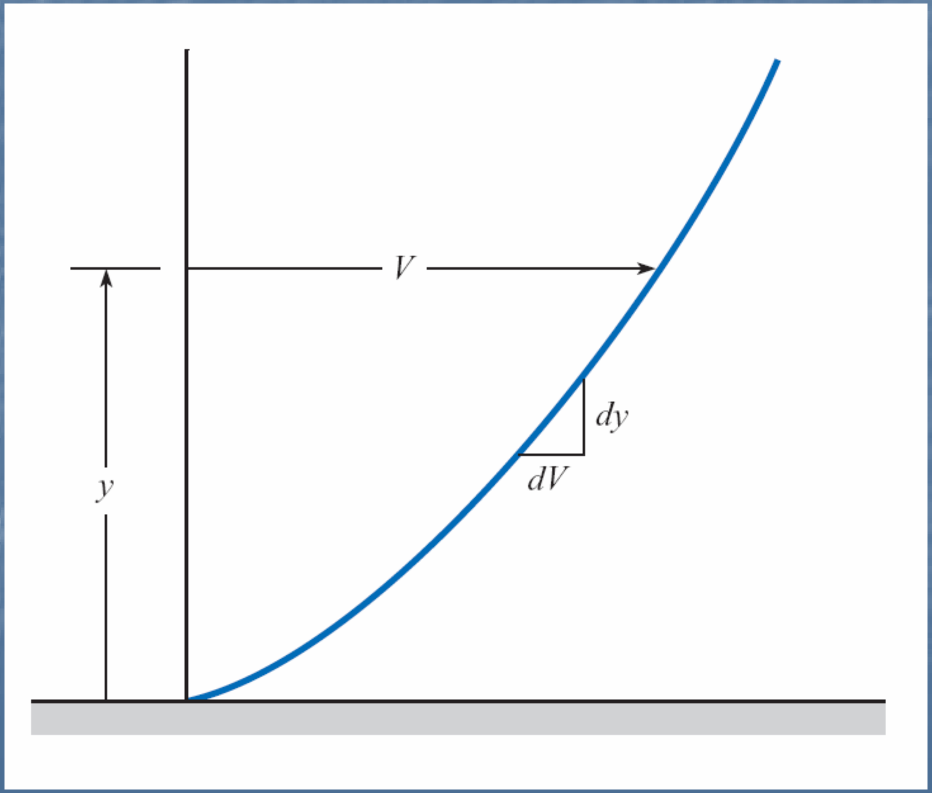
FLUID PROPERTIES

Viscosity (derives from the Latin word "viscum")

Is a measure of the resistance of a fluid which is being deformed by shear stress.

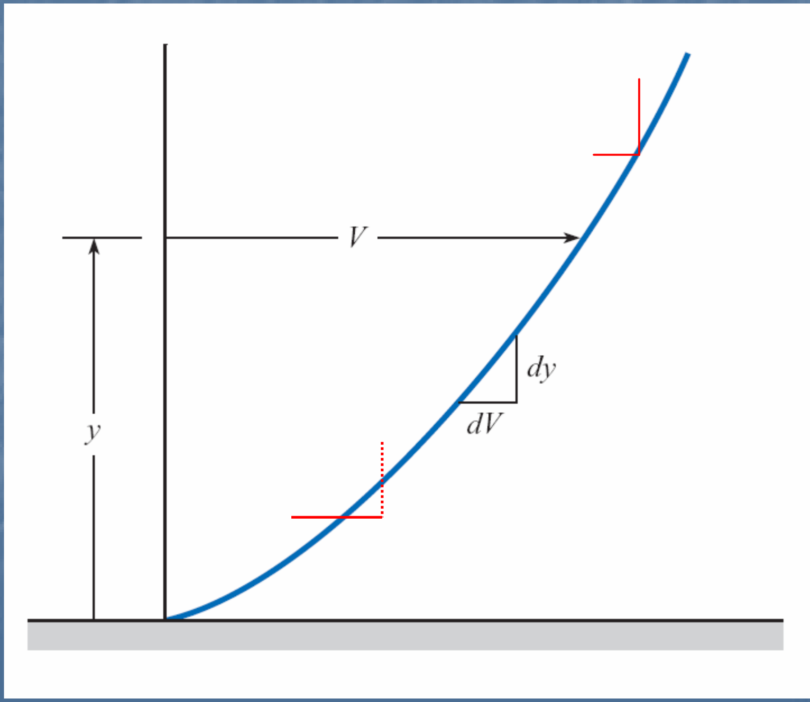
Figure 1



FLUID PROPERTIES

Consider the flow shown Fig. 1 where the velocity distribution is typical of a laminar flow next to a solid boundary. The following observation can be identified which are:

