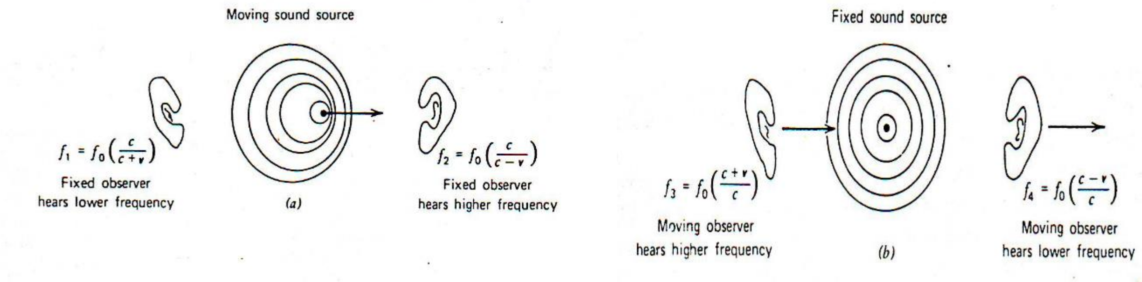
L-27 The Doppler technique

2. The Doppler technique, which is used to measure blood flow.

- Ultrasound, like normal sound, is a wave.
- Apparent change in received frequency due to a relative motion between a sound source and sound receiver
- If a source of sound of frequency f_o moves towards the listener, the waves begin to catch up with each other. The wavelength gets shorter and so the frequency gets higher – the sound has a higher pitch.
- And a lower pitch when it is moving away from him.

- It also has a higher pitch when the listener is moving toward the source than when he is moving away from it



- The frequency change is called the Doppler shift
- We use this principle to work out how fast blood cells move.
- Ultrasound reflects off the blood cells and causes a Doppler shift.
- (c: speed of sound in air , *v : speed of observer(listener)*

Moving sound source & Fixed observer

1. $f_1 = f_0\left(\frac{c}{c+v}\right)$ Moving away from him , hear lower frequency

2. $f_2 = f_0\left(\frac{c}{c-v}\right)$ Moving towards him , hear higher frequency

Fixed sound source & Moving observer

$f_3 = f_0\left(\frac{c+v}{c}\right)$ Moving observer towards source , hear higher frequency

$f_4 = f_0\left(\frac{c-v}{c}\right)$ Moving observer away from source , hear lower frequency

- Important to note that the effect does not result because of an <u>actual</u> change in the frequency of the source.
- The source puts out the same frequency; the observer only perceives a different frequency because of the relative motion between them.
- The Doppler Effect is a shift in the apparent or observed frequency and not a shift in the actual frequency at which the source vibrates.

- An example is the speed of blood in an artery, which does not exceed about 0.4 m/s even in the aorta.
- When an ultrasound beam is directed at an artery, the waves reflected from the moving blood cells exhibits a Doppler shift because the cells then act as moving wave sources, and from this shift the speed of the blood can be found.
- *Doppler effect*: change in wavelength with speed
- When the blood is moving at an angle θ from the direction of the sound waves , the frequency change f_d is

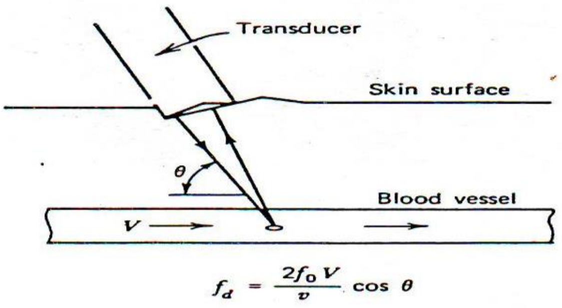
$$f_d = \frac{2f_o V}{v} \cos\theta$$

Where f_o is the frequency of the initial ultrasonic wave.

