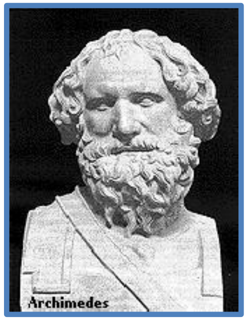
BMEE204L
Fluid Mechanics & Machinery

Lecture – 1 & 2, Date : 07-12-2022 & 08-12-2022

G. Vinayagamurthy Dr. Engg.
School of Mechanical Engineering
VIT Chennai

History of Fluid Mechanics

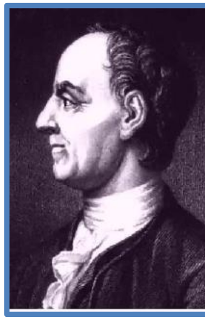


Archimedes
(C. 287-212 BC)

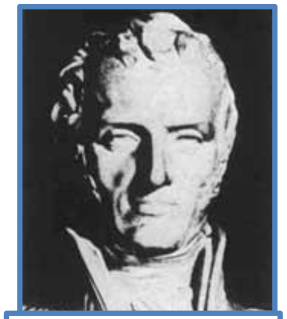
Newton
(1642-1727)

Leibniz
(1646-1716)

Bernoulli
(1667-1748)



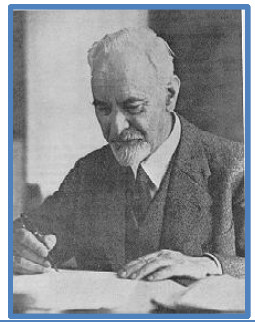
Euler
(1707-1783)



Navier
(1785-1836)

Stokes
(1819-1903)

Reynolds
(1842-1912)



Prandtl
(1875-1953)

Taylor
(1886-1975)

Applications of Fluid Mechanics – Weather monitoring

Natural flows and weather
© Vol. 16/Photo Disc.

Boats
© Vol. 5/Photo Disc.

Aircraft and spacecraft
© Vol. 1/Photo Disc.

Power plants
© Vol. 57/Photo Disc.

Human body
© Vol. 110/Photo Disc.

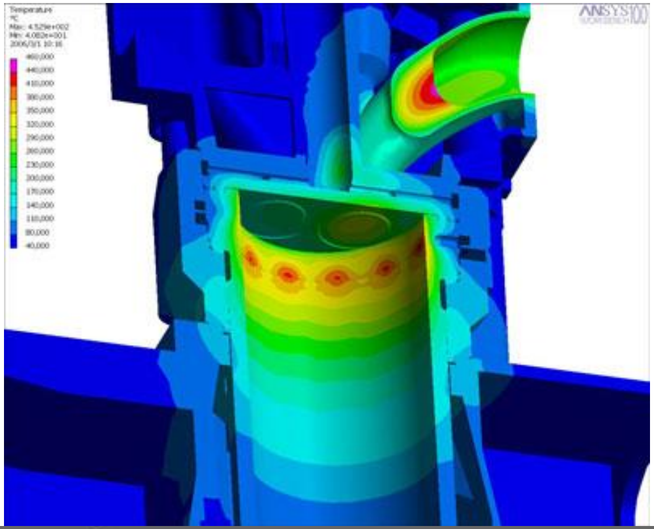
Cars
Photo by John M. Cimbala.

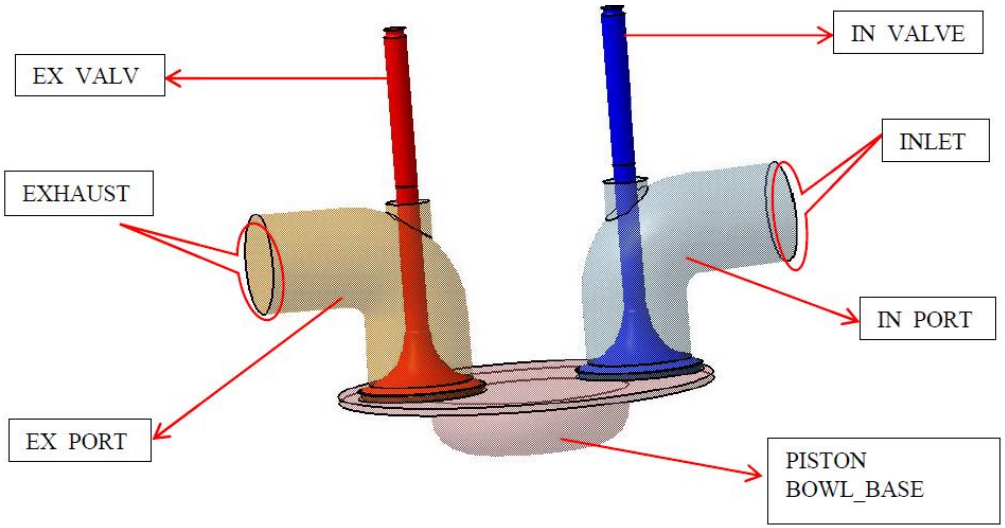
Wind turbines
© Vol. 17/Photo Disc.