- The velocity gradient at the boundary is finite.
- The velocity gradient $\left(\frac{dV}{dy}\right)$, becomes smaller, with distance from the boundary.
- The velocity at the boundary is zero.



By definition, $\tau \propto \frac{dV}{dy}$, Then $\tau = \mu \frac{dV}{dy}$

Where:

$\tau =$ Shear stress applied

$\frac{dV}{dy} =$ Velocity gradient (Shear Strain)

FLUID PROPERTIES

Units of Viscosity:

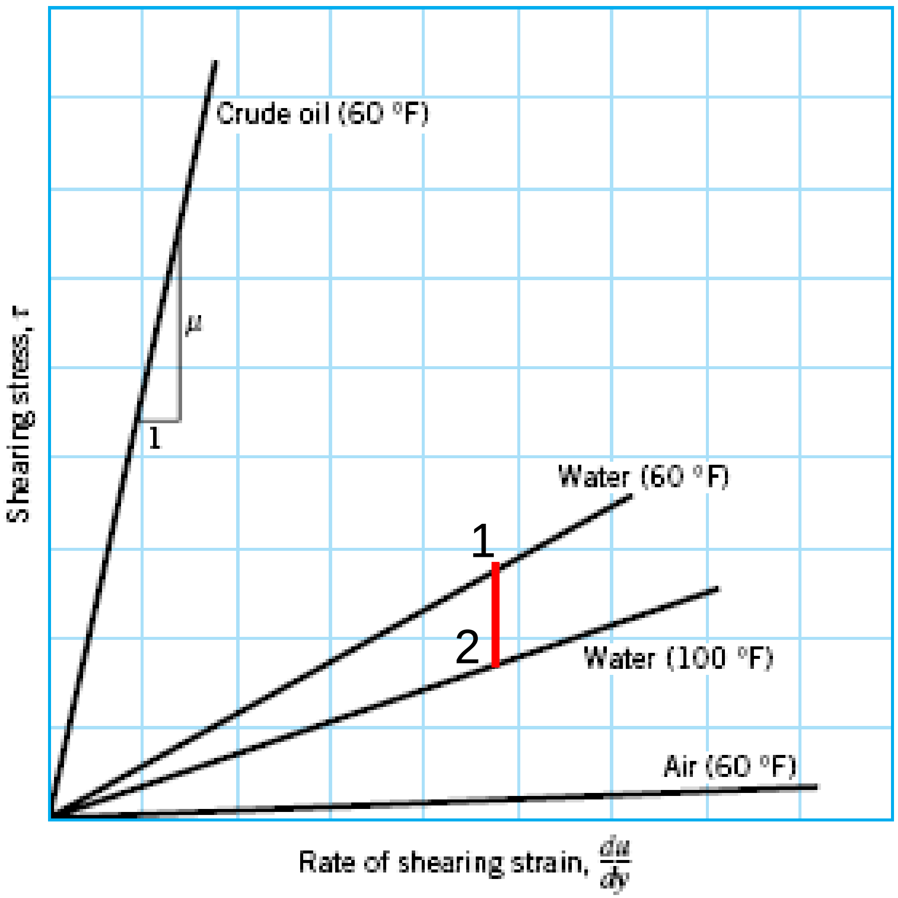
$$\mu = \frac{\tau}{\left(\frac{dV}{dy}\right)} = \frac{N/m^2}{\frac{m/s}{m}} = \frac{N\,s}{m^2}$$

Common Unit for Viscosity is Poise. (1 poise = $0.1\frac{Ns}{m^2}$).

