FLUID MECHANICS

(AME 3810)

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Course Contents

References

1. *R.W. Fox, A.T. McDonald, and P. J. Pritchard, "Introduction to Fluid Mechanics", John Wiley & Sons, 7th Edition, 2008.*
2. *P.J. Pritchard and J.C. Leylegian, "Introduction to Fluid Mechanics", 8th Ed., 2011.*
3. *J.F. Douglas, J. M. Gasiorek, J. A. Swaffield and Lynne B. Jack "Fluid Mechanics", 5th. Ed., 2006.*
4. *B. R. Munson, D.F. Young, T.H. Okiishi, and W.W. Huebsch. "Fundamentals of Fluid Mechanics", 6th Ed., 2009.*
5. *F. White, "Fluid Mechanics", 4th. Ed.,*

Assessment

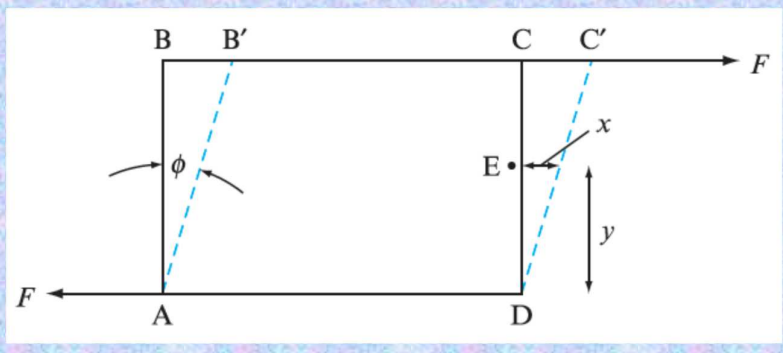
	Assessment task (e.g. essay, test, group project, examination etc.)	Week due	%
1	Homework Assignments	Every weeks	10
2	Attendance and Participation	Every weeks	10
3	Mid Term Exam	8	10
4	Quizzes	…	10
5	Laboratory reports	Every weeks	10
6	Laboratory Tests	…	10
	Final Exam	17	40

Chapter 1:

