CHEN.3030 Fluid Mechanics

I. Fundamental Concepts and Fluid Properties

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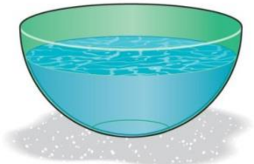
See Chapter 1 (sections 1–10) in your text by Hibbeler

Solids, Liquids, and Gases

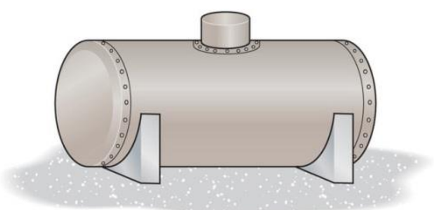
Solids maintain a constant shape

(a)

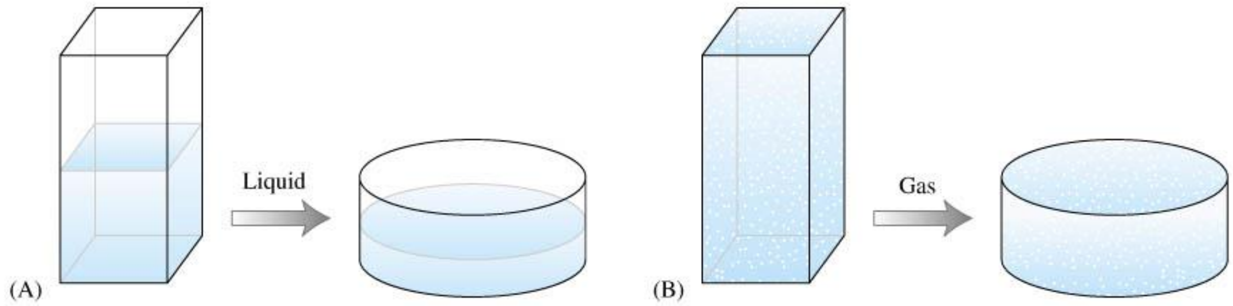


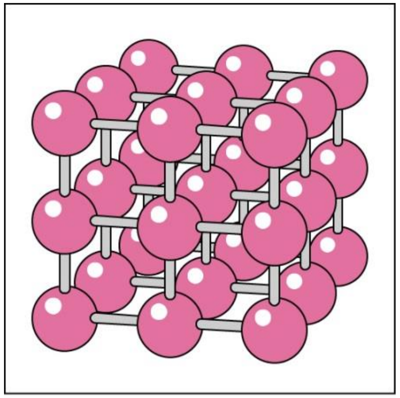
Liquids take the shape of their container

(b)



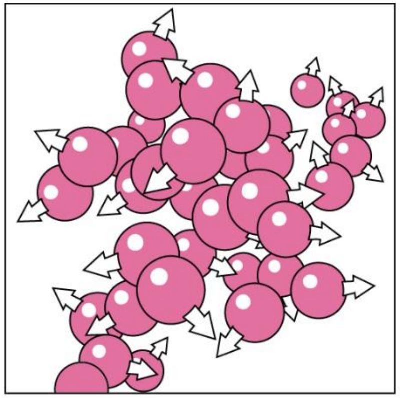
Gases fill the entire volume of their container





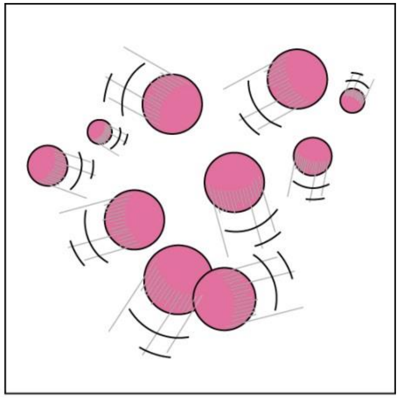
(*a*)

solids



(*b*)

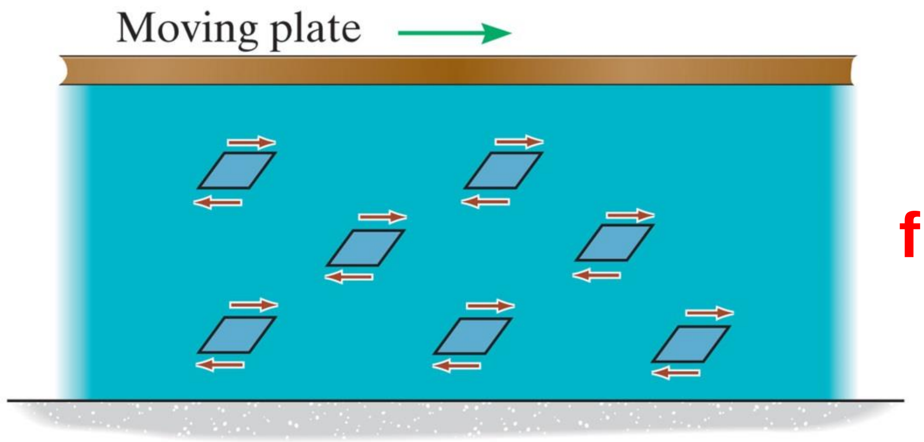
liquids



(*c*)