Units of Kinematic Viscosity:

$$\nu = \frac{\mu}{\rho} = \frac{Ns/m^2}{kg/m^3} = \frac{m^2}{s}$$

FLUID PROPERTIES



$$\left(\frac{dV}{dy}\right)_1 = \left(\frac{dV}{dy}\right)_2$$

$$\tau_1 > \tau_2$$

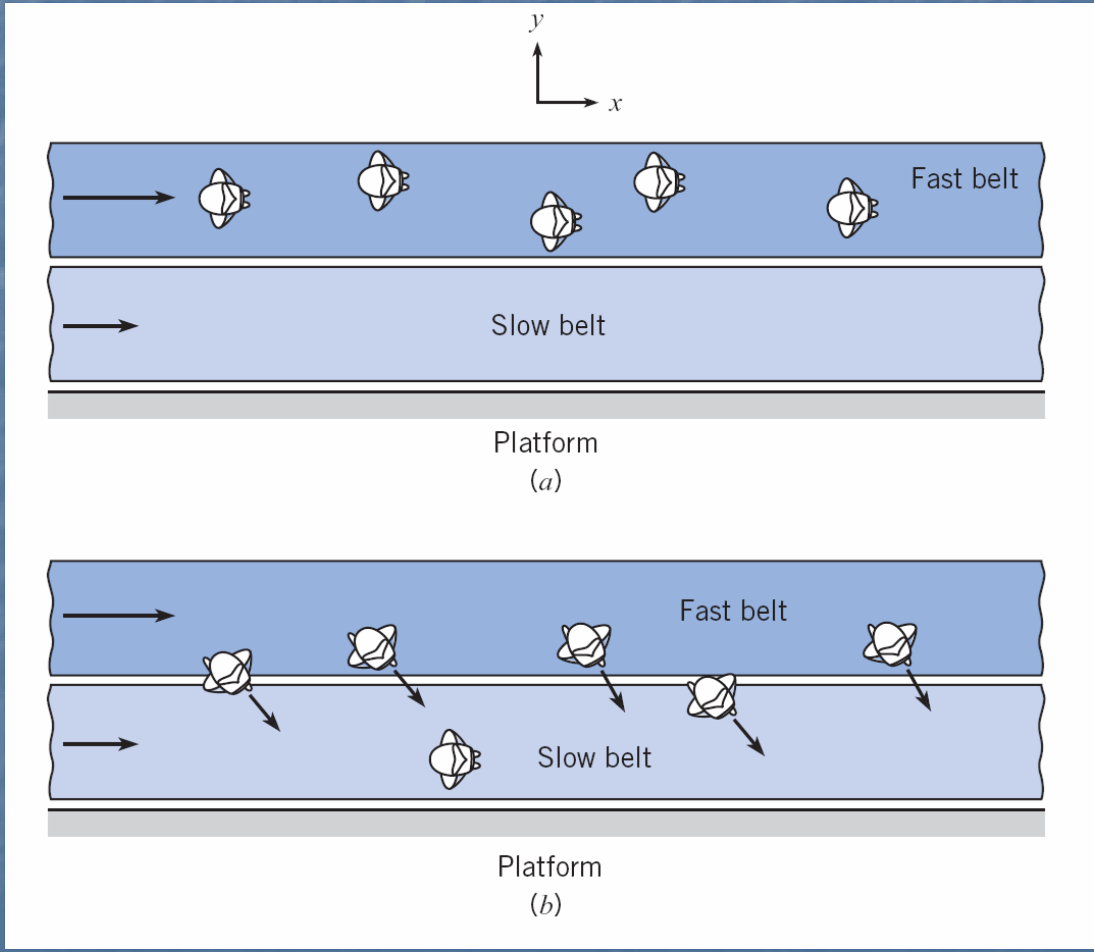
$$\tau = \mu \frac{dV}{dy}$$

$$\mu_1 > \mu_2$$

■ FIGURE 1.4 Linear variation of shearing stress with rate of shearing strain for common fluids.