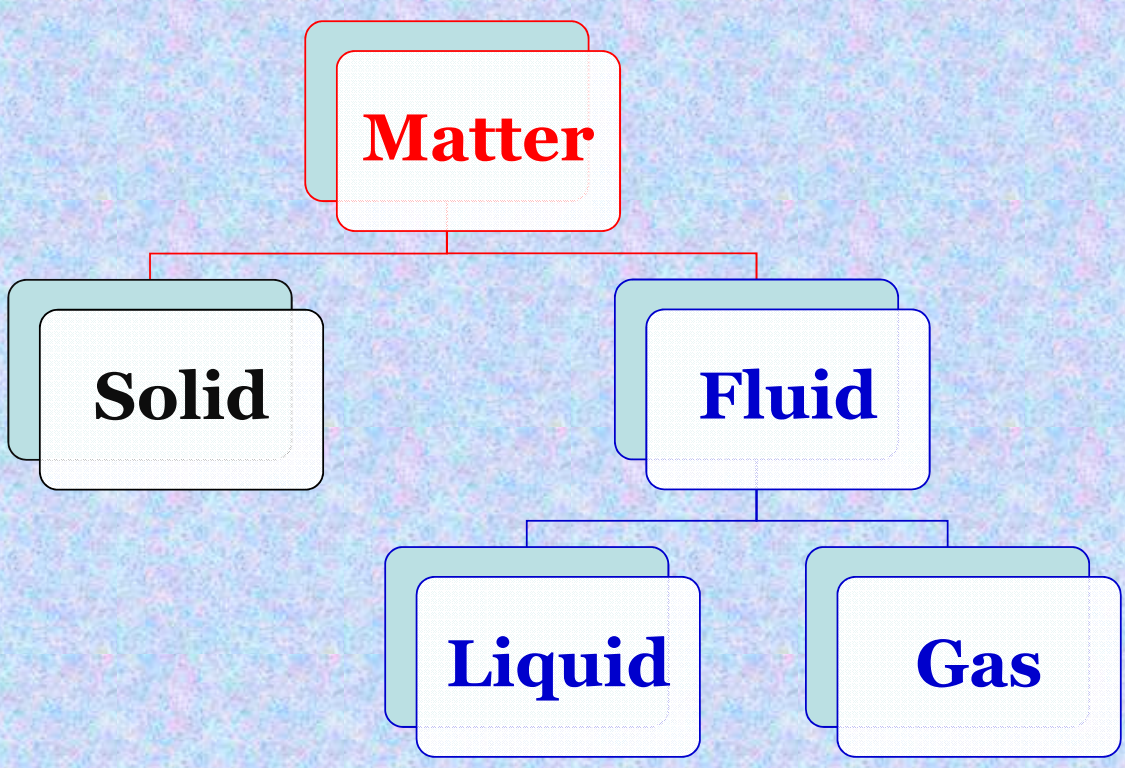
Introduction & Dimensions and Units

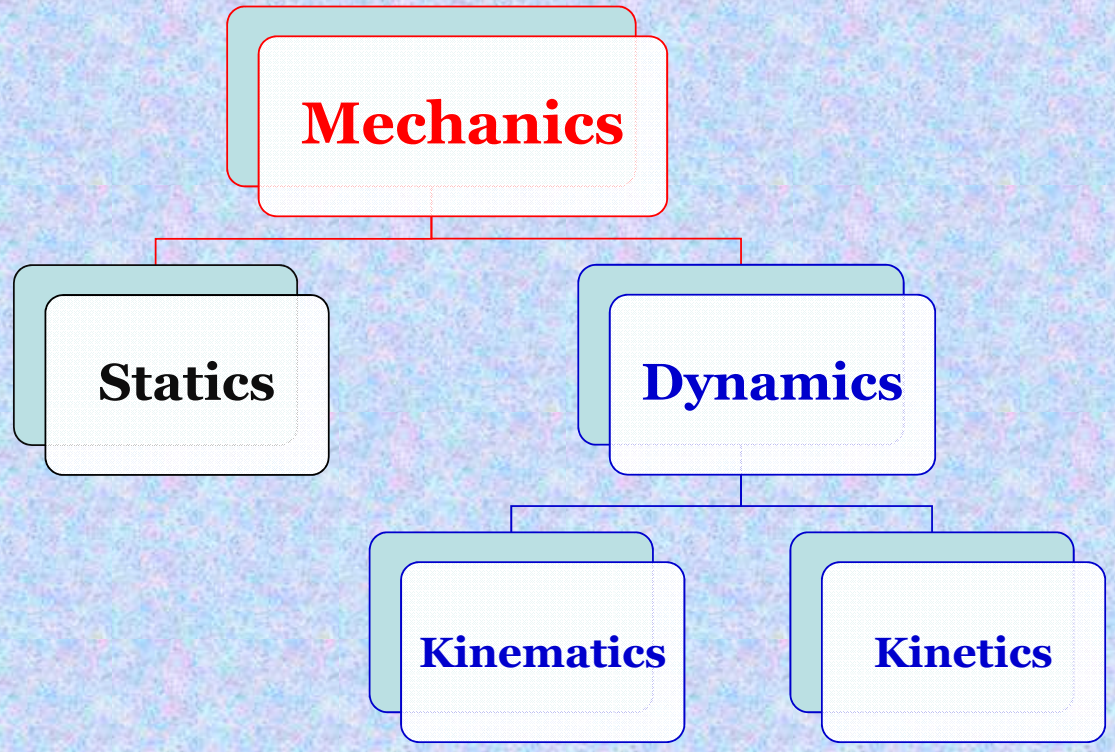
FLUID

A fluid is a substance which deforms continuously under the action of shearing forces, however small they may be.



Deformation caused by shearing forces





Classification Of Mechanics

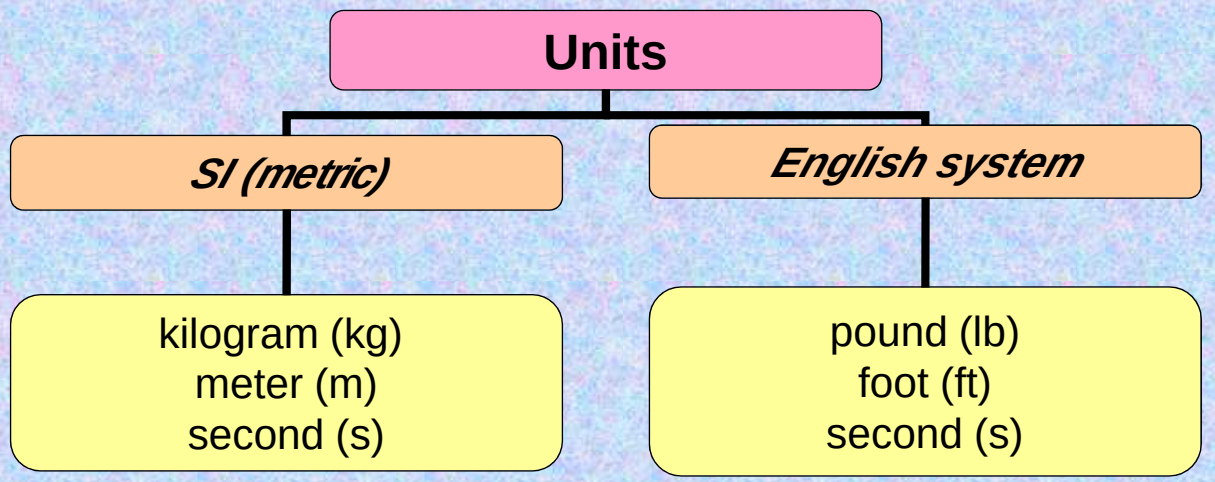
Statics:
Statics is the branch of mechanics which deals with forces and their effects while acted upon bodies which are at rest.

