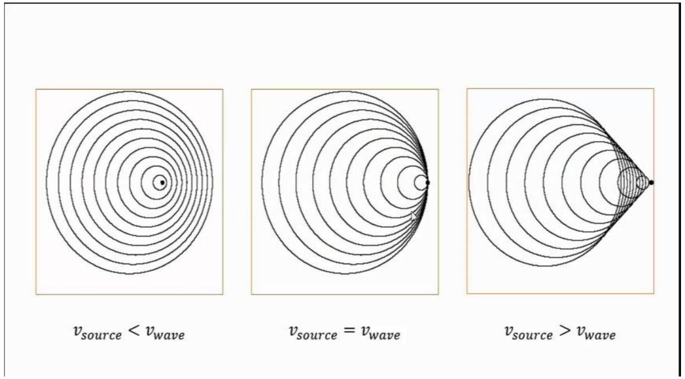
# Example 6

- An person is approaching a stadium on a motorcycle at a speech of 10m/s. Assuming that the frequency of the sound coming out of the stadium is 400Hz. Find out the frequency which the person hears in the sound. (Velocity of the sound in air = 360 m/s).

# Shock wave

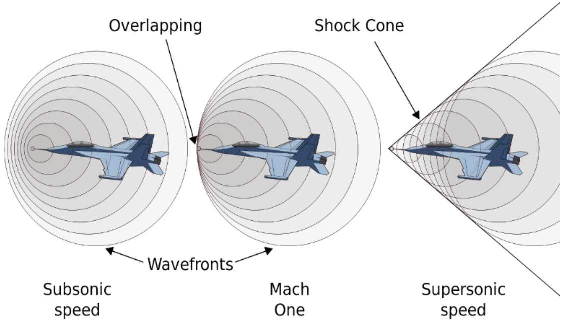
- If the speed of the source > the speed of the wave ( *u* > *v*), a shock wave is formed with very large amplitude.
- Example : waves formed behind a fast boat or a fast jet plane.

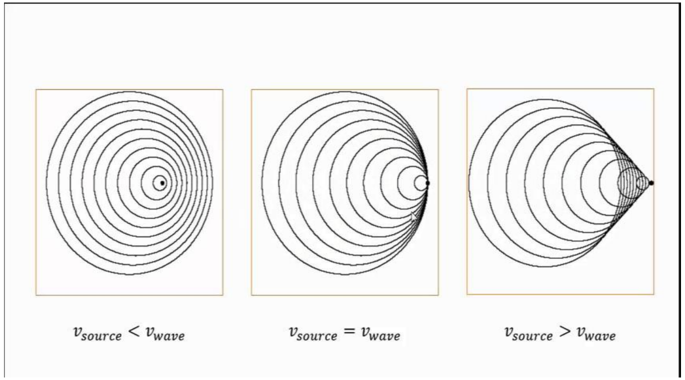


# Shock wave

- If the speed of the source > the speed of the wave ( *u* > *v*), a shock wave is formed with very large amplitude.
- Simulation : https://ophysics.com/waves11.html



