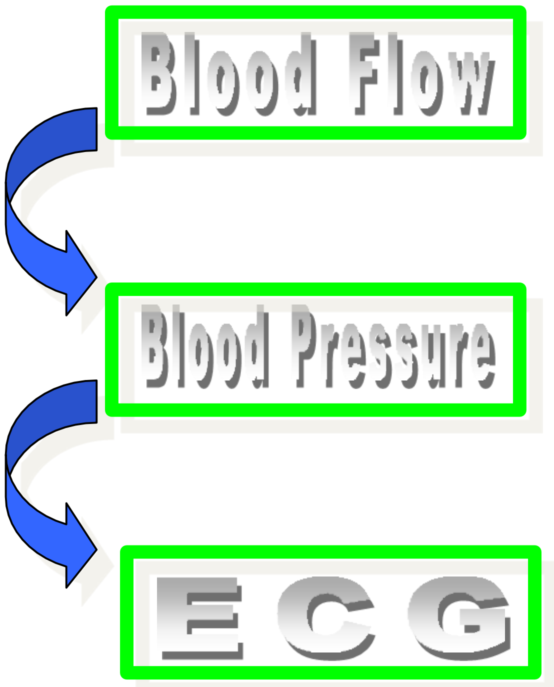
Blood Flow Measurement

Blood Flow

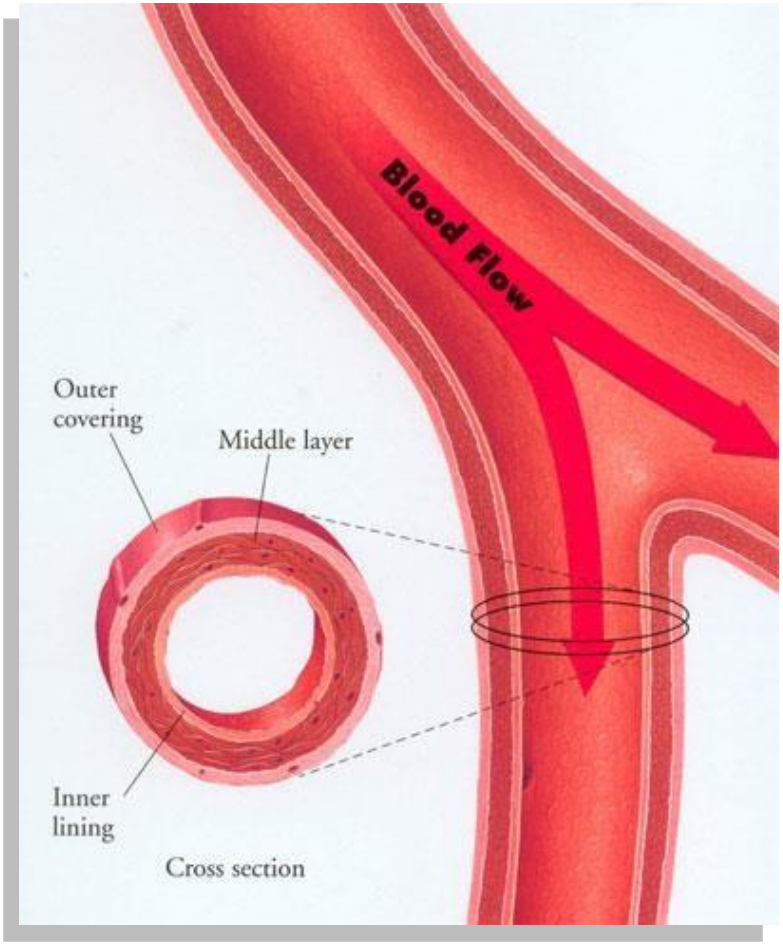


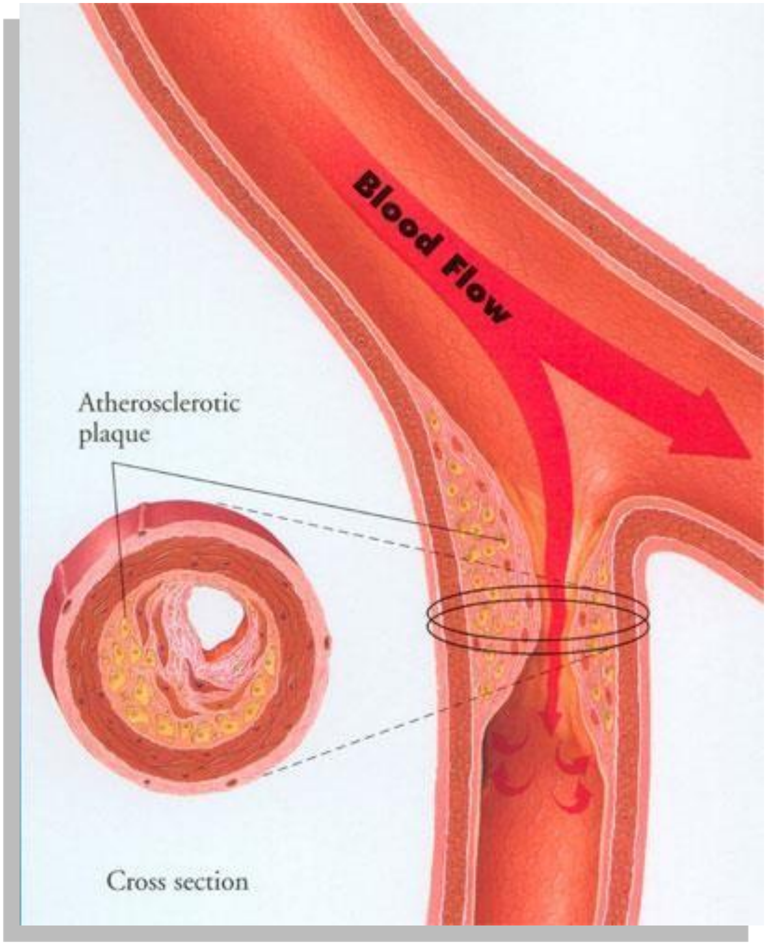
Blood flow helps to understand basic physiological processes and e.g. the dissolution of a medicine into the body.

It also helps to understand many pathological conditions, since many diseases alter the blood flow. Also the blood clots in the arterial system can be detected.

Usually the blood flow measurements are more invasive than blood pressure measurements / ECG

Blood Flow (2)