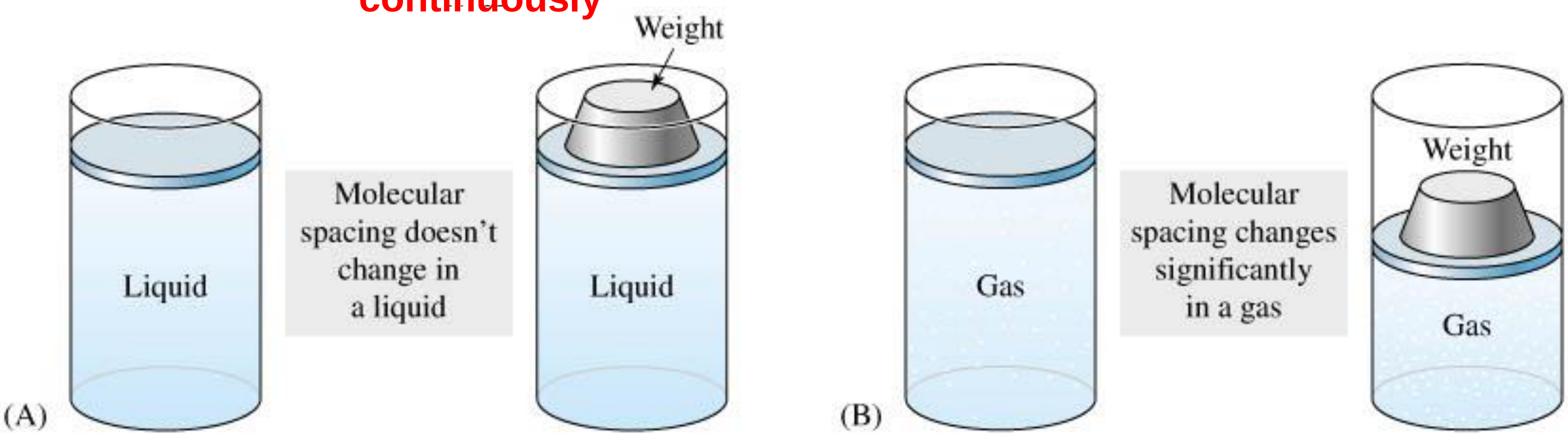
gases

Fluid Definition and Compressibility



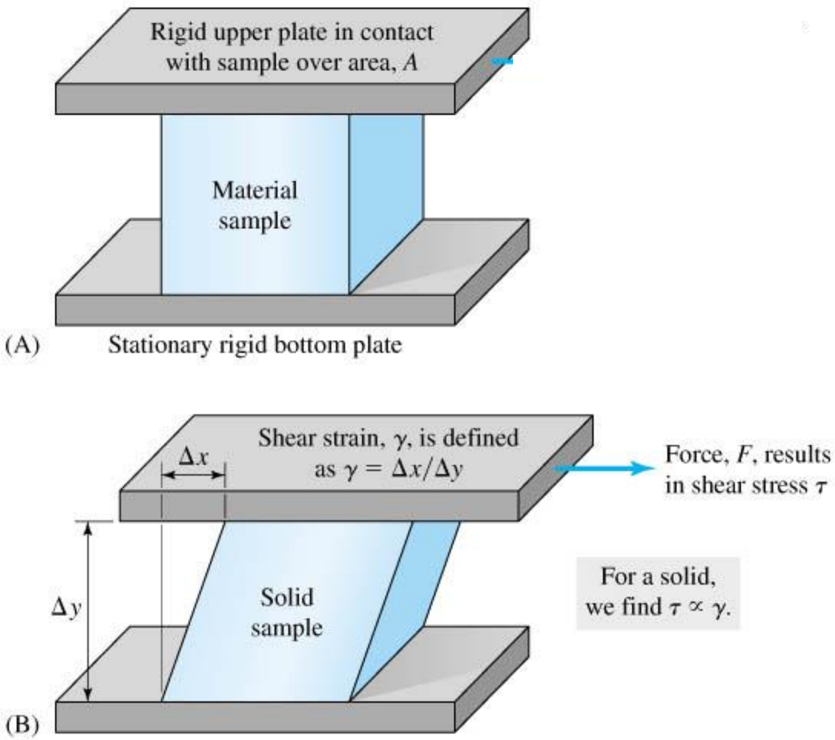
All fluid elements *deform* when subjected to shear
^continuously

