Al-Mustaqbal University
Department of Biomedical Engineering
Third Stage / 1st Course
"Transport Phenomena for BME"
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Lecture 2
"Basic Concepts in Fluid Mechanics"

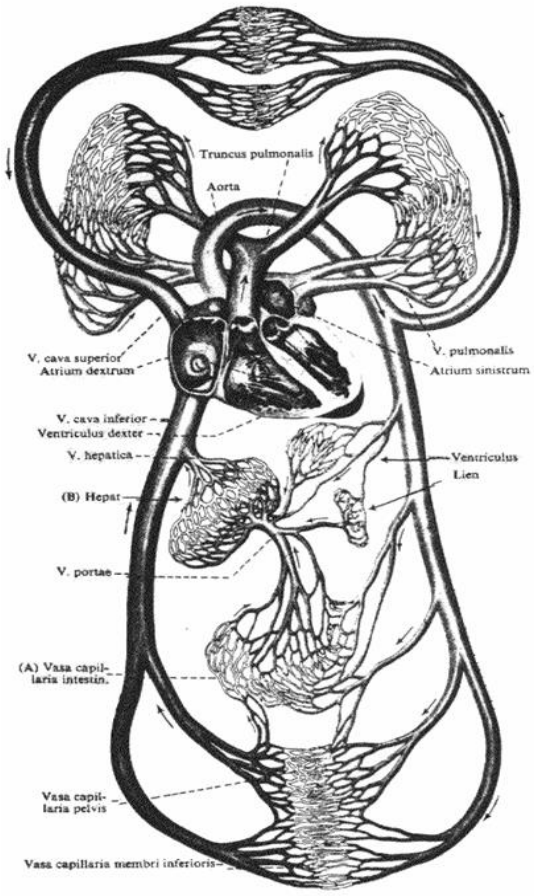
Introduction:

Biological Fluid Mechanics can be roughly sub-divided into two main areas:

• **Internal (physiological) flows**: (Blood flow in veins and arteries, Respiratory flows, Peristaltic pumping, Interstitial flows, …. etc.)

• **External flows**: (Flying "the birds and the bees", ...)– Swimming (fish, micro-organisms, man, ...), etc.

In this course, we will concentrate on internal, physiological flows.



Characteristics of the Circulatory System:

- The circulatory system is a highly branched network of elastic tubes.
- Diameters range from ≈ 30 mm (vena cava) to ≈ 8 μm (capillaries).
- Flow velocities range from 0.5 m/sec to less than 1 cm/sec in the capillaries; the associated Reynolds numbers range from Re ≈4500 to Re ≈ 0.001.
- The flow is pulsatile and hence highly unsteady.
- The vessel walls tend to deform strongly: Arteries tend to be inflated; veins can be strongly collapsed.
- The vessel walls have a very complicated structure and often include layers of active muscle fibers.

- **Fluid mechanic** is defined as the science that deals with the behavior of fluids at rest (fluid statics) or in motion (fluid dynamics), and the interaction of fluids with solids or other fluids at the boundaries.
- In the process industries, many of the materials are in fluid form and must be stored, handled, pumped, and processed, so it is necessary that we become familiar with the principles that govern the flow of fluids and with the equipment used. Typical fluids encountered include water, acids, air, O_2, and oil.
- If a fluid is affected by changes in pressure, it is said to be "compressible fluid", otherwise, it is said to be "incompressible fluid".
- Most liquids are incompressible, and gases are can considered being compressible fluids. However, if gases are subjected to small percentage changes in pressure and temperature, their densities change will be small and they can be considered incompressible fluids. Fluid mechanics can be divided into two branches: "Fluid static" which means fluid at rest, and "Fluid dynamics" which means fluid in motion.

Useful Information:

1. **The Mass flow rate** [symbol is ($\dot{m}$, pronounced "m-dot")] Mass flow rate is the mass of a substance that passes per unit of time. Its unit is kilogram per second or pound per second.