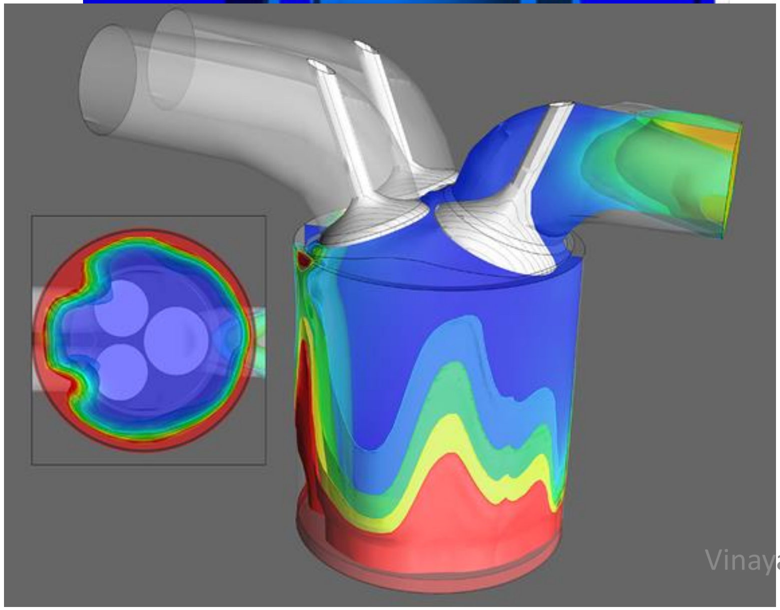
Piping and plumbing systems
Photo by John M. Cimbala.

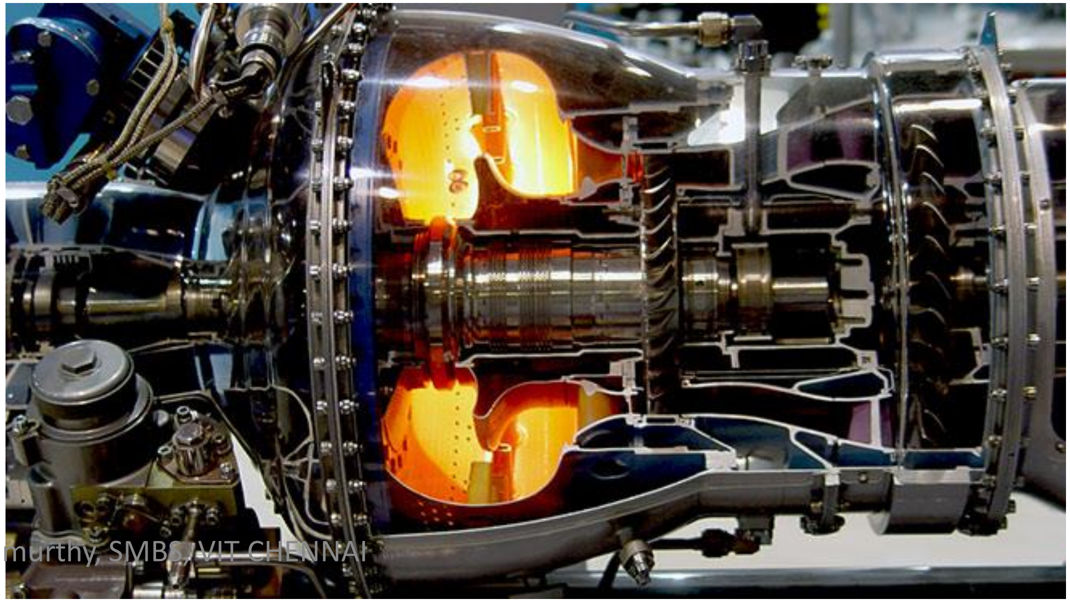
Industrial applications
Courtesy UMDE Engineering, Contracting, and Trading. Used by permission.

