FLUID PROPERTIES

Elasticity

The elasticity of a fluid is related to the amount of deformation (expansion or contraction) *for a given pressure change*.

Expressing this in a mathematical form,

$$dp \;\alpha\; \frac{dV}{V}$$

Then

$$dp = -E_V \frac{dV}{V}$$

Where E_V **= Degree of Elasticity**

$$M = \rho V$$

$$dM = \rho dV + V d\rho$$

$$But\ dM = 0 \quad (Mass\ is\ Con\tan t)$$

$$\frac{d\rho}{\rho} = -\frac{dV}{V}$$

FLUID PROPERTIES

$$dp = E_V \frac{d\rho}{\rho}$$

$$Hence\ E_V = \rho \frac{dp}{d\rho}$$

For an Isothermal process (Constant temperature)

$$P = \rho RT$$

$$\frac{dP}{d\rho} = RT$$

Then $$E_V = \rho \frac{dp}{d\rho} = \rho RT = p$$

For an Adiabatic process (No heat transfer)

$$E_V = kp$$

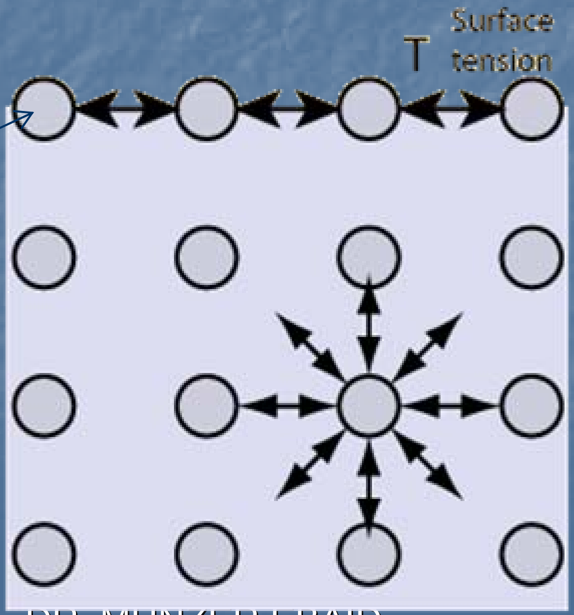
Where $$K = \frac{C_P}{C_V}$$

FLUID PROPERTIES

Surface Tension

The cohesive forces between molecules down into a liquid are shared with all neighboring atoms. Those on the surface have no neighboring atoms above, and exhibit stronger attractive forces upon their nearest neighbors on the surface. This enhancement of the intermolecular attractive forces at the surface is called Surface Tension

Surface Tension



FLUID PROPERTIES

The surface tension Force is given by $F_s = \sigma L$

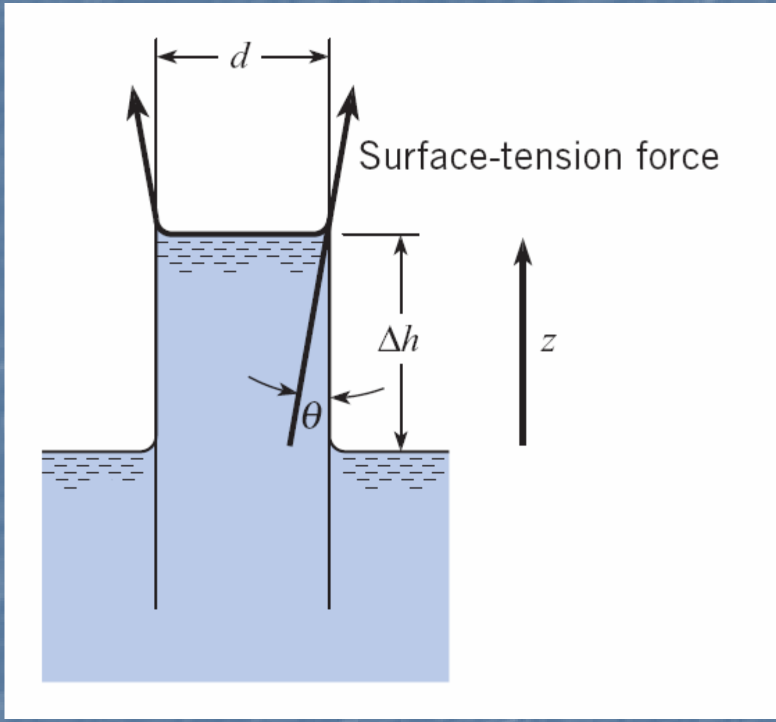
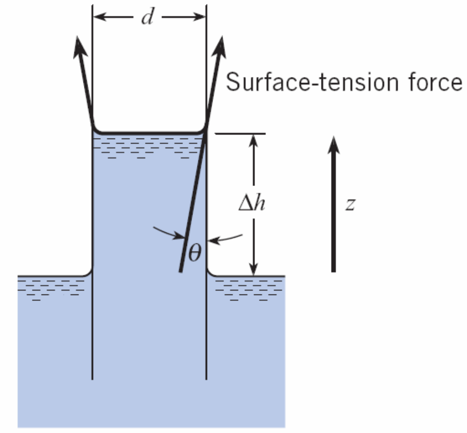