fluids → liquids + gases

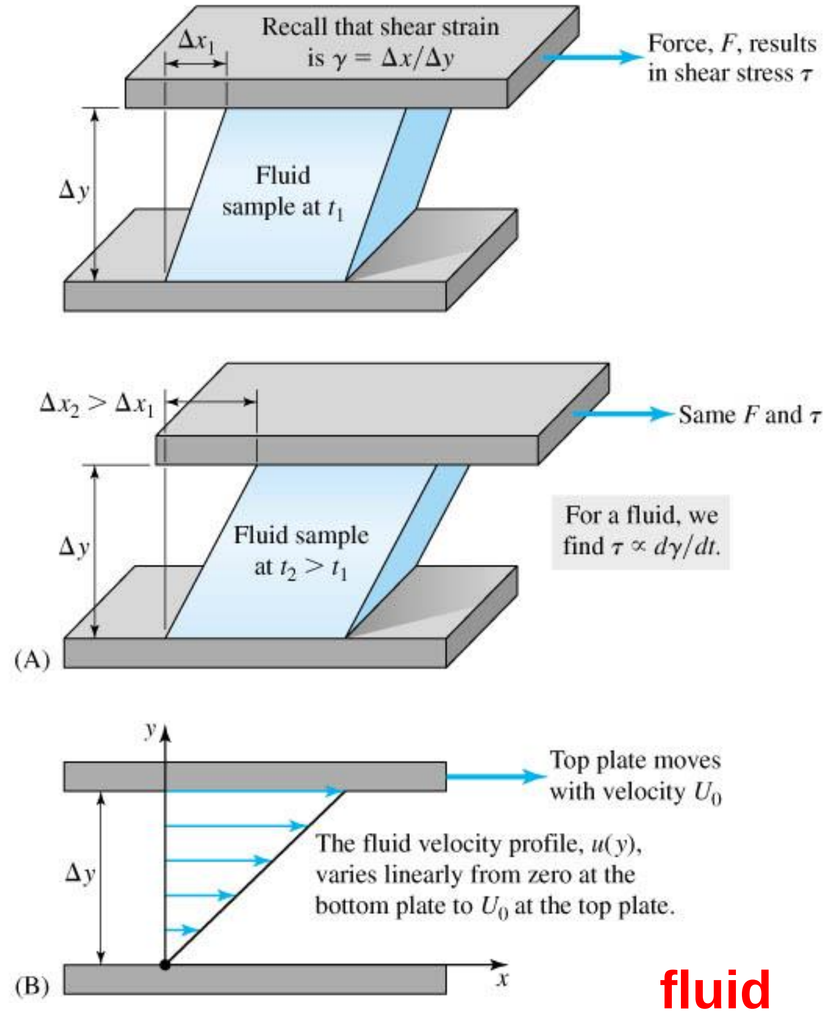


nearly incompressible **readily compressible**

Fluids Continuously Deform under a Shear Stress

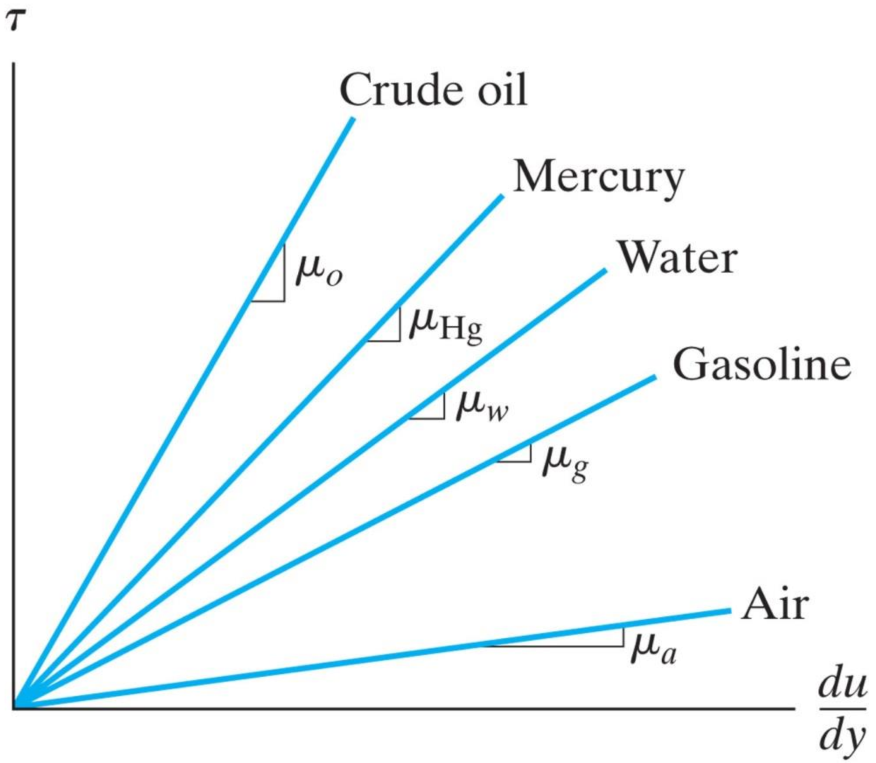