Applications of Fluid Mechanics



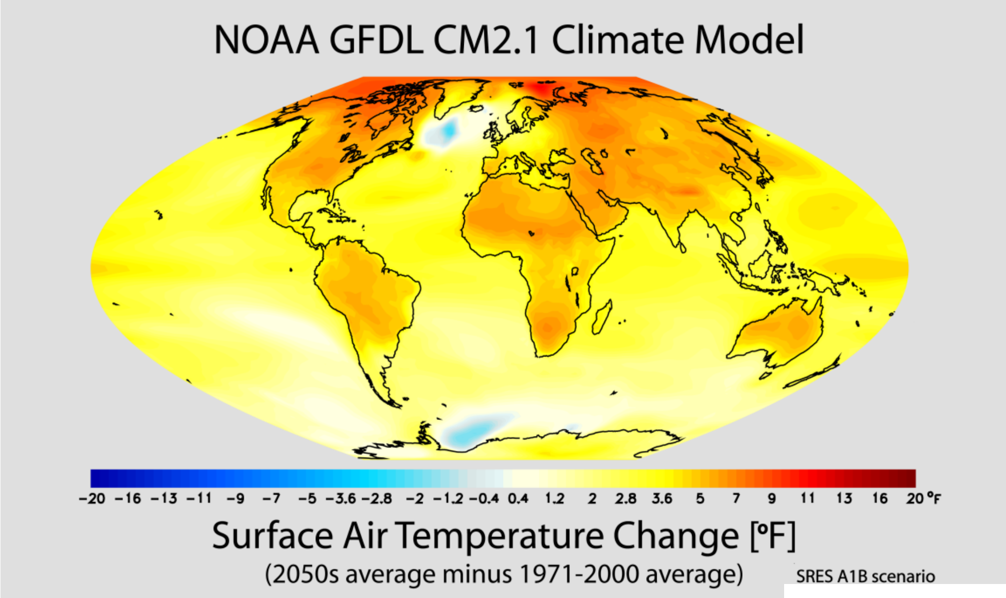


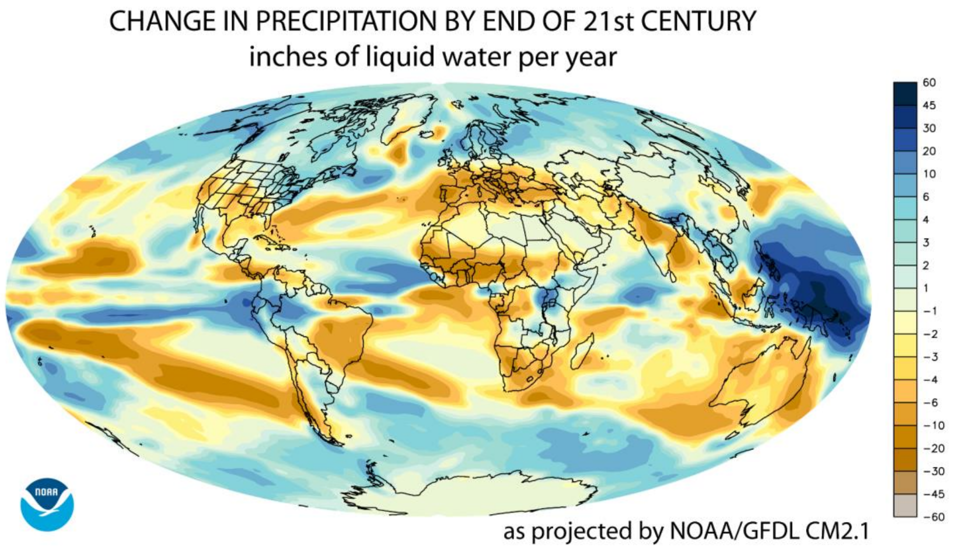




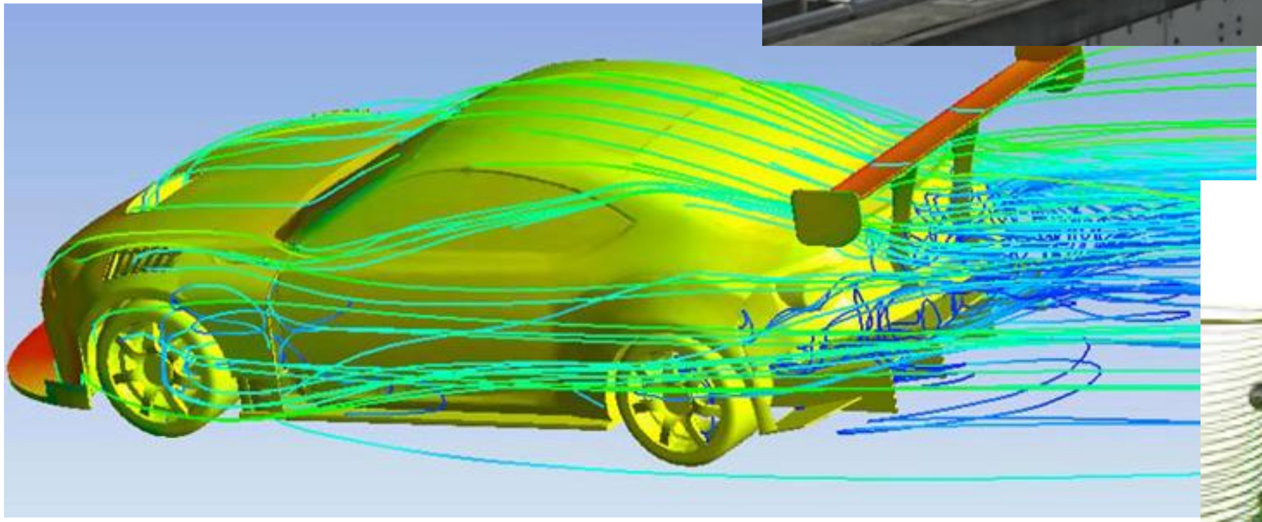
Applications of Fluid Mechanics

Applications of Fluid Mechanics – Weather monitoring