2. **Volumetric flow rate** [symbol: Q] Volumetric flow rate (also known as volume flow rate, rate of fluid flow, or volume velocity) is the volume of fluid, that passes per unit of time; usually represented by the symbol Q (sometimes V). The SI unit is m^3/s.

3. **The shear stress** [symbol: τ (tau)] It is the force per unit surface area that resists the sliding of the fluid layers. The common units used of shear stress is ($N/m^2 \equiv Pa$) and (lbf/ft^2).

4. **The energy** [symbol: E], Energy is defined as the capacity of a system to perform work or produce heat. There are many types of energy such as [Internal energy (U), Kinetic energy (K.E), Potential energy (P.E), Pressure energy (Prs. E), and others. The common units used for energy is (J ≡ N.m), (Btu), (lbf.ft) (cal). The energy may be expressed in relative quantity per unit mass or mole (J/kg).

5. **The Power** [symbol: P] It is the energy per unit of time. The common units used for Power are (W ≡ J/s), (Btu/time), (cal/time), and (hp).

Units and Dimensions

A dimension is a measure by which a physical variable is expressed quantitatively, and the unit is a particular way of attaching a number to the quantities of dimension. All the properties of the fluid are assigned with certain units and dimensions. Some basic dimensions such as mass (M), length (L), time (t), and temperature (T) are selected as Primary/Fundamental dimensions/units. While others such as velocity, volume is expressed in terms of primary dimensions and is called secondary/derived dimensions/unit.

Quantity	Name of unit	Symbol	Equivalent
Length	Meter	m	
Mass	Kilogram	kg	
Time	Second	s	
Temperature	Kelvin	K	
Frequency	Hertz	Hz	s^{-1}
Force	Newton	N	$kg\ ms^{-2}$
Pressure	Pascal	Pa	$N\ m^{-2}$
Energy	Joule	J	N m
Power	Watt	W	$J\ s^{-1}$

Two-unit systems are in use today, the international or metric (SI) system and the imperial (British) system. The SI is very common, and most of the countries in the world use the SI system.

A simple example of the difference is in temperature units. In the SI system, the unit of temperature is Kelvin (K) (or centigrade (˚C)), and in the imperial system, it is Fahrenheit (˚F). In the SI system, the temperature is expressed in terms of absolute value in the Kelvin scale (K = °C+ 273).

Physical Properties of Fluids:

1. **Mass density or density** [symbol: ρ (rho)] It is the ratio of the mass of fluid to its volume.

ρ = (mass of fluid) / (volume of fluid)

The common units used for density is (kg/m^3), (g/cm^3), (lb/ft^3).

2. Specific Volume [symbol: υ] It is the ratio of the volume of fluid to its mass (or mole); it is the reciprocal of its density.

υ= (volume of fluid) / (mass of fluid).

3. Weight density or specific weight [symbol: sp. wt. or γ] It is the ratio of the weight of the fluid to its volume.

sp. wt. = (weight of fluid) / (volume of fluid)

The common units used of weight density is (N/m^3), (lbf/ft^3).

4. Specific gravity [symbol: sp.gr. or SG] It is the ratio of mass density or (density) of fluid to mass density or (density) of water, Physicists use 39.2°F (4°C) as the standard, but engineers ordinarily use 60°F (15.556°C)

S.G.=(mass density of fluid)/(mass density of water)

The common density used of water is (1000 kg/m^3), (1.0g/cm^3), (62.43 lb/ft^3).

5. Dynamic viscosity [symbol: μ (mu)] It is the property of a fluid, which offers resistance to the movement of one layer of fluid over another adjacent layer of the fluid. The common units used for dynamic viscosity are (kg/m.s), (g/cm.s), (lb/ft.s), (poise) ($N.s/m^2 \equiv Pa.s$).

6. Kinematic viscosity [symbol: ν (nu)] It is the ratio of the dynamic viscosity to the mass density of the fluid, **$\upsilon = (\mu)/\rho$**.

The common units used for kinematics viscosity are (m^2/s), (cm^2/s), (ft^2/s), and (stoke). [stoke ≡ cm^2/s].