solid

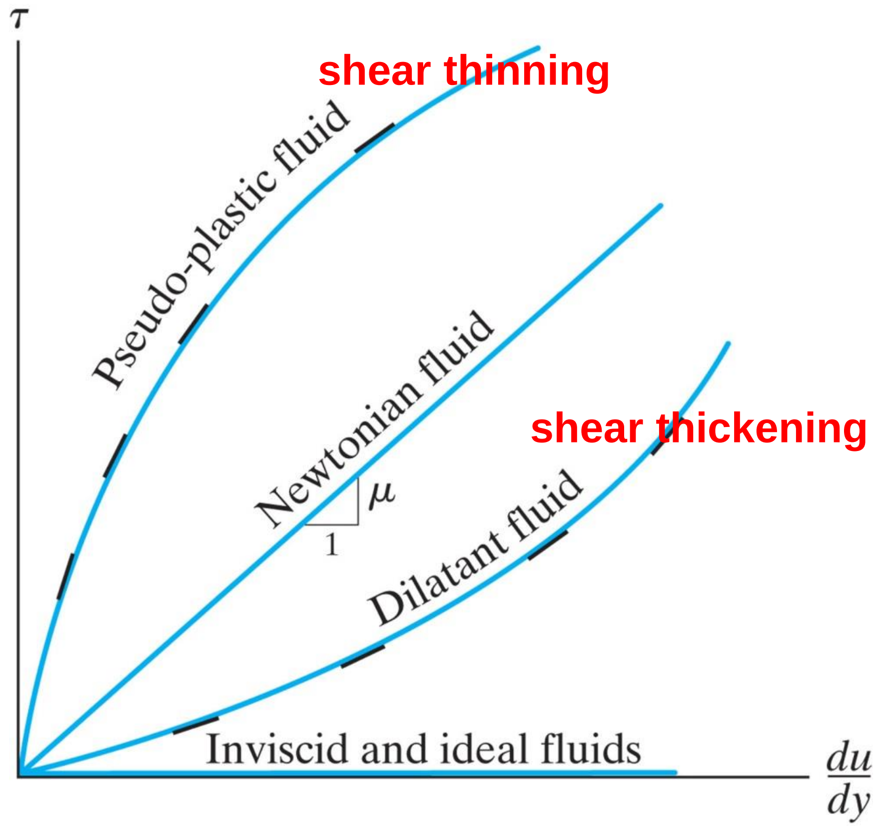


fluid

Newtonian & Non-Newtonian Fluids



The higher the viscosity, the more difficult it is for a fluid to flow.