Figure above illustrates the effect of surface tension force to raise the water in a small diameter tube when is put into a reservoir of water.

Example (2-5)



To what height above the reservoir level will water (at 20°C) rise in a glass tube, such as that shown in Fig. 2.5, if the inside diameter of the tube is 1.6 mm?

Solution By taking the summation of forces in the vertical direction on the water in the tube that has risen above the reservoir level, we have

$$F_{\sigma,z} = \sigma \times L$$

$$F_{\sigma,z} - W = 0$$

$$W = mg = (\rho V)\, g = \rho g\left(\pi d^2\, \Delta h\right)$$

$$\sigma \pi d \cos\theta - \gamma(\Delta h)(\pi d^2/4) = 0$$

However, θ for water against glass is so small it can be assumed to be 0°; therefore $\cos\theta \approx 1$. Then

$$\sigma \pi d - \gamma(\Delta h)\left(\frac{\pi d^2}{4}\right) = 0$$

or

$$\Delta h = \frac{4\sigma}{\gamma d} = \frac{4 \times 0.073 \text{ N/m}}{9790 \text{ N/m}^3 \times 1.6 \times 10^{-3} \text{ m}} = 18.6 \text{ mm} \quad \lhd$$

TABLE A.4 APPROXIMATE PHYSICAL PROPERTIES OF COMMON LIQUIDS AT ATMOSPHERIC PRESSURE

Liquid and Temperature	Density, kg/m^3 ($slugs/ft^3$)	Specific Gravity (S), Water at 4°C is Ref.	Specific Weight, N/m^3 (lbf/ft^3)	Dynamic Viscosity, $N \cdot s/m^2$ ($lbf\text{-}s/ft^2$)	Kinematic Viscosity, m^2/s (ft^2/s)	Surface Tension, N/m* (lbf/ft)
Ethyl alcohol[3][1]	799	0.79	7,850	1.2×10^{-3}	1.5×10^{-6}	2.2×10^{-2}
20°C (68°F)	(1.55)		(50.0)	(2.5×10^{-5})	(1.6×10^{-5})	(1.5×10^{-3})
Carbon tetrachloride[3]	1,590	1.59	15,600	9.6×10^{-4}	6.0×10^{-7}	2.6×10^{-2}
20°C (68°F)	(3.09)		(99.5)	(2.0×10^{-5})	(6.5×10^{-6})	(1.8×10^{-3})
Glycerine[3]	1,260	1.26	12,300	1.41	1.12×10^{-3}	6.3×10^{-2}
20°C (68°F)	(2.45)		(78.5)	(3×10^{-2})	(1.22×10^{-2})	(4.3×10^{-3})
Kerosene[2][1]	814	0.81	8,010	1.9×10^{-3}	2.37×10^{-6}	2.9×10^{-2}
20°C (68°F)	(1.58)		(51)	(4×10^{-5})	(2.55×10^{-5})	(2.0×10^{-3})
Mercury[3][1]	13,550	13.55	133,000	1.5×10^{-3}	1.2×10^{-7}	4.8×10^{-1}
20°C (68°F)	(26.3)		(847)	(3.2×10^{-5})	(1.3×10^{-6})	(3.3×10^{-2})
Sea water 10°C	1,026	1.03	10,070	1.4×10^{-3}	1.4×10^{-6}	
at 3.3% salinity	(1.99)		(64.1)	(3×10^{-5})	(1.5×10^{-5})	
Oils—38°C (100°F)						
SAE 10W[4]	870	0.87	8,530	3.6×10^{-2}	4.1×10^{-5}	
	(1.69)		(54.4)	(7.4×10^{-4})	(4.4×10^{-4})	
SAE 10W-30[4]	880	0.88	8,630	6.7×10^{-2}	7.6×10^{-5}	
	(1.71)		(55.1)	(1.4×10^{-3})	(8.2×10^{-4})	
SAE 30[4]	880	0.88	8,630	1.0×10^{-1}	1.1×10^{-4}	
	(1.71)		(55.1)	(2.0×10^{-3})	(1.2×10^{-3})	