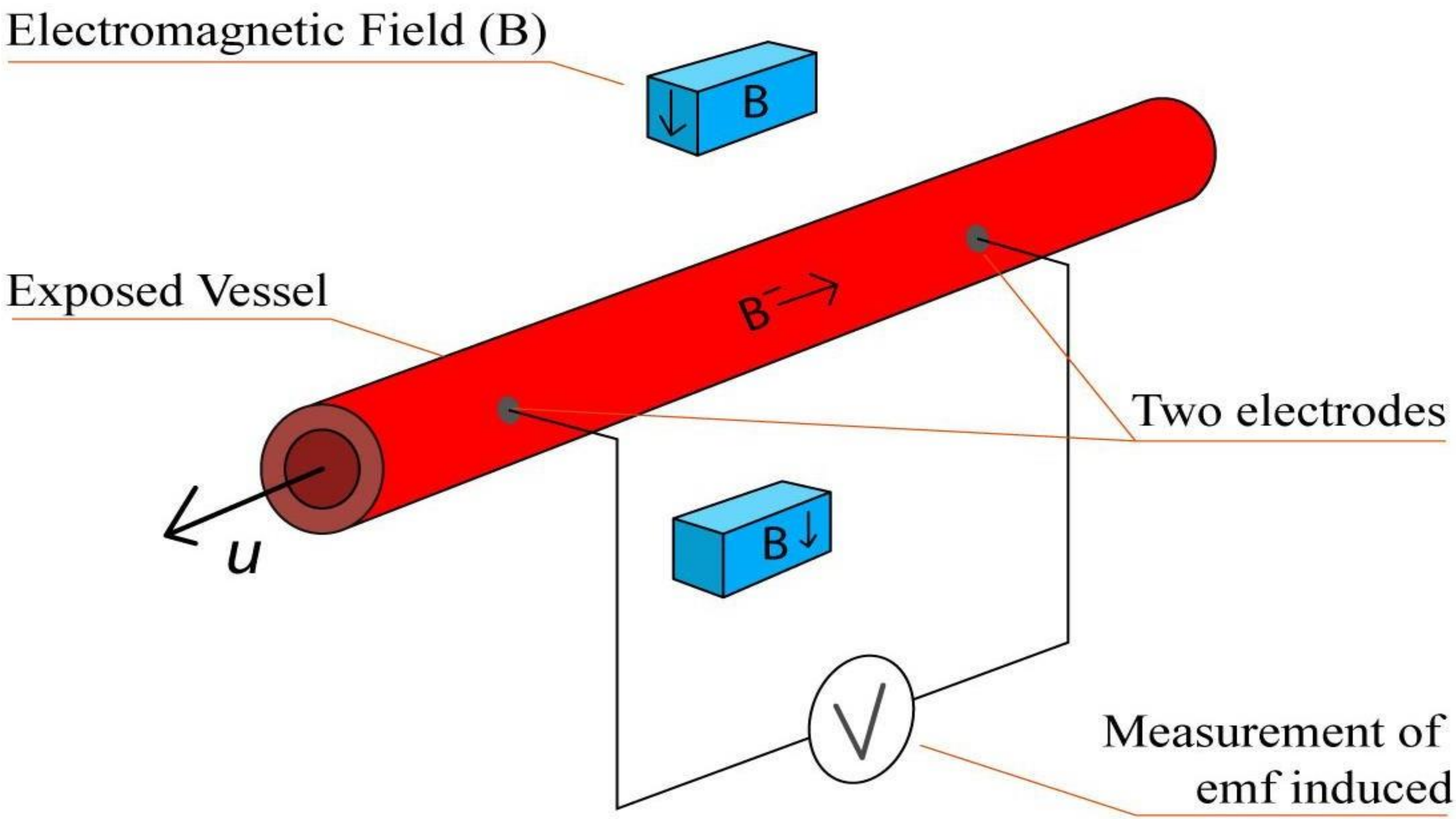


Normal blood flow velocity 0.5 m/s – 1 m/s (Systolic, large vessel)

1.Electromagnetic Blood Flow Meters

- Measures instantaneous pulsatile flow of blood
- Works based on the principle of electromagnetic induction
  - The voltage induced in a conductor moving in a magnetic field is proportional to the velocity of the conductor
- The conductive blood is the moving conductor

Principle of Electromagnetic Blood flow Measurement



Principle of Electromagnetic Blood Flow Meters

- A permanent magnet or electromagnet positioned around the blood vessel generates a magnetic field perpendicular to the direction of the flow of the blood.

- Voltage induced in the moving blood column is measured with stationary electrodes located on opposite sides of the blood vessel and perpendicular to the direction of the magnetic field.