Dynamics:
Dynamics is the branch of mechanics which deals with forces and their effects while acted upon bodies which are in motion.

Kinematics:
Kinematics is the branch of mechanics which deals with motion parameters without considering the forces responsible for motion.

Kinetics:
Kinetics is the branch of mechanics which deals with motion parameters as well as forces responsible for motion.

Units & Properties



lb = 0.45359 kg

ft = 0.3048 m

The seven fundamental (or primary) dimensions and their units in SI	
Dimension	**Unit**
Length	meter (m)
Mass	kilogram (kg)
Time	second (s)
Temperature	Kelvin (K)
Electric current	Ampere (A)
Amount of light	candela (cd)
Amount of matter	mole (mol)

Length	m		Work	
Mass	kg		Heat	
Time	s		Energy	
Area	m^2		Power	
Volume	m^3			
Velocity				
Acceleration				
Density				
Specific Volume				
Mass flow rate				
Discharge				
Pressure				
Force				

SI Units	Quantity	Unit	SI Symbol	Formula
SI base units:	Length	meter	m	—
	Mass	kilogram	kg	—
	Time	second	s	—
	Temperature	kelvin	K	—
SI supplementary unit:	Plane angle	radian	rad	—
SI derived units:	Energy	joule	J	$N \cdot m$
	Force	newton	N	$kg \cdot m/s^2$
	Power	watt	W	J/s
	Pressure	pascal	Pa	N/m^2
	Work	joule	J	$N \cdot m$

SI Unit Prefixes

Factor	Prefix	Symbol
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{2}	hecto	h
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p

Useful Conversion Factors:

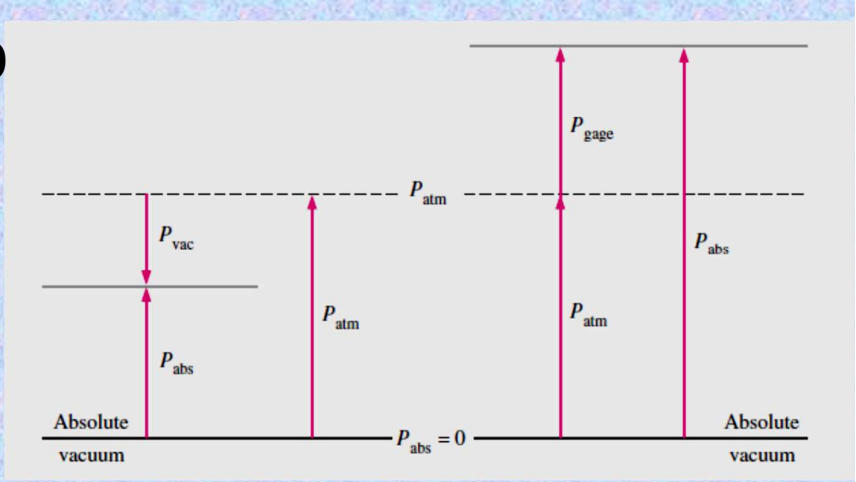
Length:	1 ft = 0.3048 m
	1 in. = 25.4 mm
Mass:	1 lbm = 0.4536 kg
	1 slug = 14.59 kg
Force:	1 lbf = 4.448 N
	1 kgf = 9.807 N
Velocity:	1 ft/s = 0.3048 m/s
	1 ft/s = 15/22 mph
	1 mph = 0.447 m/s
Pressure:	1 psi = 6.895 kPa
	1 lbf/ft^2 = 47.88 Pa
	1 atm = 101.3 kPa
	1 atm = 14.7 psi
	1 in. Hg = 3.386 kPa
	1 mm Hg = 133.3 Pa
Energy:	1 Btu = 1.055 kJ
	1 ft · lbf = 1.356 J
	1 cal = 4.187 J
Power:	1 hp = 745.7 W
	1 ft · lbf/s = 1.356 W
	1 Btu/hr = 0.2931 W
Area	1 ft^2 = 0.0929 m^2
	1 acre = 4047 m^2
Volume:	1 ft^3 = 0.02832 m^3
	1 gal (US) = 0.003785 m^3
	1 gal (US) = 3.785 L
Volume flow rate:	1 ft^3/s = 0.02832 m^3/s
	1 gpm = 6.309 × 10^{-5} m^3/s
Viscosity (dynamic)	1 lbf · s/ft^2 = 47.88 N · s/m^2
	1 g/(cm · s) = 0.1 N · s/m^2
	1 Poise = 0.1 N · s/m^2
Viscosity (kinematic)	1 ft^2/s = 0.0929 m^2/s
	1 Stoke = 0.0001 m^2/s