FLUID PROPERTIES

Surface Tension

Forces

Case (b) $2F_{\sigma} = 2\sigma 2\pi r = p\pi r^{2}$

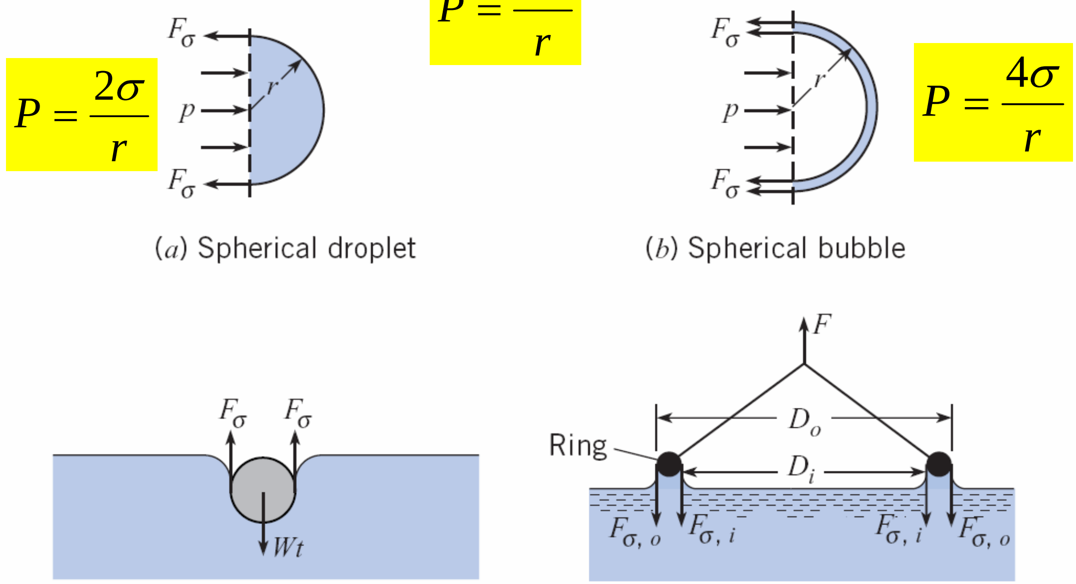
Case (c) $2F_{\sigma} = 2\sigma L = Wt$

Case (d $F_{\sigma} = F_{\sigma,i} + F_{\sigma,o}$

$$F_{\sigma} = \sigma L = pA$$

$$2\pi r\sigma = \pi p r^{2}$$

$$P = \frac{2\sigma}{r}$$



(a) Spherical droplet

(b) Spherical bubble

(c) Cylinder supported by surface tension (liquid does not wet cylinder)

(d) Ring pulled out of liquid (liquid wets the ring)

