FDE 205 Fluid Mechanics

Lecture 1

- Many raw materials for foods and many finished foods are in the form of fluids.
- These fluids have to be transported and processed in the factory.
- Food engineers must be familiar with the principles that govern the flow of fluids, and with the machinery and equipment that is used to handle fluids.

- Fluids in the food industry vary considerably in their properties. They include such materials as:
- Thin liquids – milk, water, fruit juices,
- Thick liquids – syrups, honey, oil, jam, tomato puree
- Gases – air, nitrogen, carbon dioxide,
- Fluidized solids – grains, flour, peas.

Fluid: a substance that does not permenantly resist distortion and, hence, will change its shape.

gases liquids vapors

Mechanics: is the science of force and motion.

Fluids can be classified in two groups according to their behaviour against pressure change.

incompressible

inappraciately affected
by changes in pressure
and temperature
e.g. Liquids

compressible

considerably affected
by changes in pressure
and temperature
e.g. Gases

The fluid mechanics → science that deals with the fluids (such as gases and liquids) as well as the effects of forces and energy acting on them.

fluid mechanics

fluid statics   fluid dynamics

The focus of fluid statics is the fluids at rest while fluid in motion and motion of bodies through fluids are the subject of fluid dynamics.

SI System of Basic Units

- Unit of force:

1 Newton (N)=1 kg.m/s^2

- Unit of work, energy, heat:

1 joule (j)= 1 Newton.meter (N.m)= 1 kg.m^2/s^2

- Unit of power:

1 Watt (W)=1 Joule/second

- Unit of pressure:

1 Pascal(Pa)=1 Newton/$meter^2$(N/m^2)

- Unit of temperature:

Kelvin

Fluid Statics

- Fluid Statics: Deals with the fluids at rest and the forces acting upon them
- Pressure and gravitational force acts upon fluids at rest.

Pressure

➡ the normal force per unit area

$$P = \frac{F}{A}$$

unit of pressure is Pascal (Pa) which can also be shown as N/m^2 in SI system

$1\ Pa = 1\ N/m^2 = 10^{-5}\ bar = 9.8692\times10^{-6} atm$
$= 7.5006\times10^{-3}\ torr$
$= 145.04\times10^{-6}\ psi$

Example 1

A 58 kg girl has a foot surface area of 140 cm^2.

a. What is the pressure (Pa) exerted on the floor by the girl?

b. What should be the surface area (cm^2) of one snowshoe (Figure below) if the girl wants to lower the pressure to 3400 Pa during winter hiking?

Figure Picture of a pair of snowshoe

Pressure can be expressed as absolute (mutlak) or gauge (bağıl) pressure.

- The absolute pressure is measured relative to absolute zero pressure meaning that it includes the pressure that is also exerted by the atmosphere.
- Gauge pressure, is the most commonly used reference pressure and does not take into account the atmospheric pressure.
- The term 'abs' or the letter 'g' is placed after the unit to signify if a particular measurement is absolute or gauge. The relation between absolute and gauge pressure is expressed in equation below

$$P_{absolute} = P_{gauge} + P_{atmosphere}$$

- $p_{absolute\ (mutlak)} = p_{gauge(bağıl)} + p_{atmosphere(atmosferik)}$
- Pressure measuring devices are usually calibrated to measure gauge pressure only. Therefore they do not consider the atm pressure.

Pressure in a fluid

- The most important property of the static fluid is the normal force exerted by the fluid per unit area.
- Pressure is the same in all directions at any point in a uniform static fluid.
- The pressure exerted by the fluid increases only with vertical distance and does not change on a given horizontal plane.
- As more fluid rests on deeper layers, the pressure in a fluid increases with depth. This is why our ears feel more and more pressure as we dive deeper in the ocean.

Derivation of pressure equation

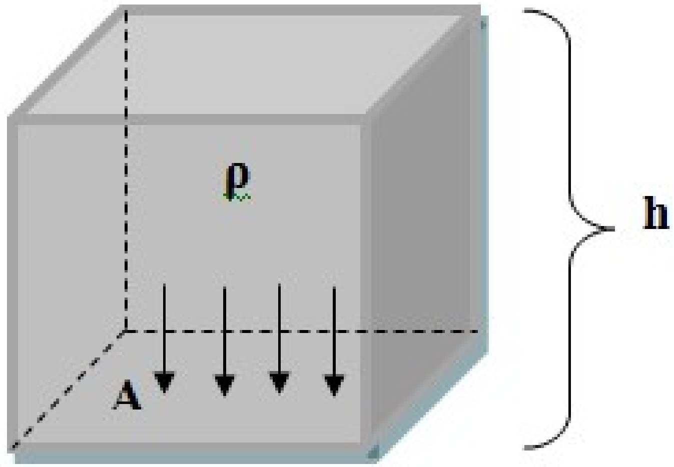


Figure A closed tank filled with a fluid with a height of h and density of ρ. The surface area of the bottom of the tank is represented by A (m^2).

$$Force = m \times g$$

$$P = \frac{F}{A} = \frac{m \times g}{A} = \frac{\rho \times V \times g}{A} = \frac{h \times A \times \rho \times g}{A} = \rho \times h \times g$$

- if the tank was open to atmosphere, P_0 (the atmospheric pressure) has to be taken into account to find total pressure applied on surface A.

$$P = h\rho g + P_o$$

Example 2:

A tank contains oil (s.g. 0.917), water and glycerol (s.g. 1.261). The tank is open to 1 atm atmospheric pressure and 10 m tall.

a. Calculate P_1 and P_2 (Pa) shown in Figure below.
b. Calculate the gauge pressure at the bottom of the tank.