Convert:

- **100 km/hr → m/s.**
- **5 m^2 → ft^2 .**
- **2 kg/s → lb/min.**
- **9.81 m/s^2 → ft/s^2.**

Pressure

$P = F/A \equiv N/m^2$ (Pa)



$$P_{gage} = P_{abs} - P_{atm}$$

$$P_{vac} = P_{atm} - P_{abs}$$

1 bar = 10^5 Pa = 0.1 MPa = 100 kPa

1 atm = 101,325 Pa = 101.325 kPa = 1.01325 bars

1 kg_f/cm^2 = 9.807 N/cm^2 = 9.807×10^4 N/m^2 = 9.807×10^4 Pa

1 atm = 14.696 psi

Temperature

The Kelvin scale is related to the Celsius scale by

$$T\,(K) = T\,(°C) + 273.15 \qquad (1)$$

The Rankine scale is related to the Fahrenheit scale by

$$T\,(R) = T\,(°F) + 459.67 \qquad (2)$$

It is common practice to round the constant in Eq. 1 to 273 and that in Eq. 2 to 460.

The temperature scales in the two unit systems are related by

$$T\,(R) = 1.8\,T\,(K)$$
$$T\,(F) = 1.8\,T\,(°C) + 32$$

DENSITY

The density of a substance is that quantity of matter contained in unit volume of the substance.

$\rho = m/V$ $[kg/m^3]$

Note:

Specific volume (υ):

$\upsilon = 1/\rho$ $[m^3/kg]$

Specific Weight

$\gamma = W/V$ $[N/m^3]$

$\gamma = \rho g$ $[N/m^3]$

Relative Density

$s = \rho/\rho_w = \gamma/\gamma_w$ [-]

Viscosity

The dynamic viscosity

$$\mu = \tau \Big/ \frac{dv}{dy} = \frac{\text{Force}}{\text{Area}} \Big/ \frac{\text{Velocity}}{\text{Distance}} = \frac{\text{Force} \times \text{Time}}{\text{Area}} \quad \text{or} \quad \frac{\text{Mass}}{\text{Length} \times \text{Time}}.$$

μ : The dynamic viscosity *[Pa.s]*

Poise =0.1 Pa.s

The kinematic viscosity

$\nu = \mu/\rho.$ stokes (St); [10^4 St = 1 m^2/s]

Equation Of State Of A Perfect Gas

$$Pv = RT \qquad p = \rho RT,$$

$$PV = mRT \qquad v = V/m$$

$$PV = NMRT \qquad m = NM$$

$$PV = N\bar{R}T \qquad \bar{R} = MR$$

$$P\bar{v} = \bar{R}T \qquad \bar{v} = V/N$$

- where,
  - P = absolute pressure, N/m²
  - V = volume, m³
  - $\bar{v}$ = molar specific volume, m³/kmol
  - N = No of kmoles
  - T = absolute temperature, K
  - $\bar{R}$ = Universal gas constant, J/kmol.K
  - M = Molecular Weight, kg/kmol
  - v = specific volume, m³/kg
  - m = NM= mass, kg
  - R = gas constant, J/kg.K = $\bar{R}$/M

Convert:

- 220 kPa → kg/cm² & bar & psi
- 30 °C → F & K & R.
- 20 Pa.s → lb.s/ft².
- 4 m³ → gallon & ft³.