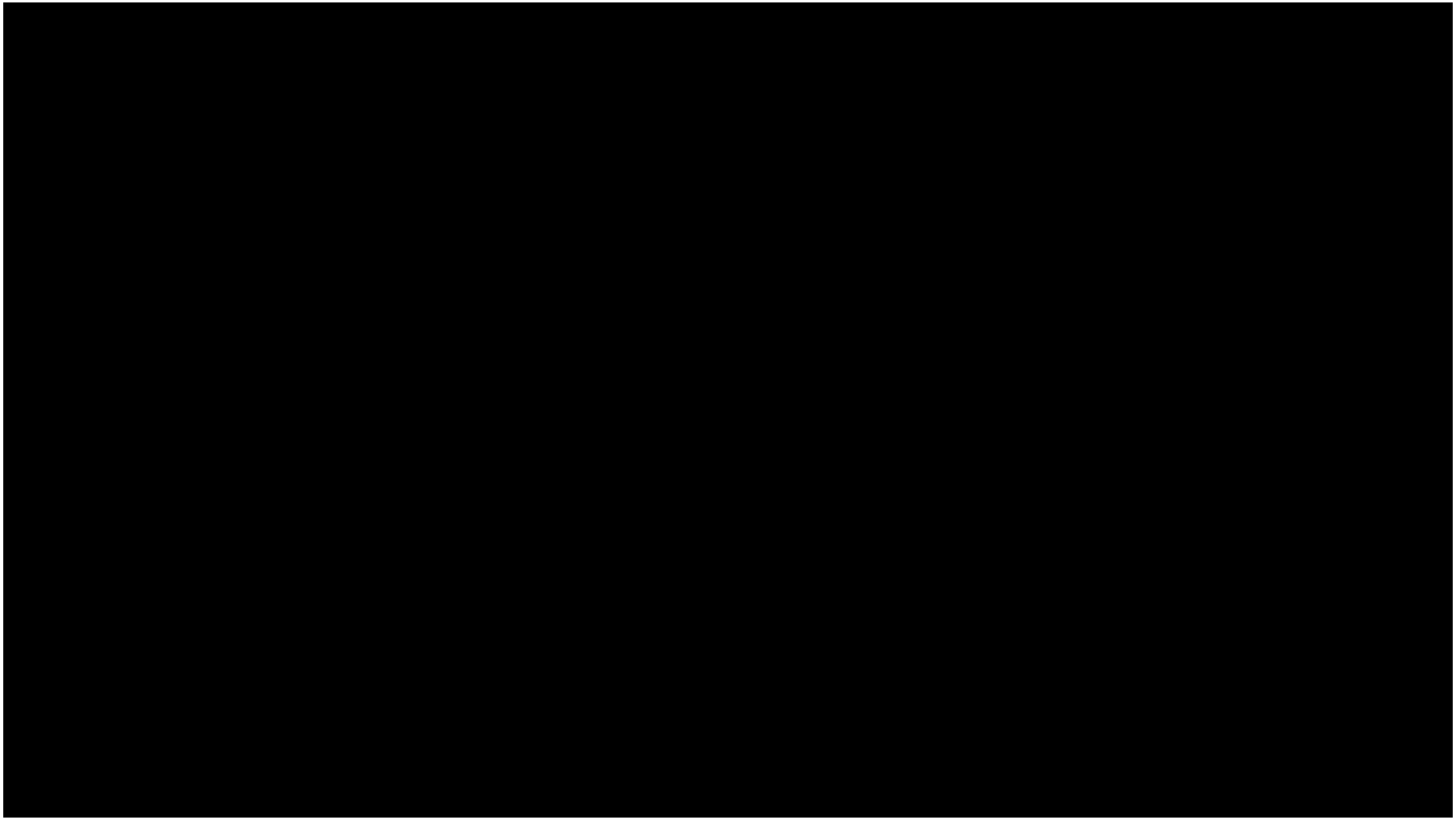




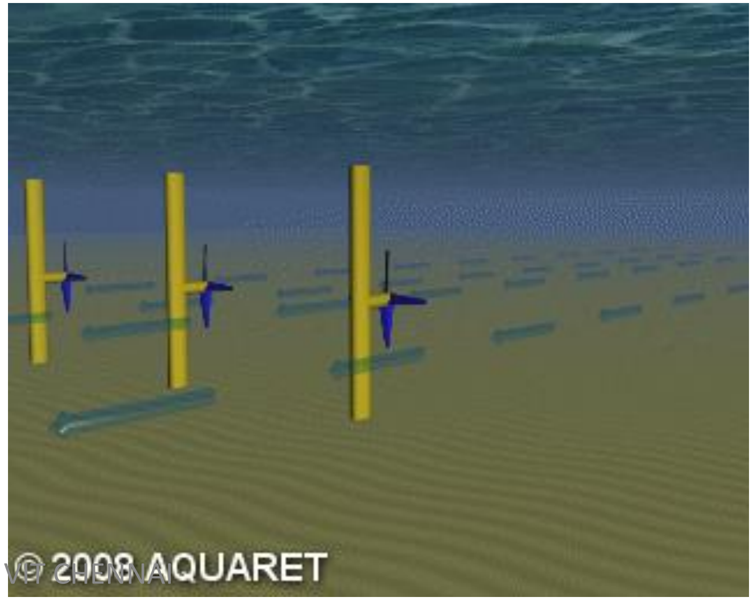
Applications of Fluid Mechanics – Vehicles



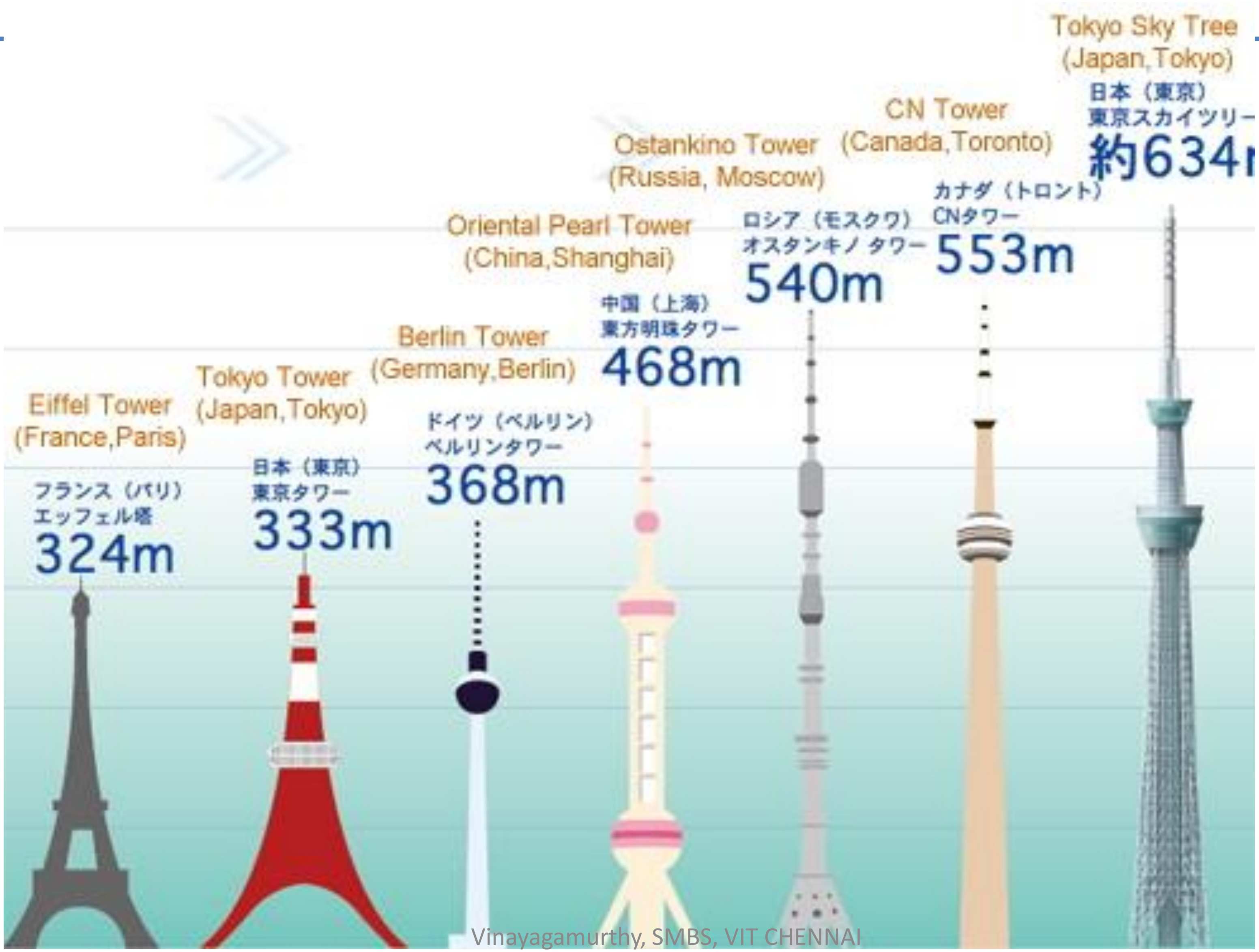
Applications of Fluid Mechanics – Vehicles