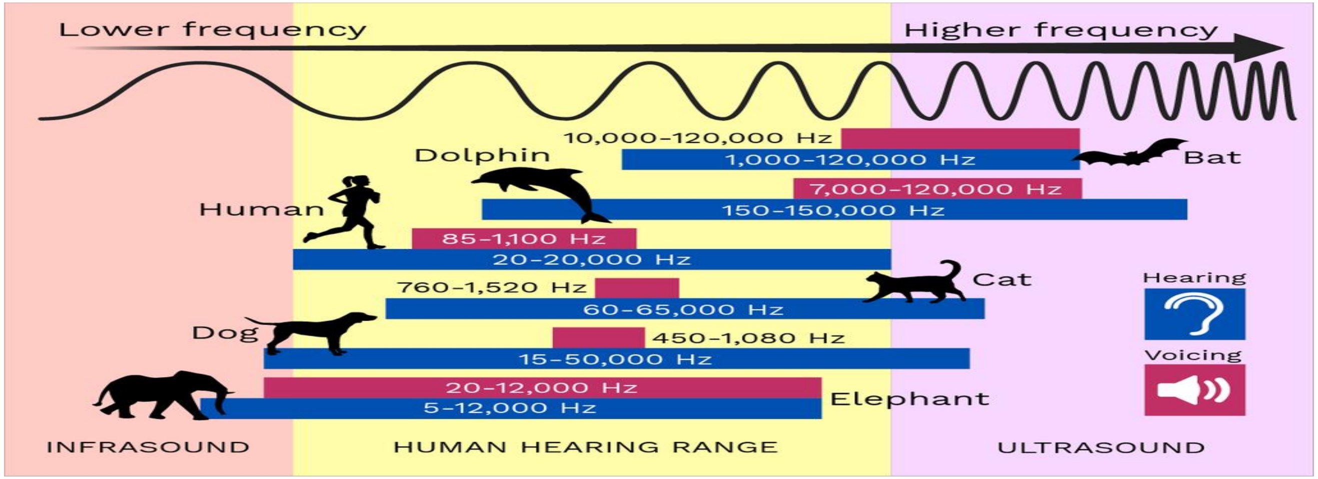



# Medical application

- Human beings hear only sounds that have frequencies from about:

  20 Hz to 20000 Hz (20 kHz), These are the limits of audibility. The upper limit decreases with age.

- Frequencies of 20 000 Hz upwards, are above the range of the human ear These are called ultrasonic sound waves.



# Medical application

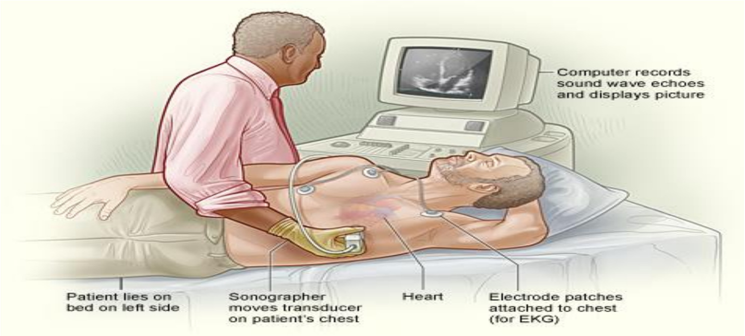
- Ultrasound as a Diagnostic Tool:

i. A scan to check the progress of a baby (fetus) in the womb, provide detailed information on heartbeat of fetus during labor and delivery and By measuring the diameter of the head, the doctor can check the age of the baby.

ii. A scan to check the functioning of the valve in heart , and can show movement , so it is used to assess heart valve function and monitor blood flow in large blood vessels

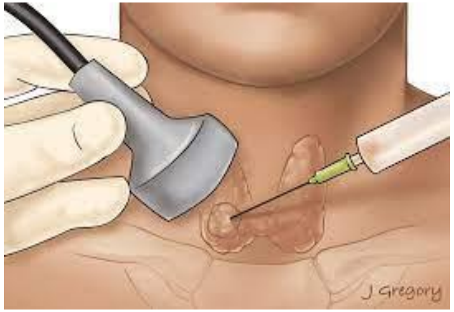
iii. Measurement of the thickness of the eye lens.

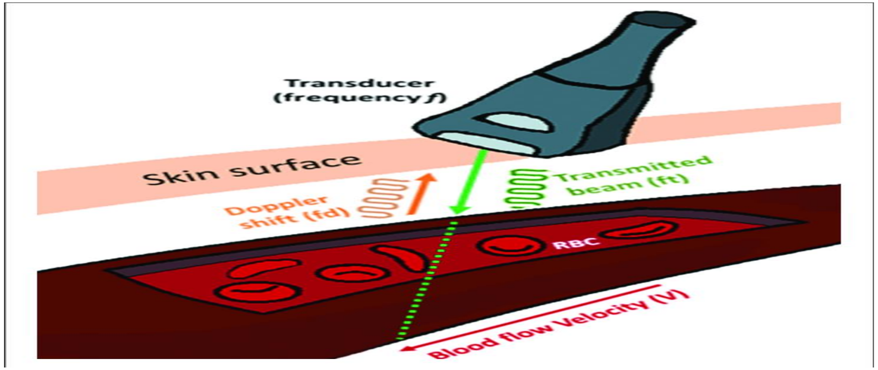
# Ultrasound as a Diagnostic Tool:




# Doppler applications

- Doppler ultradsound: is a technique that is used to examine blood flow
- Also because this technique provides real-time images, it is sometimes used to guide procedures such as biopsies in which a needle is used to take a sample from an organ or tumor for testing.



# Ultrasound as a Treatment Tool:

Ultrasound can be used to treat
patients with kidney stones.
These are particles of material which may form in the kidneys.
The stones block the flow of waste material and can cause severe pain.
Instead of surgery the
stones can be broken up
by a lithotripter.

# Ultrasound as a Treatment Tool:

## How the lithotripter works ?

- This uses several ultrasound beams focused on the stones so that shock waves are produced at a common focus.

The stones are shattered and not the surrounding tissue.