Principle of Electromagnetic Blood Flow Meters

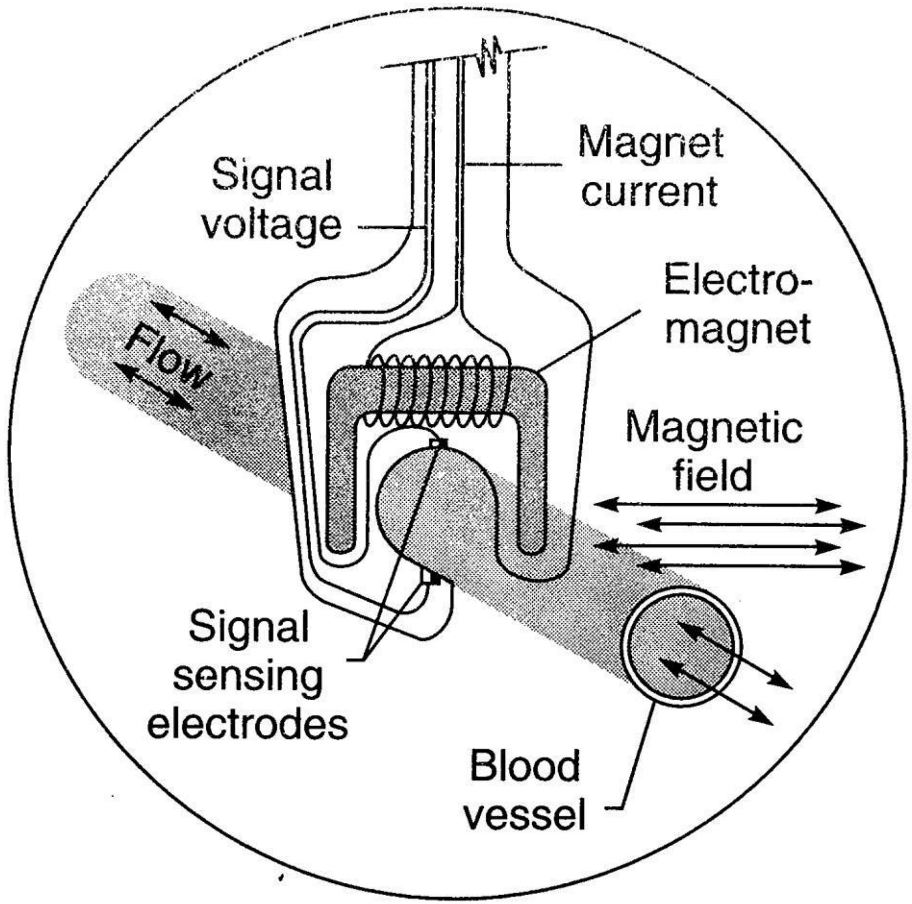
- The Induced ***emf***

$$\boldsymbol{e} = \int_0^{L_1} \mathrm{u} \times \mathrm{B}.\, d\mathbf{L}$$

- Where
  - **B** = magnetic flux density, T
  - **L** = length between electrodes, m
  - **u** = instantaneous velocity of blood, m/s

Principle of Electromagnetic Blood Flow Meters

- This method requires that the blood vessel be exposed so that the flow head or the measuring probe can be put across it.