Newtonian & Non-Newtonian Fluids

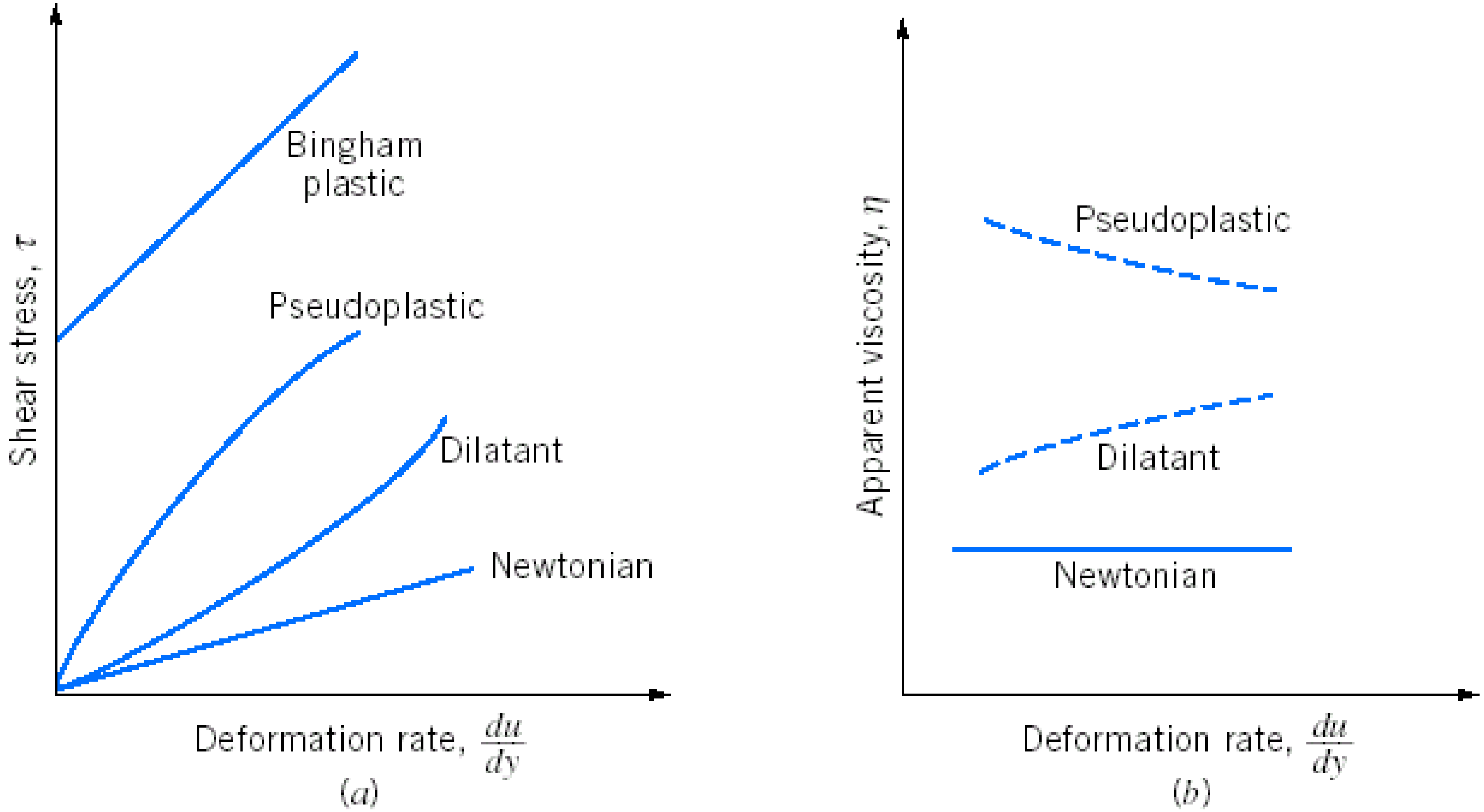
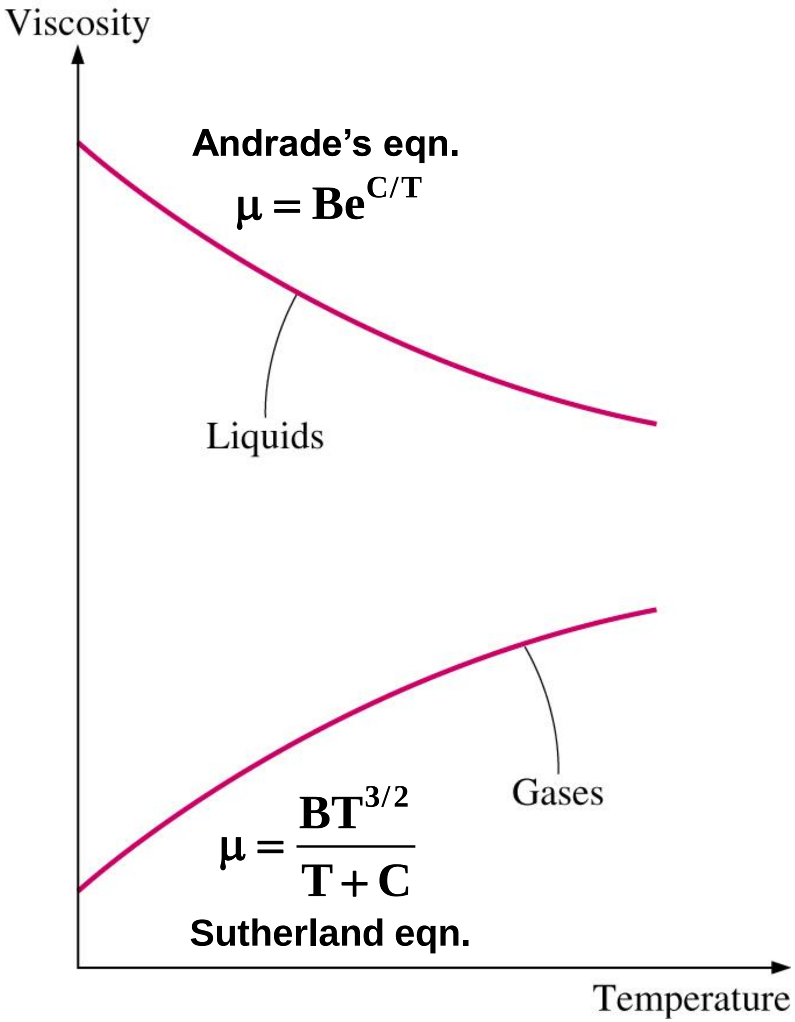