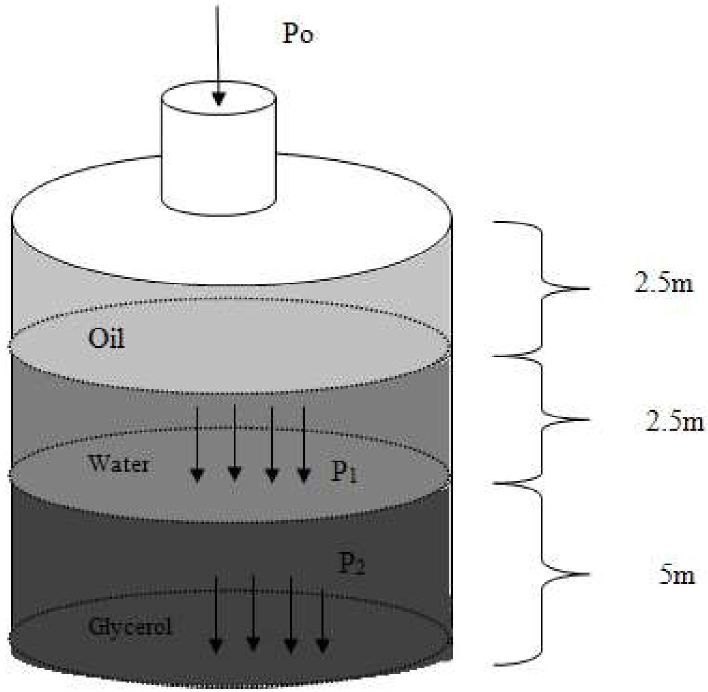


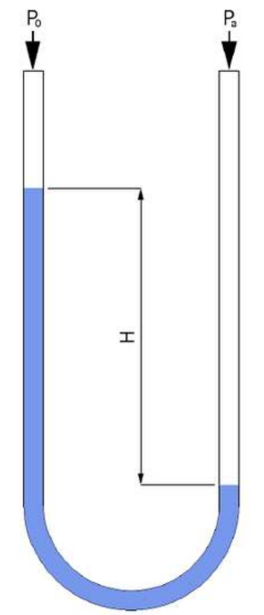
Figure An open tank filled with oil, water and glycerol

Devices to measure pressure and pressure differences

- In food processing it is often important to measure and control the pressure in a vessel or the liquid level in a vessel.
- It is also necessary to measure the rate at which the fluid is flowing. Many of the flow meters depend upon devices to measure pressure or pressure differences.

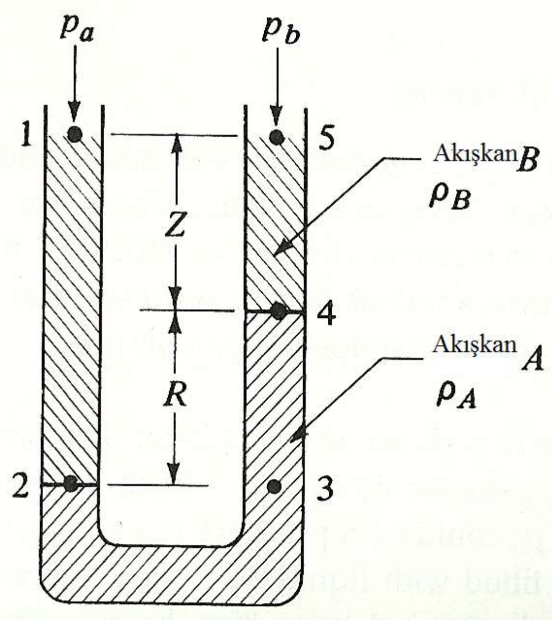
Some common devices are:

1. U-tube manometer
2. Two-fluid U tube
3. Bourdon pressure gage etc.



U-tube manometer

In a U-tube manometer, the pressure at the same height are equal.



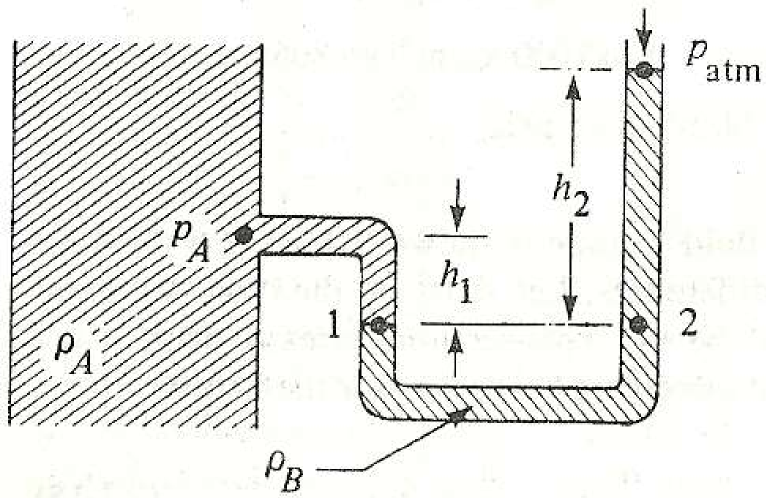
(a)

Derivation of the equation

Pa -Pb = R x $(\rho_A - \rho_B)g$

Example 3

- The u-tube manometer in figure below is used to measure the pressure Pa in a vessel containing a liquid with a density ρ_a . Derive the equation relating the pressure Pa to h1 and h2.



(a)

Inclined manometer

- P1−P2 =?