2. Ultrasonic Blood Flow Meters

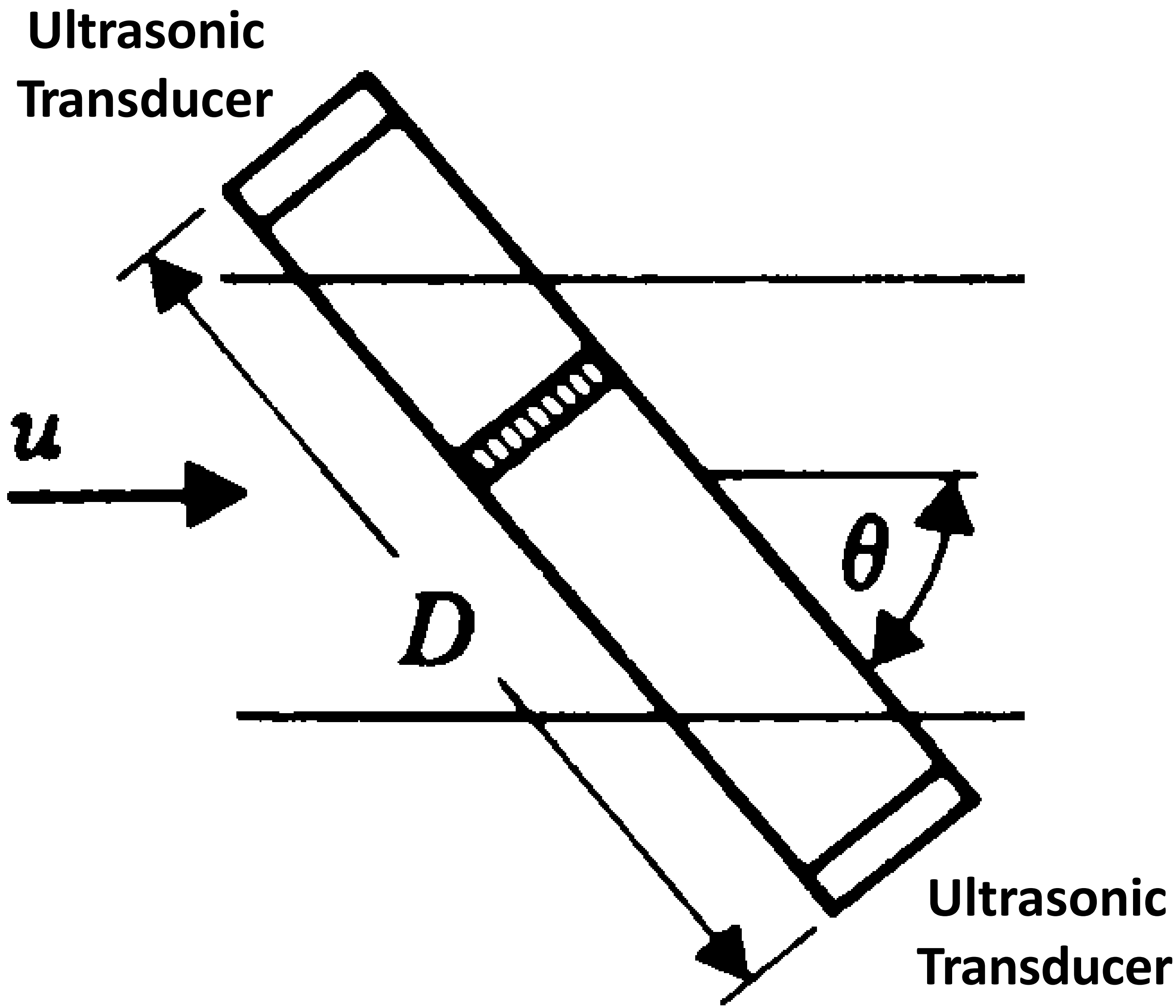
- A beam of ultrasonic energy is used to measure the velocity of flowing blood.

- Two types:

    - Transit time flow meters

    - Doppler type.

Transit-Time Ultrasonic Flow Meters



Transit-Time Ultrasonic Flow Meters

$$conduction\ velocity = \frac{distance}{t}$$

$$t = \frac{distance}{conduction\ velocity}$$

$$t = \frac{D}{c \pm u \cos\theta}$$

- Where
  - *t* - transit time
  - *D* - Distance between the transducers
  - *c* - Sound velocity
  - *u* - blood flow velocity

