Units: slug, lbm, lb and N

slug: the unit of mass in BG system.

lbm: pound mass, the unit of mass in EE system.

lb: pound force, i.e. lbf, the unit of force in both BG and EE systems.

N: Newton, the unit of force in SI system.

BG system:

The mass unit slug is defined from the "Big Idea" of $F = ma$.

$$\underset{(1\ lb)}{F} = \underset{(1\ slug)}{m}\ \underset{(1\ ft/s^2)}{a}$$

$$(1\ lb) = (1\ slug)(1\ ft/s^2)$$

- That is, 1 slug is defined so that a force of 1 lb acting on a mass of 1 slug will give the mass an acceleration of 1 ft/s^2.
- In other words, 1 slug of mass is defined by $F = ma$ with $F = 1\ lb$ and $a = 1\ ft/s^2$. (F and $a \longrightarrow m$)

SI system:

The force unit N defined from the "Big Idea" of $F = ma$.

$$(1\ N) = (1\ kg)(1\ m/s^2)$$

- That is, 1 N is defined so that a force of 1 N acting on a mass of 1 kg will give the mass an acceleration of $1\ m/s^2$.

- In other words, 1 N of force is defined by $F = ma$ with $m = 1$ kg and $a = 1\ m/s^2$. (m and a $\longrightarrow$ F)

EE system:

The force unit lb (or lbf) is defined by the "Big Idea" of $F = ma$.

$$\begin{array}{ccccc} F & = & m & & a \\ \uparrow & & \uparrow & & \uparrow \\ (1\ \text{lb}) & = & (1\ \text{lbm}) & & (32.174\ ft/s^2) \end{array}$$

- That is, 1 lb is defined so that a force of 1 lb acting on a mass of 1 lbm will give the mass a "standard" gravitational acceleration of $32.174\ ft/s^2$.
- In other words, 1 lb of force is defined by $F = ma$ with $m = 1$ lbm and $a = 32.174\ ft/s^2$. (m and a $\longrightarrow$ F)
- 1 lb of force can be considered as "standard" weight of a mass of 1 lbm.

Conversion of Units

$$\left.\begin{aligned} 1\ \text{lb} &= 1\ \frac{\text{slug}\cdot\text{ft}}{s^2} \\ 1\ N &= 1\ \frac{\text{kg}\cdot\text{m}}{s^2} \end{aligned}\right\}$$

These two unit conversions will be regularly used in our course of fluid mechanics, especially in Chapter 5.

$$1\ \text{slug} = 32.174\ \text{lbm}$$

Dimensionally Homogeneous Equation

- An equation is dimensionally homogeneous if the dimensions of its left side are the same as the dimensions of its right side.
- For a general homogeneous equation, the constant is dimensionless, and all the physical quantities involved can keep the same dimensions of the two sides of the equation.
- For a restricted homogeneous equation, the constant is not dimensionless; in other words, the constant must have dimensions to ensure the same dimensions of the two sides of the equation; this type of equations can work only with the values of the involved physical quantities in particular units.

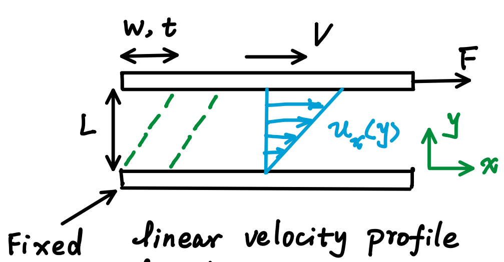
Shear Stress and Rate of Shear Strain

$$\tau_{yx} = \mu \cdot \frac{du}{dy}$$

- τ_{yx}: shear stress $\left(\frac{\text{Force}}{\text{Area}}\right)$
- μ: Viscosity (Proportionality coefficient)
- $\frac{du}{dy}$: Velocity gradient (Local slope of velocity profile, Rate of shear strain or shear rate)

Interpretation for $\dot{\gamma} = \frac{du}{dy}$

i.e. rate of shear strain = velocity gradient



linear velocity profile for this simple case

Velocity: $V = \frac{W}{t}$

Shear strain: $\gamma = \frac{W}{L}$

Rate of shear strain: $\dot{\gamma} = \left(\frac{W}{L} - \frac{0}{L}\right)/t$

$$\dot{\gamma} = \frac{W/t}{L} = \frac{V}{L} = \frac{V-0}{L-0} = \frac{du}{dy}$$