Applications of Fluid Mechanics – Energy

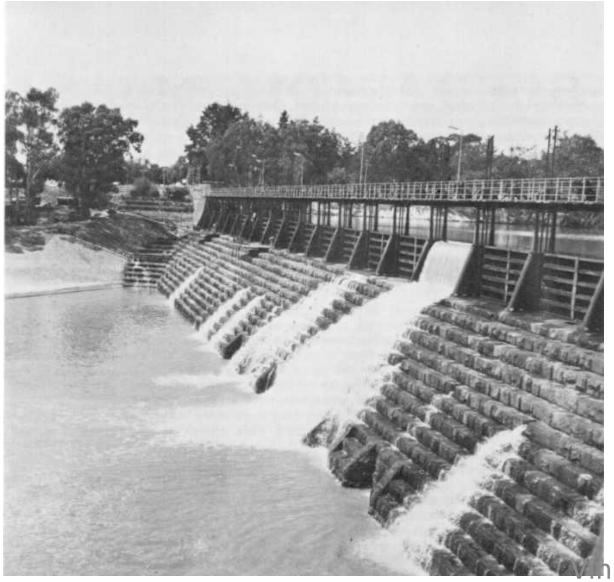


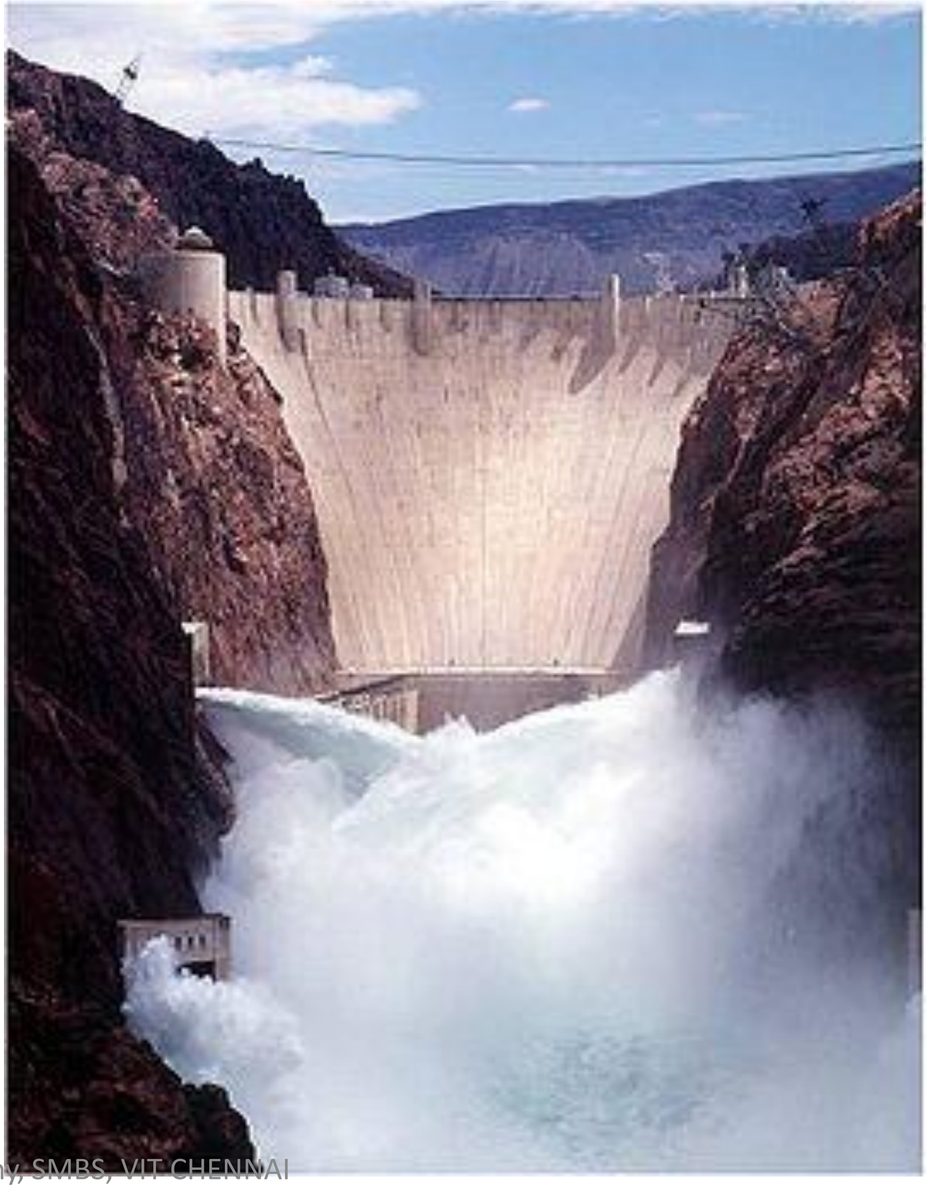
Applications of Fluid Mechanics – Civil structures