V is the velocity of the blood

v is the velocity of sound

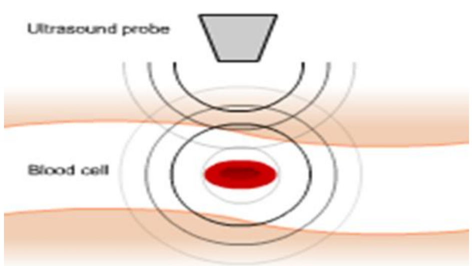
θ is the angle between V and v

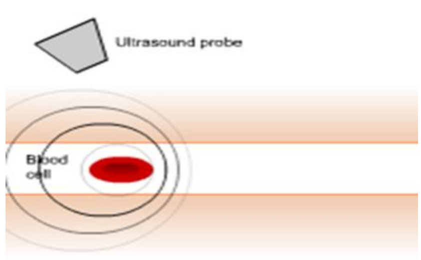


Schematic arrangement for using the Doppler effect to measure the velocity of blood in a blood vessel. The transducer contains two crystals—one for transmitting the sound wave and one for receiving the echo. A continuous rather than a pulsed sound wave is used.

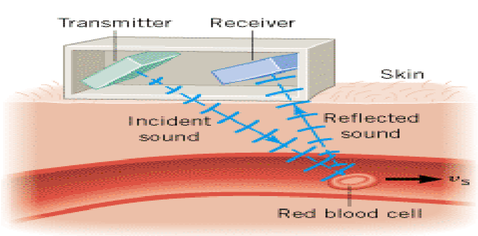
The ultrasound probe emits an ultrasound wave

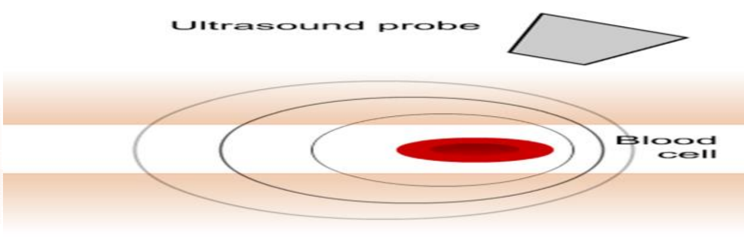
1. A stationary blood cell reflects the incoming wave with the same wavelength: there is no Doppler shift
2. A blood cell moving away from the probe reflects the incoming wave with a longer wavelength. In reality, there is actually two Doppler shifts:-
   - The first one occurs between the probe and the moving blood cell (not shown here)
   - The second one occurs as the red blood cell reflects the ultrasound.





3. Now, the blood cell moves towards the probe. It reflects the incoming wave with a shorter wavelength





Doppler Effect: blood flow in artery

The Doppler flow meter is a particularly interesting medical application of the Doppler effect. This device measures the speed of blood flow, using transmitting and receiving elements that are placed directly on the skin.

***Doppler imaging*: combine imaging and Doppler**

- **Use both normal ultrasound imaging and Doppler imaging**
- **Used to image blood flow**

From the change in frequency, the speed of the blood flow can be determined. Typically, the change in frequency is around 600 Hz for flow speeds of about 0.1 m/s. The Doppler flow meter can be used to locate regions where blood vessels have narrowed, since greater flow speeds occur in the narrowed regions, according to the equation of continuity. In addition, the Doppler flow meter can be used to detect the motion of a fetal heart as early as 8–10 weeks after conception.

***Ultrasound imaging*: carotid artery**

Carotid ultrasound uses sound waves to produce pictures of the carotid arteries in the neck, which carry blood from the heart to the brain. A Doppler ultrasound study is usually part of this exam. Its most frequently used to screen patients for blockage or narrowing of the carotid arteries, a condition called stenosis, which may increase the risk of stroke.

***Ultrasound imaging*: 4D Doppler ultrasound**

This is a complicated image of the heart of a foetus. It shows the blood moving between the ventricles and the arteries.

***Ultrasound*: safety**

- **Ultrasound is energy and is absorbed by tissue, causing heating**
- **2D ultrasound has be used to image the foetus for about 50 years. It is thought to be completely safe and does not cause significant heating**
- **4D ultrasound is new, requires more energy and therefore generates more heating. We think it is safe.**
- **Should we use it to diagnose foetal illness?**
- **Should we use it to make videos of healthy babies for parents?**

The physiological effects of ultrasound

- **Ultrasound may induce thermal and non-thermal physical effects in tissues.**
- **Non-thermal effects can be achieve with or without thermal effects.**
- **Thermal effects of ultrasound upon tissue may include increased blood flow, reduction in muscle spasm, increased extensibility of collagen fibers and a pro-inflammatory response.**
- **It is estimated that thermal effects occur with elevation of tissue temperature to 40–45°C for at least 5 min.**
- **Excessive thermal effects, seen in particular with higher ultrasound intensities, may damage the tissue.**