ENGR 292 Fluids and Thermodynamics

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Review of Last Class

- ***Course Outline Class Information***
  - *Contact Information, Website*
  - *Objectives - Mechanical Engineering Bridge (UBC)*
  - *Teaching Style, Lectures, Assignments, Methodology*
  - *Evaluation and Grading System*
  - *Academic honesty etc.*
- ***Brief Review Course Schedule (Jan.10 – Apr.18)***

Course Schedule

No.	Contents	Days
1	General • Fluid Properties	Jan.13
2	Fluid Statics • Pressure • Buoyancy • Hydrostatics Forces • Pressure Measurement	Jan.17, 20, 24, 27
3	Fluid Dynamics • Conservation of Mass • Momentum and Energy • Bernoulli's Equation & Navier-Strokes Equation • Laminar & Turbulent Flow in Pipes • Turbo-machinery	Jan.31, Feb.03, Feb.07, Feb.24, Feb.28

Course Schedule

No.	Contents	Days
4	Thermodynamics & Heat Transfer • Equations of State • Conduction • Convection	Mar. 03, 07,14, 17, 21, 24, 28
5	Analytical Tools • Dimensional Analysis • Modeling • LaGrange Multipliers • Second Derivative Test • Multiple Integrals and Applications	Mar.31, Apr.04
6	Other topics as required to ensure the student has a rounded knowledge of Fluid Dynamics, Thermodynamics & Heat Transfer	Apr.07

ENGR 292

- ***K Drive: Li\ENGR 292***
- ***Website:*** ***http://www.fireflylabs.com/disted/courses/e292(2017)/e292-index.html***
- ***D2L ?***

What is Fluid?

- ***In physics, a state of matter is one of the distinct forms that matter takes on.***
- ***Four states of matter are observable in everyday life: solid, liquid, gas, and plasma.***

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What is Fluid?

- Solid, Liquid, Gas, Plasma
- Fluid: may be defined as a substance that deforms continuously when acted upon by a shear stress of any magnitude.

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What is Fluid?

- Fluid
  - Liquid
  - Gas

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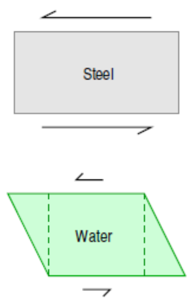
What is Fluid?



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What is Fluid?

- Main Differences between Liquid and Gas
  - Relative compressibility
    - Liquid are only slightly compressible (Bulk Modulus)
    - Gases are readily compressible
  - Shape and flowability
    - Liquid covers the bottoms and sides, flowability is low compare with gas - Viscosity
    - Gas fills all the container and escape if possible
- Fluid Power
  - Hydraulics – Liquid
  - Pneumatics – Gas

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Fluid Mechanics

- Fluid Mechanics is the study of fluids at rest and in motion
  - Fluid statics
  - Fluid dynamics
- Before we start Fluid Statics and Fluid Dynamics, we need to know the properties of Fluids

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Fluid Properties of State

- Properties of State: properties that can be measured at a single point in time.
- Properties of state describe the state of the substance right now. No knowledge of past or future conditions required.

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Primary Dimensions

- Primary Dimensions and Units
  - Mass
  - Length
  - Time
  - Temperature

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Primary Dimensions

- Some notes about units
  - There are two unit systems:
    - The international system of units (SI)
    - The U.S. Customary System (Imp)
  - Standard units vary widely within industry
  - While SI is most common, Imp units are quite common and must be well understood
  - People can die when units are not converted property or correctly

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Primary Dimensions

- Mass (m)
  - A measure of an object's resistance to changing it's state of motion when a force is applied
  - How much inertia can it have?
  - SI Unit: Kilogram (kg)
  - Imp Unit: Slug
  - Conversion factor: 1 Slug = 14.59 kg

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Primary Dimensions

- Length (L)
  - The distance from one end of something to the other
  - SI Unit: meter (m)
  - Imp Unit: foot (ft)
  - Conversion factor: 1 ft = 0.3048 m

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Primary Dimensions

- Time (t)
  - The measure or measurable period during which an action, process, or condition exists or continues.
  - How long does it take?
  - SI Unit: second (s)
  - Imp Unit: second (s)
  - Conversion factor: N/A