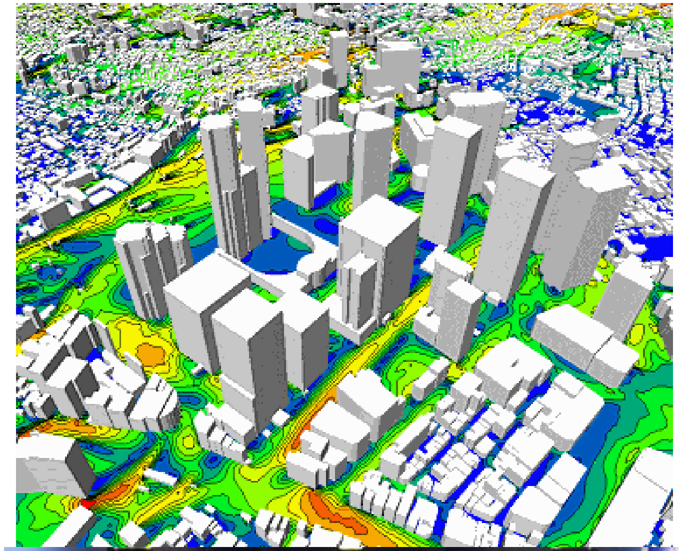
Applications of Fluid Mechanics – Civil structures

Applications of Fluid Mechanics – Civil Structures

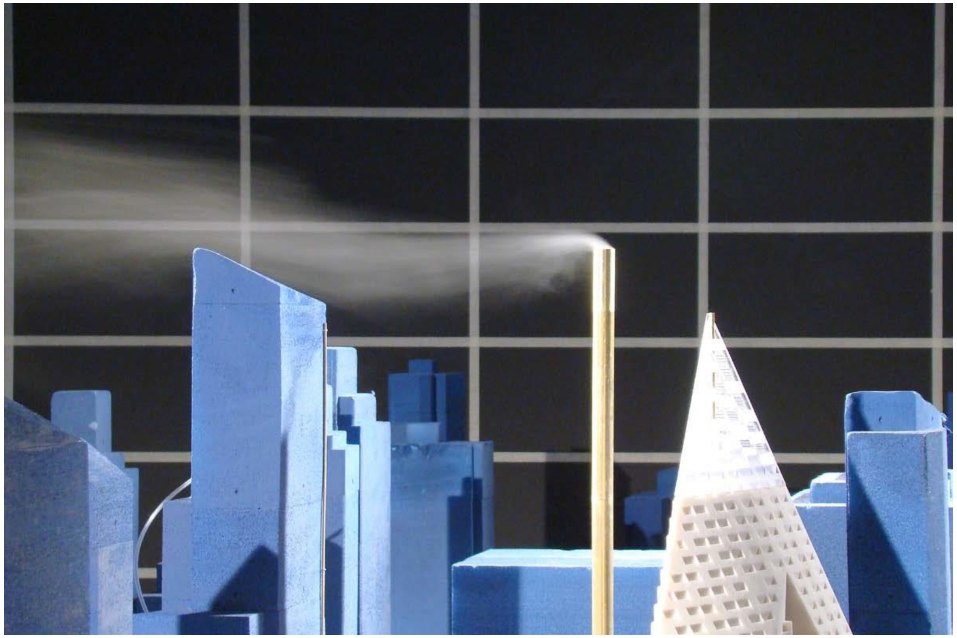


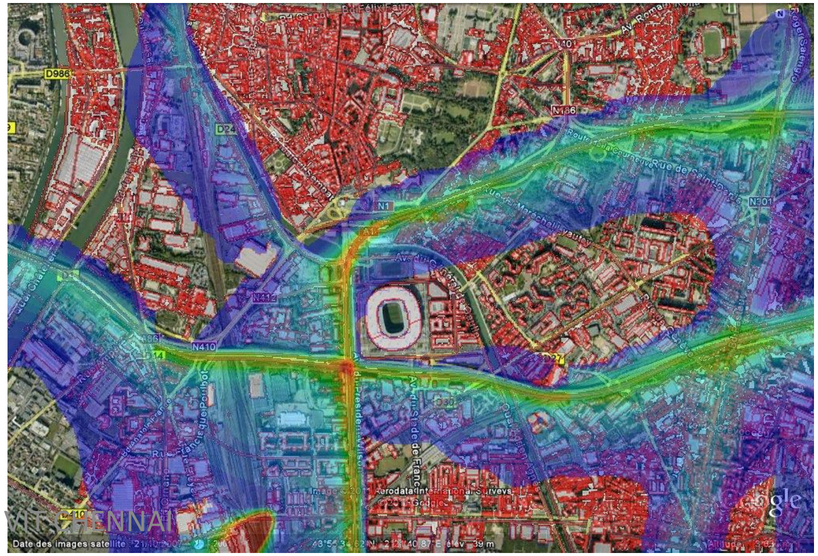


Applications of Fluid Mechanics – Civil structures



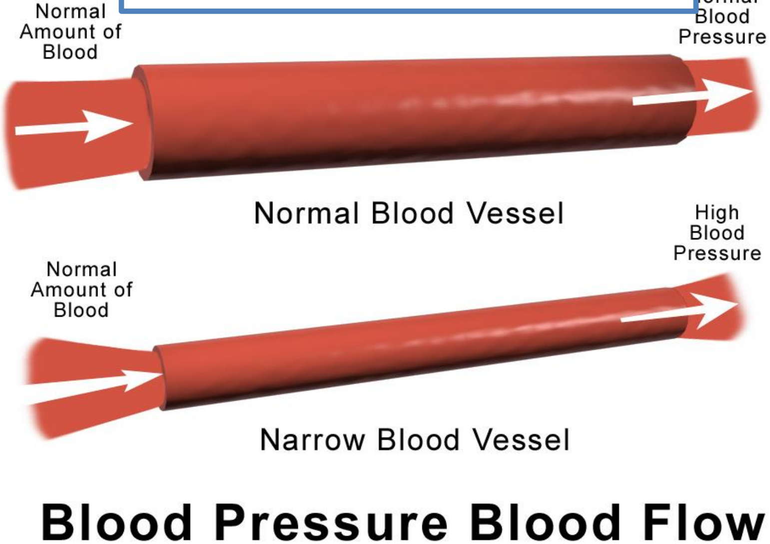
Applications of Fluid Mechanics – Urban planning