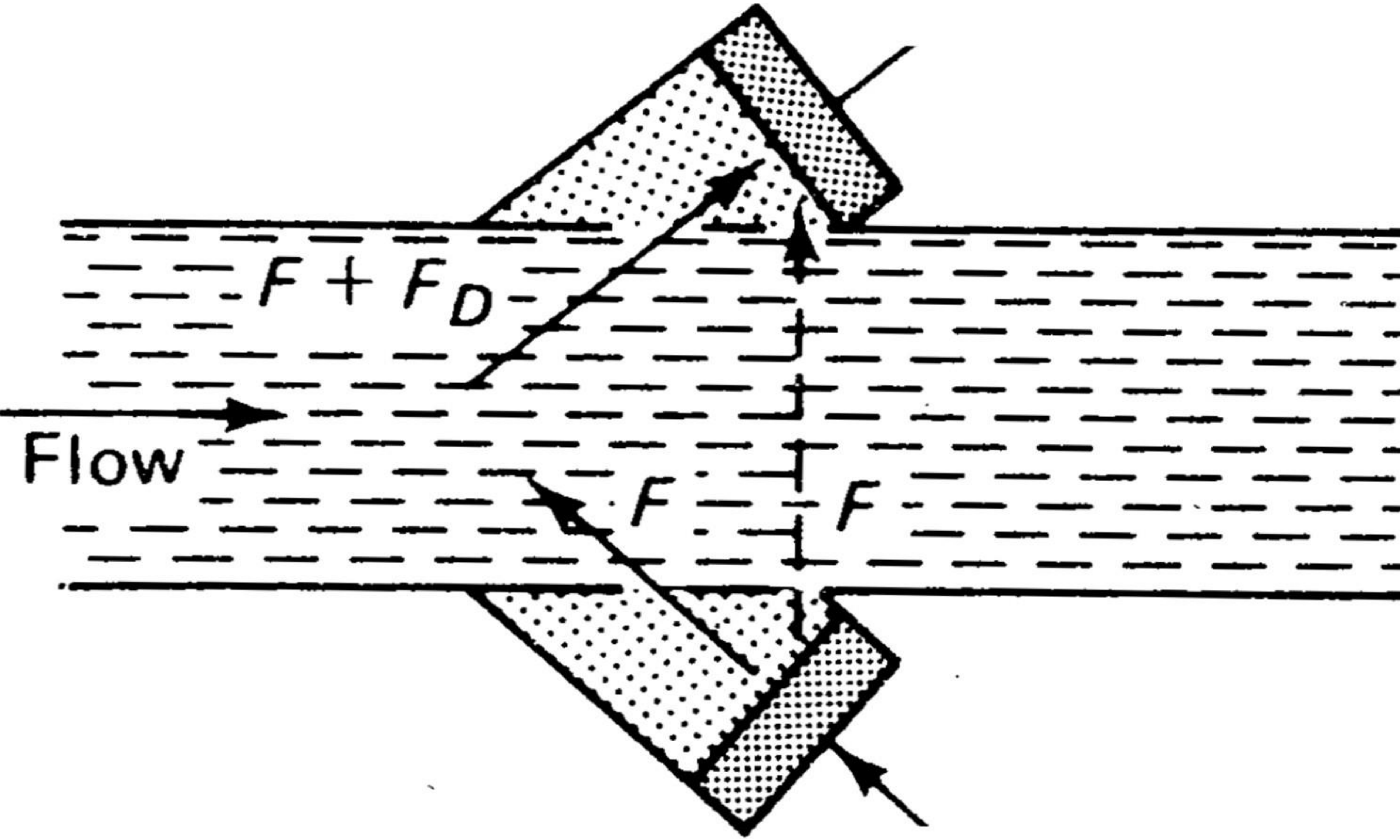
Transit-Time Ultrasonic Flow Meters

- The pulsed beam is directed through a blood vessel at a shallow angle and its transit time is measured.

- The transit time is shortened when the blood flows in the same direction as the transmitted energy

- The transit time is lengthened otherwise.

Doppler Type Ultrasonic Flow Meters



Doppler type Ultrasonic Flow Meters

- Based on the Doppler principle

- A transducer sends an ultrasonic beam with a frequency ***F*** into the flowing blood.

- A small part of the transmitted energy is scattered back and is received by a second transducer arranged opposite the first one.

- The reflected signal has a different frequency $F + F_D$ *or* $F - F_D$ due to Doppler effect.