FLUID PROPERTIES

Conveyor Belt

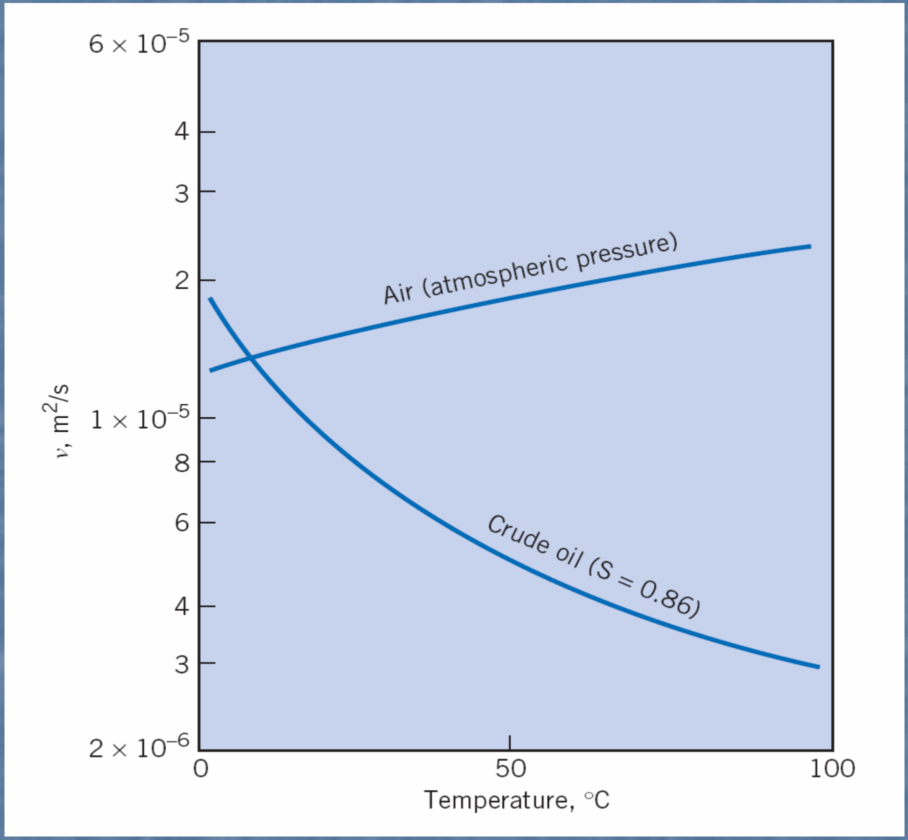


Kinematic Velocity = $\nu = \frac{\mu}{\rho}(\frac{m^2}{s})$

1. Variation of viscosity with temperature for gases

Sutherland Constant

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



(S) are found from Table (A.2)

2. Variation of viscosity with pressure for gases

Viscosity is **minmal** for pressure less **than 10 atmospheres**

Table (A-2) on Page (A-11)

TABLE A.2 PHYSICAL PROPERTIES OF GASES AT STANDARD ATMOSPHERIC PRESSURE AND 15°C (59°F)

Gas	Density, kg/m^3 ($slugs/ft^3$)	Kinematic Viscosity, m^2/s (ft^2/s)	R, Gas Constant, J/kg K (ft-lbf/slug-°R)	c_p, $\frac{J}{kg\ K}$ $\left(\frac{Btu}{lbm\text{-}°R}\right)$	$k = \frac{c_p}{c_v}$	S, Sutherland's Constant, K (°R)
Air	1.22 (0.00237)	1.46×10^{-5} (1.58×10^{-4})	287 (1716)	1004 (0.240)	1.40	111 (199)
Carbon dioxide	1.85 (0.0036)	7.84×10^{-6} (8.48×10^{-5})	189 (1130)	841 (0.201)	1.30	222 (400)
Helium	0.169 (0.00033)	1.14×10^{-4} (1.22×10^{-3})	2077 (12,419)	5187 (1.24)	1.66	79.4 (143)
Hydrogen	0.0851 (0.00017)	1.01×10^{-4} (1.09×10^{-3})	4127 (24,677)	14,223 (3.40)	1.41	96.7 (174)
Methane (natural gas)	0.678 (0.0013)	1.59×10^{-5} (1.72×10^{-4})	518 (3098)	2208 (0.528)	1.31	198 (356)
Nitrogen	1.18 (0.0023)	1.45×10^{-5} (1.56×10^{-4})	297 (1776)	1041 (0.249)	1.40	107 (192)
Oxygen	1.35 (0.0026)	1.50×10^{-5} (1.61×10^{-4})	260 (1555)	916 (0.219)	1.40	

END of

Lecture (3)