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Primary Dimensions

- Temperature (T)
  - Related to the internal energy of a fluid. A measure of the atomic scale vibration
  - How warm is it? Or how cold is it?
  - SI Unit: Celsius (°C) T_C
  - Imp Unit: Fahrenheit (°F) T_F
  - Conversion factor: $T_C = (T_F - 32)/1.8$ or $T_F = 1.8T_F + 32$

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Secondary Dimensions

- ***There are only four primary dimensions (above) in fluid mechanics***
- ***There are many secondary dimensions***
  - ***Force; Pressure***
  - ***Area; Volume***
  - ***Velocity; Acceleration***
  - ***Density; Specific weight; Specific gravity; Specific volume***
  - ***Energy; Power***
  - ***Flow rate: Volume flow rate; Mass flow rate;***
  - ***Viscosity: Absolute viscosity; Kinematic viscosity***

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Secondary Dimensions

- ***Force (F)***
  - ***The time rate of change of momentum. Newton's 2nd Law***
  - $F = ma$
  - ***SI Unit: Newton (N)*** *= 1kg·1m/s²*
  - ***Imp Unit: lbf*** *= 1 slug ·1ft/s²*
  - ***Conversion factor: 1 lbf = 4.4482 N***

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Secondary Dimensions

- ***Pressure or Stress(p)***
  - ***Compression stress at a point in static fluid. Differences in pressure often drive a fluid flow, especially in ducts.***
  - ***SI Unit:*** *Pa =N/m²*
  - ***Imp Unit:*** *lbf/ft²*
  - ***Conversion factor: 1*** *lbf/ft²* ***= 47.88*** *Pa*

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Secondary Dimensions

- ***Area (A)***
  - ***The quantity that expresses the extent of a two - dimensional figure or shape, or planar lamina, in the plane.***
  - ***SI Unit: Square meter (****m²* ***)***
  - ***Imp Unit: Square foot (****ft²****)***
  - ***Conversion factor: 1*** *m²* ***= 10.764*** *ft²*

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Secondary Dimensions

- ***Volume (V)***
  - ***The amount of space that a substance or object occupies, or that is enclosed within a container.***
  - ***SI Unit: Cubic meter (****m³****)***
  - ***Imp Unit: Cubic foot (****ft³****)***
  - ***Conversion factor: 1*** *m³* ***= 35.315*** *ft³*

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Secondary Dimensions

- ***Velocity (v)***
  - ***Physical vector quantity; both magnitude and direction are needed to define it. The magnitude of velocity is called "speed".***
  - ***SI Unit: m/s***
  - ***Imp Unit: ft/s***
  - ***Conversion factor: 1*** *m/s* ***= 0.3048*** *ft/s*

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Secondary Dimensions

- **Acceleration (a)**
  - **The rate of change of velocity**
  - **SI Unit:** m/s^2
  - **Imp Unit:** ft/s^2
  - **Conversion factor: 1** m/s^2 **= 0.3048** ft/s^2

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Secondary Dimensions

- **Density (ρ)**
  - **Mass per unit volume.**
  - $\rho = \frac{m}{V}$
  - **SI Unit:** kg/m^3
  - **Imp Unit:** $slugs/ft^3$
  - **Conversion factor: 1** $slugs/ft^3$ **= 515.4** kg/m^3

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Secondary Dimensions

- **Density (ρ) (cont'd)**
  - **Density in liquids is nearly constant but highly variable in gasses.**
  - **Liquid are often treated as "incompressible" meaning density does not change with pressure.**
- **Examples:**
  - **Density of water at 4°C, 1 atm pressure** $\rho = 1000$ kg/m^3
  - **Density of air at 4°C, 1 atm pressure** $\rho = 1,27$ kg/m^3

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Secondary Dimensions

- **Specific weight (γ)**
  - **Weight per unit volume**
  - $\gamma = \frac{W}{V}$
  - **SI Unit:** N/m^3
  - **Imp Unit:** lbf/m^3
  - **Conversion factor: 1** $slugs/ft^3$ **= 515.4** kg/m^3
  - **Density vs Specific weight:** $\gamma = \rho g$