FLUID PROPERTIES

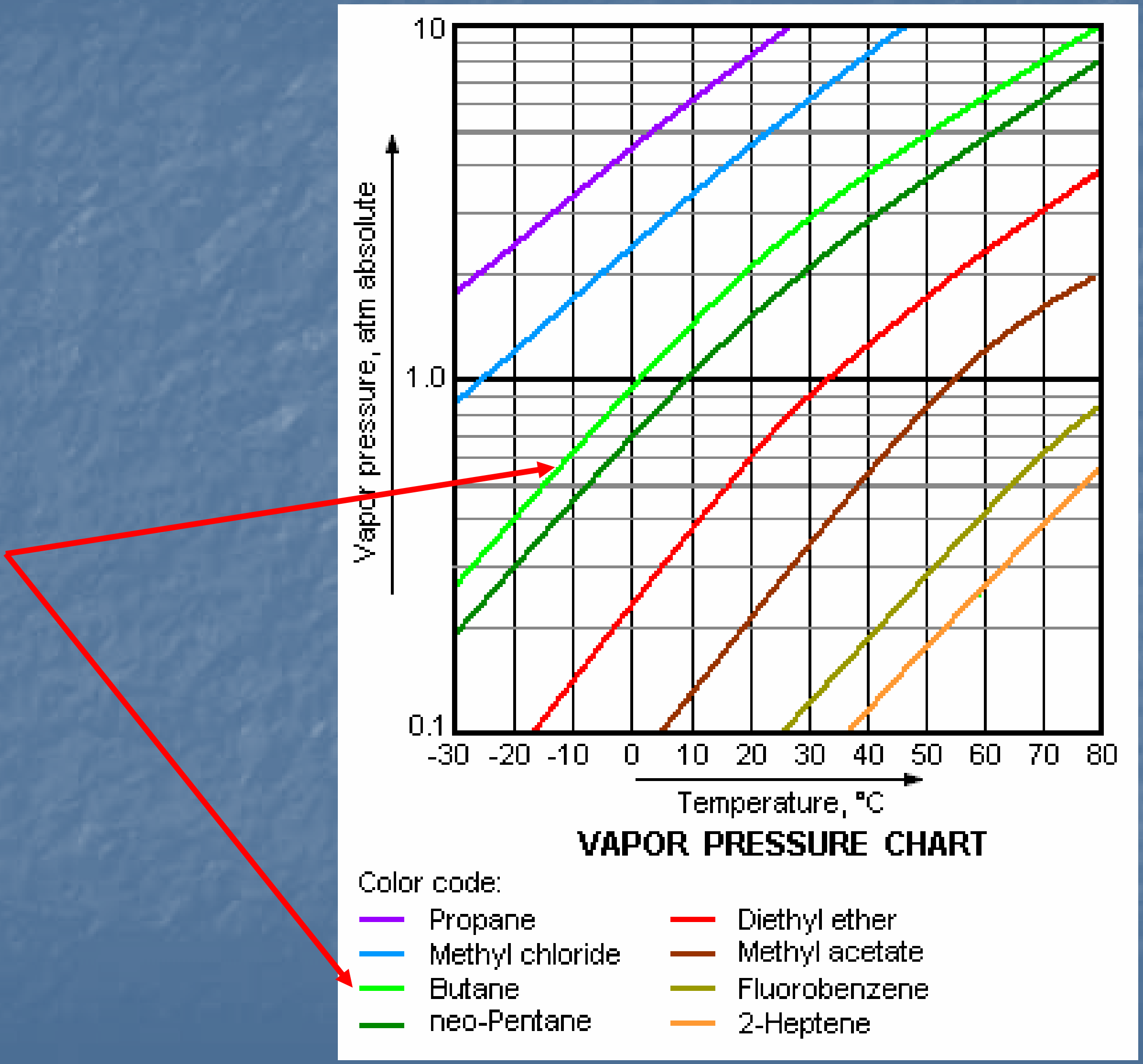
Vapour Pressure

The pressure exerted by a vapor; often understood to mean saturated vapor pressure (the vapor pressure of a vapor in contact with its liquid form and increases with temperature).

Vapor pressure depends on various factors which are:

- **The nature of the liquid.**
- **Temperature.**
- **The presence of dissolved substances.**

FLUID PROPERTIES



SUMMARY

Specific Weight = $\frac{Weight}{volume} = \frac{mg}{V} = \rho g = \gamma$

Specific Gravity=S $\frac{\text{specific weight of fluid}}{\text{specific weight of water}} = \frac{\gamma_f}{\gamma_w} = \frac{(\rho g)_{fluid}}{(\rho g)_{water}} = \frac{\rho_f}{\rho_w}$

Ideal Gas Law: (Equation of State)= $PV = mRT$

Shear stress= $\tau = \mu \frac{dV}{dy}$

Sutherland Constant= $\frac{\mu}{\mu_0} = \left(\frac{T}{T_0}\right)^{3/2} \left(\frac{T+S}{T_0+S}\right)$

Surface Tension= $F_s = \sigma L$

END of

Lecture (5)