- Fluid Mechanics - Study of behavior of fluids that are either at rest or in motion
  - Used by Mech Es to design pumps, compressors, turbines, etc.

- Branches of Fluid Mechanics
  - Hydrostatics
    - Considers forces acting on a fluid at rest
  - Fluid Kinematics
    - Study of the geometry of fluid motion
  - Fluid dynamics
    - Considers the forces that cause acceleration of a fluid

- Historical Development
  - Euler and Bernoulli pioneered the field of hydrodynamics, a branch of mathematics dealing with the motion of an idealized fluid
  - Hydraulics uses empirical equations found from fitting curves to data determined from experiments, primarily for applications involving water

- Characteristics of Matter
  - Solid
    - Maintains a definite shape and volume
    - Molecules are densely packed and held tight together
  - Liquid
    - Molecules are more spread out
    - Does not hold shape, instead flows and takes shape of container
    - resist compressive forces when confined
  - Gas
    - Fills entire volume of its container
    - Molecules are very far apart
  - Definition of a fluid
    - Liquids and gases are classified as fluids because they are substances that continuously deform or flow when subjected to a shear or tangential force
  - Continuum
    - Assume fluid is uniformly dispersed and continuous throughout this volume

- Basic Fluid Properties
  - Density ρ (rho)
    - Liquids density doesn't vary
    - gas density varies
  - Specific Weight
    - Weight per unit volume

      $$\gamma = \frac{W}{\forall} \quad \text{or} \quad \gamma = \rho g$$
  - Specific Gravity
    - Dimensionless quantity that is defined as ratio of density or specific weight to that of some other substance

      $$S = \frac{\rho}{\rho_w} = \frac{\gamma}{\gamma_w}$$

      $$\rho_w = 1000\ kg/m^3 \qquad \gamma_w = 62.4\ lb/ft^3$$
  - Ideal Gas Law
    - Consider every gas to be ideal

      $$p = \rho R T$$
    - p = absolute pressure
    - ρ = density
    - R = Gas Constant
    - T = absolute temperature
  - Bulk Modulus
    - Amount by which a fluid offers a resistance to compression

      $$E_{\forall} = -\frac{dp}{d\forall/\forall} \qquad \text{Units} = \text{Pressure}$$
    - Liquids have very large bulk modulus
    - Gases have relatively small bulk modulus

- Viscosity
  - Measures resistance to movement
  - Molecules on top layer have velocity to the right pushing molecules below them, while molecules in bottom layer are moving slower, slowing down the top layer
  - Newton's Law of Viscosity
    - Shear Stress τ (Tau)

- A Tangential force ΔF that acts on an area ΔA of the element

$$\tau = \lim_{\Delta A \to 0} \frac{\Delta F}{\Delta A} = \frac{dF}{dA}$$

- Shear Strain
  - Shear stress causes each element to deform into the shape of a parralelogram
  - Specified by small angle $\Delta\alpha$ (alpha)

$$\Delta\alpha \approx \tan\Delta\alpha = \frac{\delta x}{\Delta y}$$

  - time rate of change in this shear strain (angle) is important
  - top elements move at rate of Δu relative to its bottom, so $\delta x = \Delta u \Delta t$

$$\frac{\Delta\alpha}{\Delta t} = \frac{\Delta u}{\Delta y} \rightarrow \frac{d\alpha}{dt} = \frac{du}{dy}$$

  - $\frac{du}{dy}$ is known as velocity gradient because it is an expression of the change in velocity u with respect to y
  - Newton proposed that shear stress in the fluid is directly proportional to this shear strain rate or velocity gradient
  - This is referred to as Newton's Law of Viscosity

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

  - Constant of proportionality μ is a physical property of the fluid that measures the resistance to fluid movement called dynamic viscosity with units $N \cdot s/m^2$

- Newtonian Fluids
  - Any fluid that obeys Newton's Law of Viscosity
- Non-Newtonian fluid
  - Fluids whose very thin layers exhibit a nonlinear behavior between the applied shear stress and the shear-strain rate are classified as Non-Newtonian fluids
  - Apparent Viscosity: Slope of curve for any specific shear-strain rate
  - Dilatant Fluid: Apparent Viscosity increases as shear stress increases
    - Water with high concentrations of sugar and Quicksand
  - Pseudo-plastic fluids: Apparent Viscosity decreases as shear stress increases
    - Blood, Gelatin, and Milk
- Inviscid and Ideal Fluids
  - Inviscid Fluid: fluid with zero viscosity and offers no resistance to shear stress. Frictionless

- Ideal Fluid: Fluid that is both inviscid and incompressible
- Pressure and Temperature Effects
  - Viscosity increases with Pressure, however the increase is small so it's generally neglected
  - For liquids, as temp increases viscosity decreases
    - Andrade's Equation $\mu = Be^{C/T}$
  - For gases, as temp increases viscosity increases
    - Sutherland Equation $\mu = \frac{BT^{3/2}}{(T+C)}$

- Kinematic Viscosity
  - ν (Nu), Ratio of dynamic viscosity to density

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