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Secondary Dimensions

- **Specific gravity(sg)**
  - **The ratio of the density of a fluid to the density of water at a reference temperature**
  - $sg = \frac{\rho}{\rho_{H_2O,4°C}}$
  - **SI Unit: Dimensionless**
  - **Imp Unit: Dimensionless**
  - **Conversion factor: N/A**

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Secondary Dimensions

- **Specific volume (v)**
  - **The amount of volume occupied by 1 unit mass in a substance**
  - $v = \frac{1}{\rho}$
  - **SI Unit:** m^3/kg
  - **Imp Unit:** $ft^3/slugs$
  - **Conversion factor:**

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Secondary Dimensions

- ***Energy (E)***
  - ***The ability to do work***
  - ***SI Unit: J= N·m***
  - ***Imp Unit: lbf·ft***
  - ***Conversion factor: 1 lbf·ft = 1.3558 J***

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Secondary Dimensions

- ***Power (P)***
  - ***The amount of energy put out or produced in a given amount of time.***
  - ***SI Unit: W= J/s***
  - ***Imp Unit: lbf·ft/s***
  - ***Conversion factor: 1 lbf·ft/s= 1.3558 W***

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Secondary Dimensions

- ***Volume flow rate (Q')***
  - ***The volume of fluid which passes per unit time***
  - ***Q'=v/Δt***
  - ***SI Unit:*** *m^3/s*
  - ***Imp Unit:*** *ft^3/s*
  - ***Conversion factor: 1*** *m^3/s* ***= 35.3147*** *ft^3/s*

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Secondary Dimensions

- ***Mass flow rate (m')***
  - ***The mass of fluid which passes per unit time***
  - ***m'=m/Δt***
  - ***SI Unit:*** *kg/s*
  - ***Imp Unit:*** *slugs/s*
  - ***Conversion factor:***

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Secondary Dimensions

- ***Viscosity (μ)***
  - ***Quantitative measure of a fluid's resistance to flow.***
  - ***Qualitatively defined as the property of a fluid that signifies the ease with which the fluid flows under specified conditions***
  - ***Flowability***
  - ***SI Unit:*** *kg/(m·s)*
  - ***Imp Unit:*** *slugs/(ft·s)*
  - ***Conversion factor: 1*** *slug/(ft·s) = 47.88 kg/(m·s)*

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Secondary Dimensions

- ***Viscosity (μ) (cont'd)***
  - ***We can easily move through air, which has very low viscosity. Movement is more difficult in water, which has 50 times higher viscosity than air. SAE 30 oil is 300 times more viscous than water***

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Secondary Dimensions

- ***Viscosity (μ) (cont'd)***
  - ***Dynamic Viscosity (Absolute Viscosity)***
  - ***Kinematic Viscosity***

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Secondary Dimensions

- ***Dynamic Viscosity (Absolute Viscosity)***
  - ***Determine the fluid strain rate that is generated by a given applied shear stress (τ)***
  - ***Shear stress:***

$$\tau = \frac{F}{A} \ (N/m^2)$$

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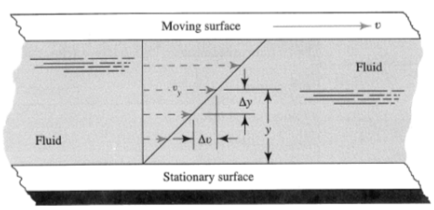
Secondary Dimensions



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Secondary Dimensions

- ***Dynamic Viscosity (cont'd)***

The fact that the shear stress in the fluid is directly proportional to the velocity gradient can be stated mathematically as:

$$\tau = \mu \frac{\Delta v}{\Delta y}$$

where the constant of proportionality μ (the Greek letter mu) is called dynamic viscosity of the fluid

Please note:

η (the Greek letter eta) is also used for Dynamic or Absolute Visocity

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Secondary Dimensions

- ***Units for Dynamic Viscosity (cont'd)***

$$\mu = \tau \frac{\Delta y}{\Delta v}$$

The unit for μ can be derived by substituting the SI units into this equation.