Applications of Fluid Mechanics – Health care

Hemodynamics



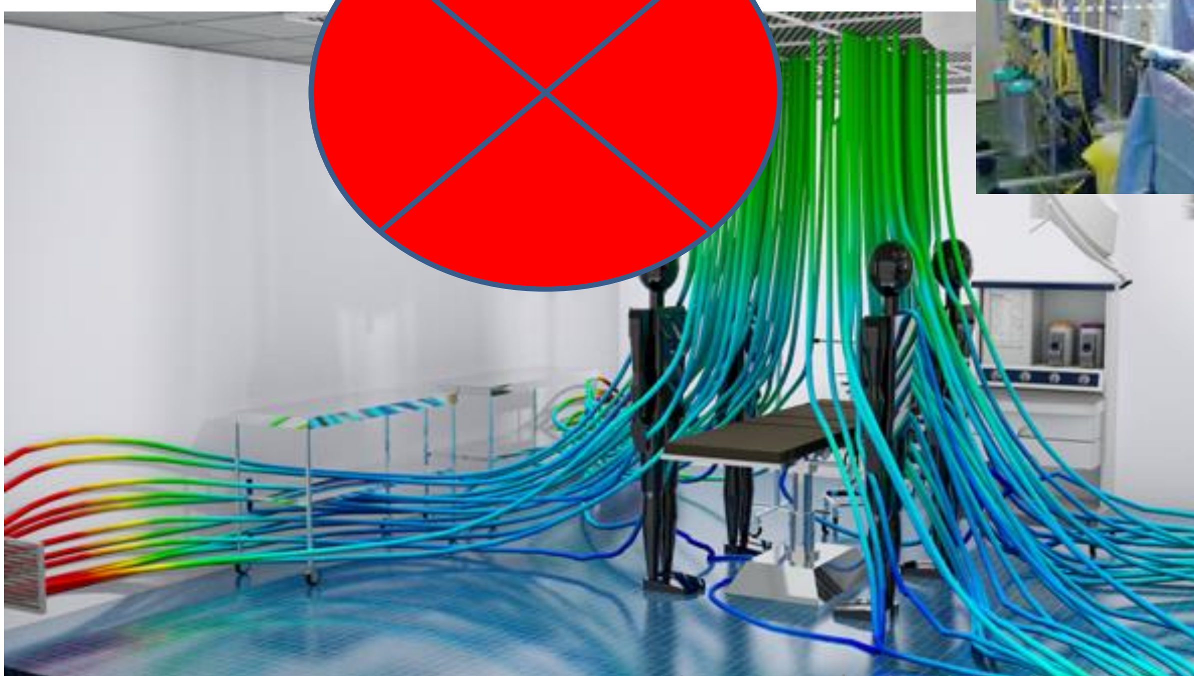
Applications of Fluid Mechanics – Health care