Fig. 2.8 (a) Shear stress, τ, and (b) apparent viscosity, η, as a function of deformation rate for one-dimensional flow of various non-Newtonian fluids.

Viscosity vs. Temperature

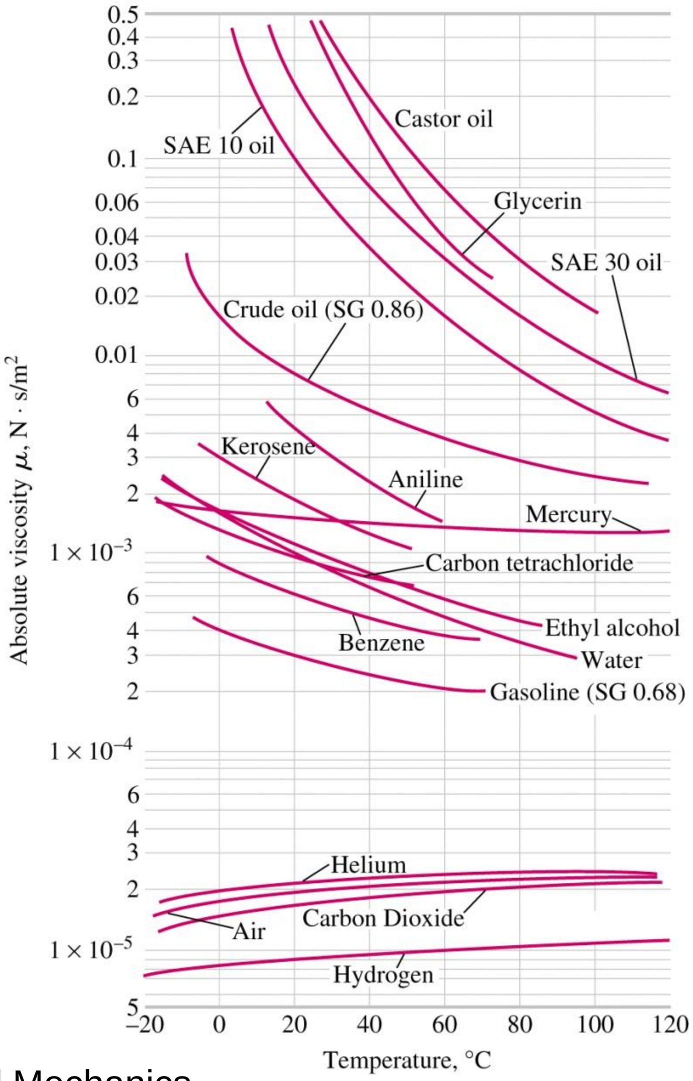


Andrade's eqn.

$$\mu = Be^{C/T}$$

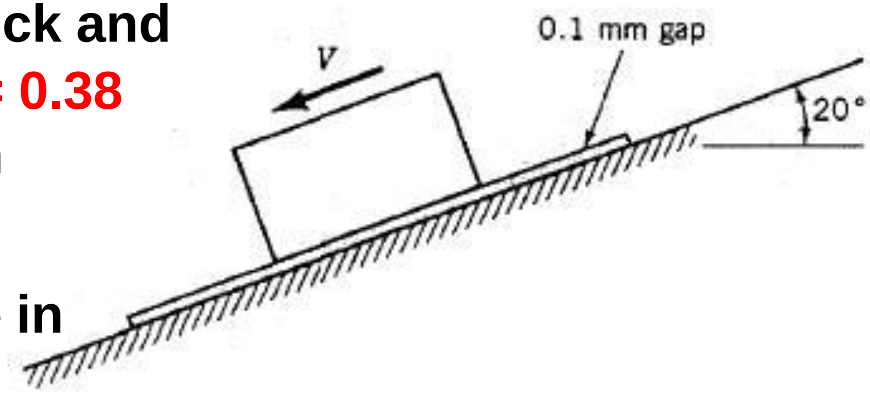
$$\mu = \frac{BT^{3/2}}{T+C}$$

Sutherland eqn.