- ***SI Unit:*** *N·s/m^2 or Pa·s or kg/(m·s)*
  - *Pa = N/m^2*
  - *N = kg · m/s^2*
- ***Imp Unit:*** *lb·s/ft^2 or slug/(ft·s)*
- ***Conversion factor:***

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Secondary Dimensions

- ***Kinematic Viscosity (v)***
  - ***A measure of the resistance to flow, equal to the absolute viscosity divided by it's density***
  - $v = \frac{\mu}{\rho}$
  - ***SI Unit:*** *m^2/s*
  - ***Imp Unit:*** *ft^2/s*
  - ***Conversion factor:***

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Secondary Dimensions

- ***Variation of Viscosity with Temperature***
  - ***All fluids exhibit similar behavior to some extent: the higher the temperature, the lower the viscosity, vice vista.***
  - ***This is especially important for lubricating oils and hydraulic fluids used in equipment that must operate at wide extreme of temperature***

Secondary Dimensions

- ***Selected values of viscosity***

Liquid	Temperature (℃)	Dynamic Viscosity (N.s/m^2)
Water	20	1.0×10^{-3}
Water	70	4.0×10^{-4}
Gasoline	20	3.1×10^{-4}
Gasoline	62	2.0×10^{-4}
SAE 30 Oil	20	3.5×10^{-1}
SAE 30 Oil	80	1.9×10^{-2}

Secondary Dimensions

- ***Viscosity Index:***
  - ***Viscosity Index: A measure of how greatly the viscosity of a fluid changes with temperature is given by its viscosity index, sometimes referred to as VI***
  - ***VI is determined by measuring the kinematic viscosity of the sample fluid at 40℃ and 100℃ and comparing these values with those of certain reference fluids that were assigned VI values of 0 and 100.***

Secondary Dimensions

- ***Viscosity Index:***
  - ***The general form of the equation for calculating the viscosity index for a type of oil that has a VI value up to and including 100 is given by the following formula. All kinematic viscosity values are in the unit of mm^2/s***

$$VI = \frac{L - U}{L - H} \times 100$$

where

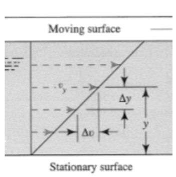
U = kinematic viscosity at 40 ℃ of the test oil

L = kinematic viscosity at 40 ℃ of a standard oil of 0 VI having the same viscosity at 100 ℃ as the test oil

H = kinematic viscosity at 40 ℃ of a standard oil of 100 VI having the same viscosity at at 100 ℃ as the test oil

Secondary Dimensions

- ***Newtonian Fluid vs. Non-Newtonian Fluid***
- ***Any fluid that behaves in accordance with Fig and equation below is called Newtonian fluid.***



$$\tau = \mu \frac{\Delta v}{\Delta y}$$

Secondary Dimensions

- ***Most common fluids are classified as Newtonian fluids:***
  - ***Water***
  - ***Oil***
  - ***Gasoline***
  - ***Alcohol***
  - ***Kerosene***
  - ***Benzene***
  - ***Glycerin***
  - ***…***

Secondary Dimensions

- ***Bulk modulus:* is defined as the ratio of change in pressure to relative change in density**
- ***Symbol:*** $E \quad (K, \beta, B)$
- ***The mathematical definition for Bulk modulus is***

$$\boldsymbol{E} = \frac{-\Delta \boldsymbol{P}}{\Delta \boldsymbol{V}/\boldsymbol{V}}$$

- ***SI Unit:*** *Pa =N/m²*
- ***Imp Unit:*** *lbf/ft²*
- ***Conversion factor: 1*** *lbf/ft²* ***= 47.88*** *Pa*

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Secondary Dimensions

- ***Values for Bulk Modulus for selected liquids at atmospheric pressure and 20*** ℃

Liquid	psi	MPa	GPa
Machine oil	189,000	1,303	1.3
Water	316,000	2,179	2.2
Mercury	3,590,000	24,750	24.75

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Thank you

- ***Any Questions?***
- ***See you next Tuesday 12:30 pm at CBA 121***
- ***We will start Fluid Statics.***