Doppler Frequency equation

$$f_d = \frac{2 f_0 u \cos\theta}{c}$$

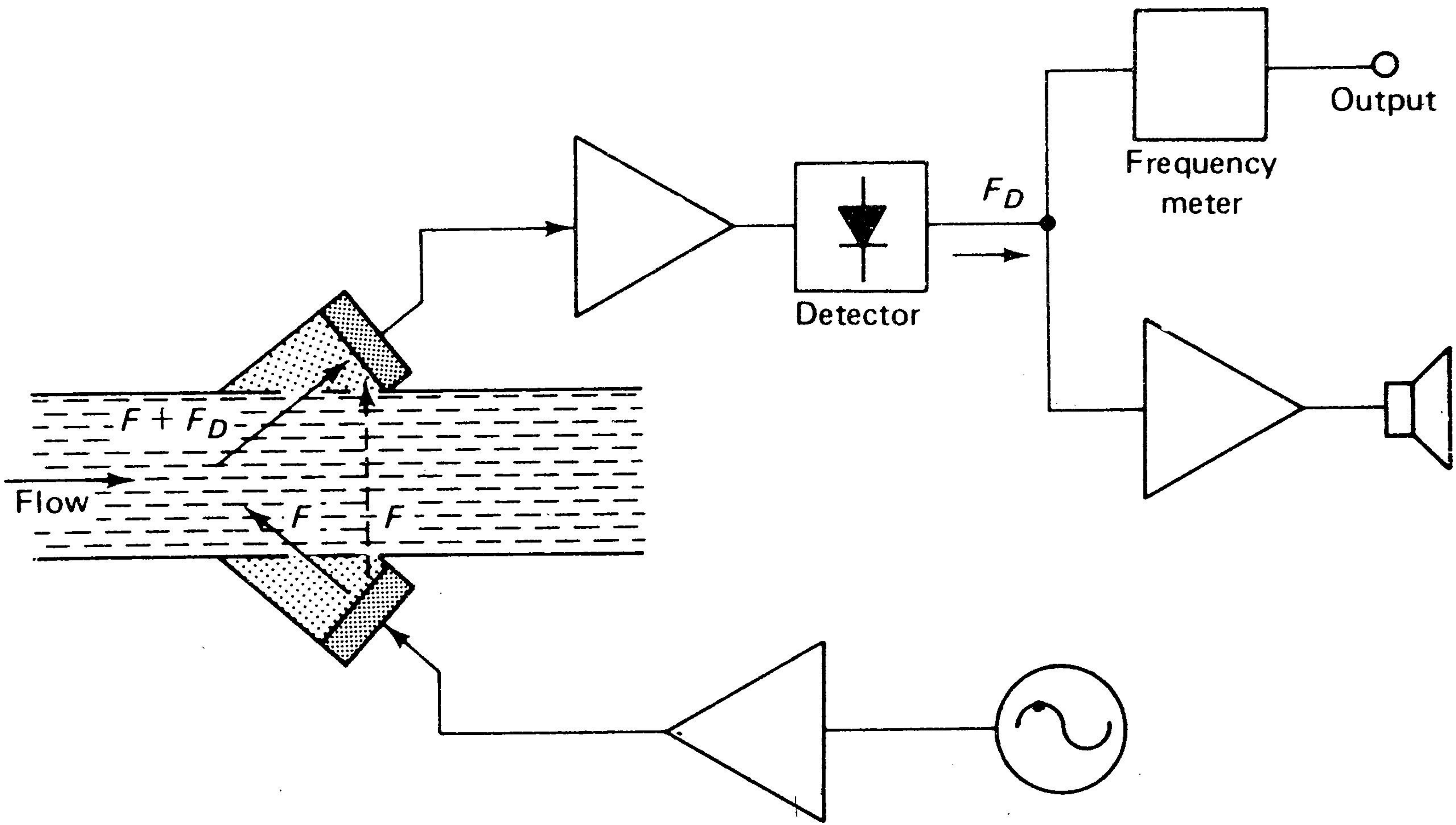
- Where
  - f_d = Doppler frequency shift
  - f_0 = source frequency
  - u = target velocity
  - c = velocity of sound

Doppler type Ultrasonic Flow Meters…

- The Doppler component $\boldsymbol{F_D}$ *is* *d*irectly proportional to the velocity of the flowing blood.

- A fraction of the transmitted ultrasonic energy reaches the second transducer directly with the frequency being unchanged.

Doppler Type Ultrasonic Flow Meters



Doppler type Ultrasonic Flow Meters…

- After amplification of the composite signal, the Doppler frequency can be obtained at the output of the detector as the difference between the direct and the scattered signal components.

- For normal blood velocities, the Doppler signal is typically in the low audio frequency range.

thank you!