Ex. #1 – Block on Inclined Surface

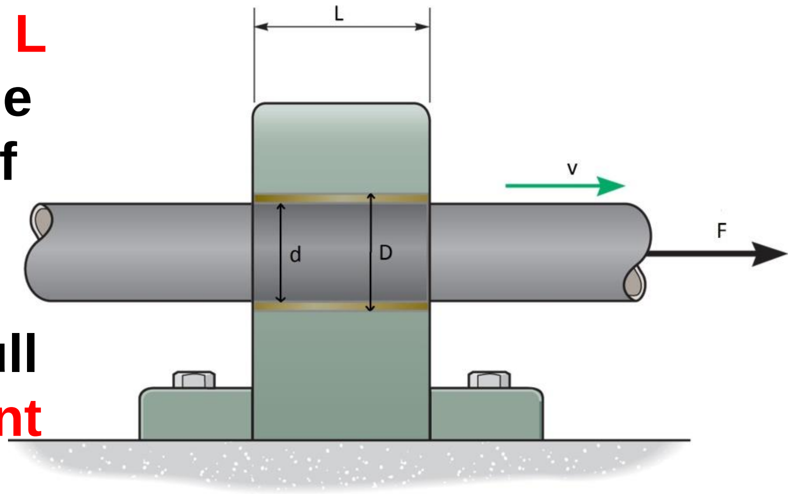
A **10 kg block** slides down a smooth inclined surface as shown. **Determine the terminal velocity v of the block** if the **0.1 mm gap** between the block and the surface contains **oil with μ = 0.38 N-s/m²**. The area of the block in contact with the oil is **0.2 m²**.



Assume that the velocity profile in the thin gap is linear.

Ex. #2 – A Simple Viscometer

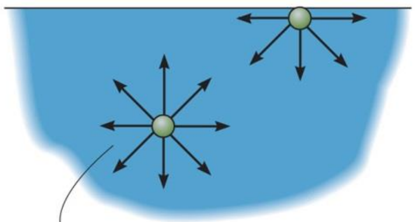
Consider a horizontal shaft of **length L** and **diameter d** being pulled along the axial centerline of a bearing sleeve of **diameter D**. The clearance is filled with the fluid of interest. At equilibrium, the **force F** needed to pull the rod through the sleeve at **constant velocity v** is exactly balanced by the viscous friction along the sides of the shaft.



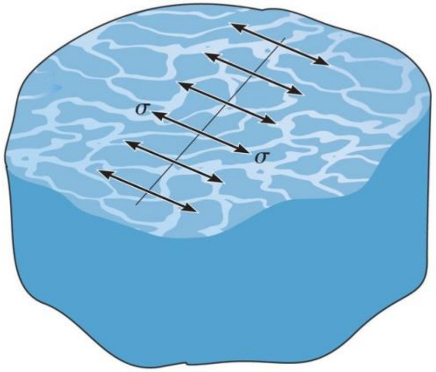
a. For this situation, **develop an expression for the fluid viscosity** in terms of the system parameters, F, v, d, D, and L. Assume a linear velocity profile in the thin gap.

b. Given that **d = 6 cm**, **D = 6.02 cm**, and **L = 40 cm**, **what is the kinematic viscosity of the test fluid** (**sg = 0.88**) if the measured steady state velocity was **0.4 m/s** for a applied force of **800 N**?

Surface Tension



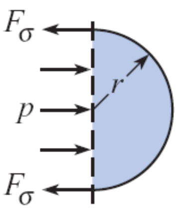
(a)



Surface tension is the force per unit length needed to separate the molecules on the surface

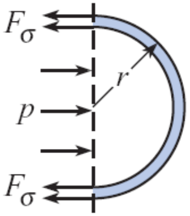
(b)

Surface tension forces for several cases ($F_\sigma = \sigma \times \text{length}$)

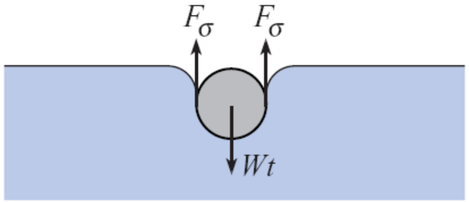


(*a*) Spherical droplet

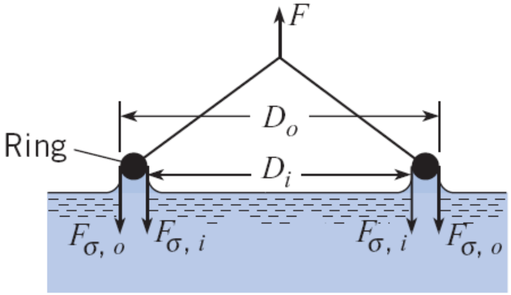
p is gage pressure here



(*b*) Spherical bubble

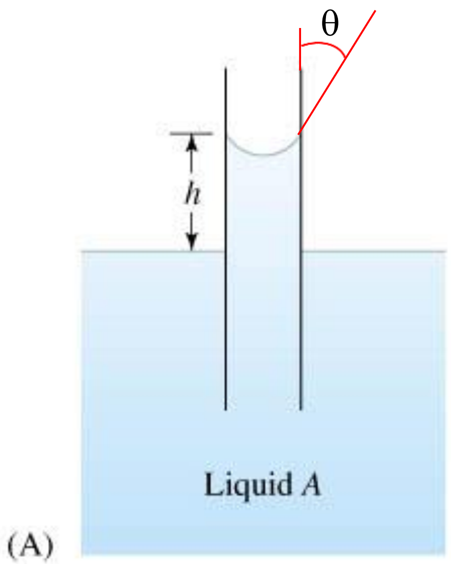


(*c*) Cylinder supported by surface tension (liquid does not wet cylinder)

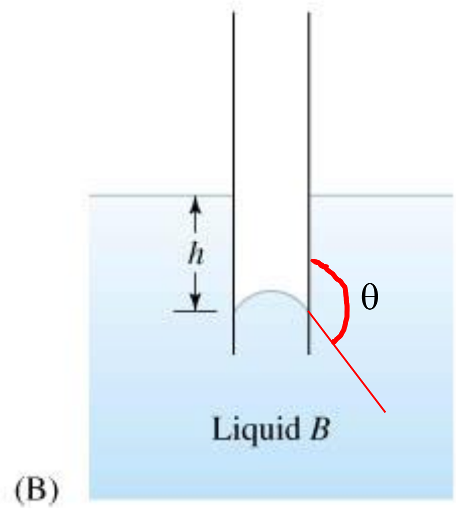


(*d*) Ring pulled out of liquid (liquid wets the ring)

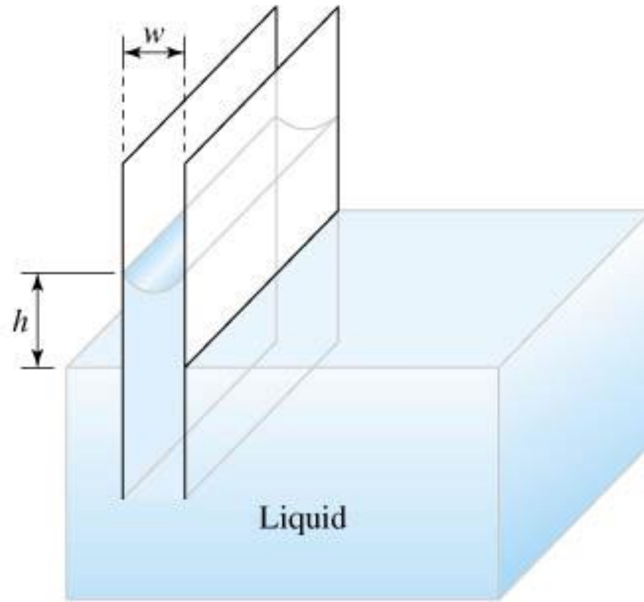
Capillary Action



wetting fluid



non-wetting fluid



Circular tube of diameter d: $\sigma\cos\theta(\pi d)-\rho g\left(\frac{\pi d^2 h}{4}\right)=0$ $\quad$ $h=\frac{4\sigma\cos\theta}{d\rho g}$

Rectangular slot of width w: $\sigma\cos\theta(2L)-\rho g(wLh)=0$ $\quad$ $h=\frac{2\sigma\cos\theta}{w\rho g}$

(assumes L >> w)