Blood pump

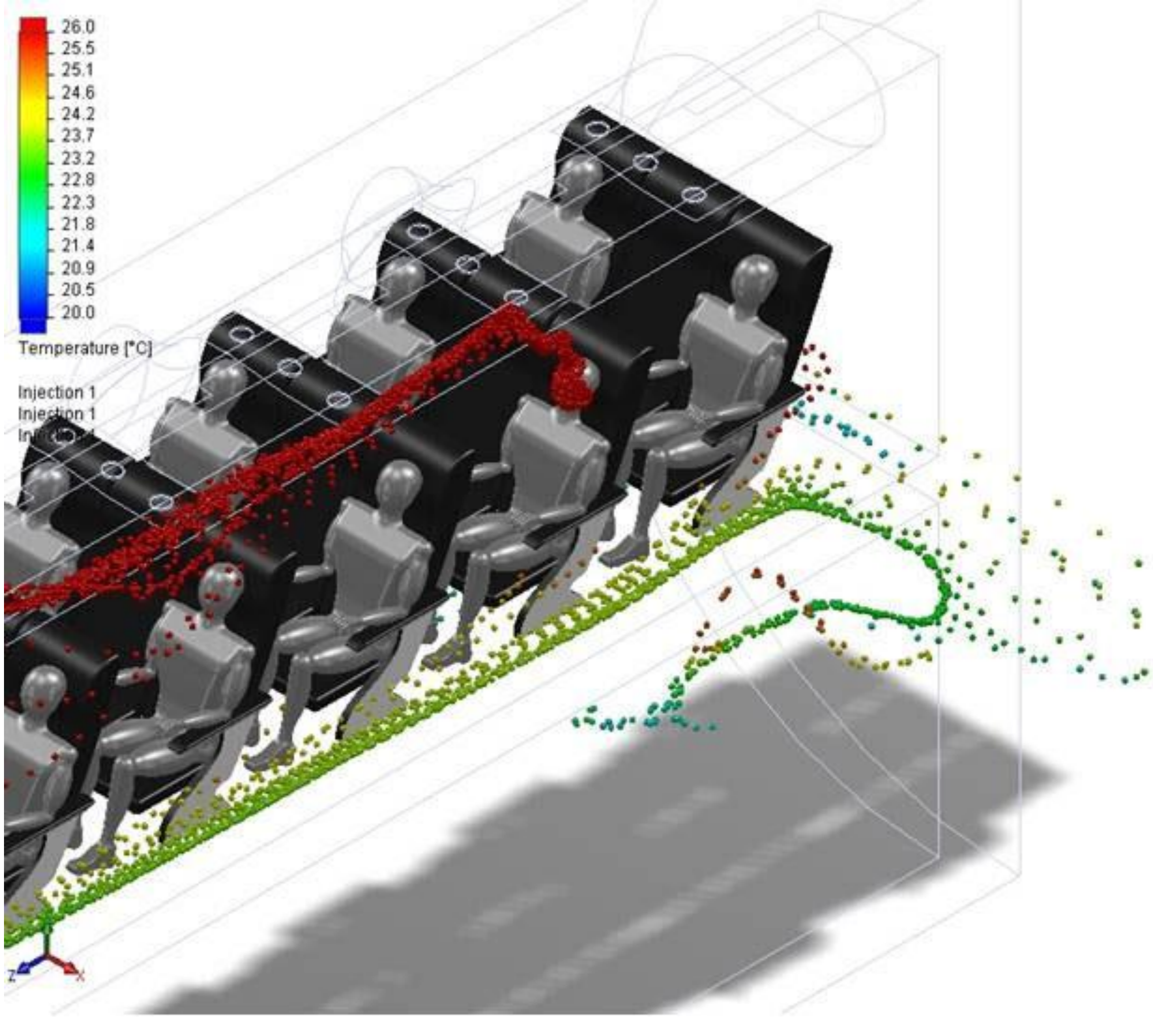
A BVS blood pump

Ventricular assist device

FM - Heat Ventilation and Air-conditioning



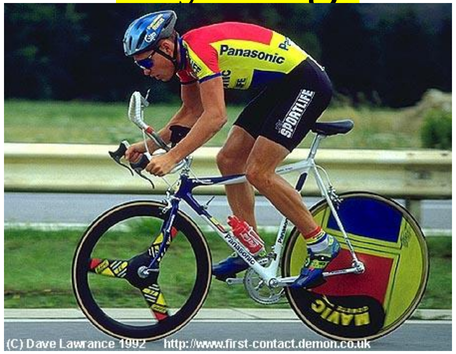
Applications of Fluid Mechanics – Health care



Applications of Fluid Mechanics
Sports & Recreation

Water sports

Cycling



Offshore racing

Auto

Surfing

FLUID MECHANICS & MACHINES - CURRICULUM

BMEE204L	**Fluid Mechanics and Machines**	**L**	**T**	**P**	**C**
		3	**0**	**0**	**3**
Pre-requisite	**NIL**	**Syllabus version**			
		1.0			

Course Objectives

1. To apply hydrostatic law, principle of mass and momentum in fluid flows, concepts in Euler's and Bernoulli equations.
2. To provide fundamental knowledge of fluids, its properties and behaviour under various conditions of internal and external flows.
3. To determine the losses in a flow system, flow through pipes, boundary layer concepts.
4. To familiarize the student with the various pumps and turbines.

Course Outcomes

At the end of the course, the student will be able to

1. Demonstrate the significance of fluid properties and laws of fluid statics to engineering systems.
2. Describe the flow fields using Lagrangian and Eulerian approaches.
3. Formulate suitable governing equations to solve fluid flow problems.
4. Analyse the viscous flow through pipes and determine various losses.
5. Perform dimensional analysis of various flow problems.
6. Apply the boundary layer concept and predict the flow separation.
7. Analyse the performance of hydraulic pumps and turbines.

FLUID MECHANICS & MACHINES - CURRICULUM

Module:1	**Fluid Statics and Buoyancy**	**8 hours**
Definition of fluid, Concept of continuum, Fluid properties, Rheological classification, Pascal's Law and Hydrostatic pressure and its measurement -Manometry. Hydrostatic forces on Plane, Inclined and Curved surfaces, Buoyancy, Condition of Equilibrium for Submerged and Floating Bodies, Centre of Buoyancy.		
Module:2	**Fluid Kinematics**	**5 hours**
Description of fluid motion – Lagrangian and Eulerian approach, Types of flows, Control volume, Material derivative and acceleration, Streamlines, Pathlines and Streaklines, Stream function and velocity potential function, The Reynolds transport theorem.		
Module:3	**Fluid Dynamics**	**5 hours**
The continuity equation, The Euler and Bernoulli equations – venturimeter, orificemeter, Pitot tube, Momentum equation and its application – forces on pipe bends, moment of momentum, The Navier–Stokes Equations.		
Module:4	**Viscous Flow in pipes**	**6 hours**
General Characteristics of pipe flow, Fully-developed laminar flow, Hagen Poiseuille equation, Turbulent flow, Darcy–Weisbach equation, Moody chart, major and minor losses, Multiple pipe systems.		
Module:5	**Dimensional Analysis**	**5 hours**
Dimensional homogeneity, Rayleigh's method, Buckingham π theorem, Non-dimensional numbers, Model laws and distorted models, Modelling and similitude.		
Module:6	**Boundary layer flow**	**5 hours**
Boundary layers, Laminar flow and turbulent flow, Boundary layer thickness, Momentum integral equation, Drag and lift, Separation of boundary layer, Methods of preventing the boundary layer separation.		

FLUID MECHANICS & MACHINES - CURRICULUM

boundary layer separation.

Module:7	**Hydraulic Machines**	**9 hours**
Introduction - Centrifugal pumps – Work done - Head developed - Pump output and Efficiencies - priming - minimum starting speed - performance of multistage pumps - Cavitation - methods of prevention - Pump characteristics – Classification of hydraulic turbines - Pelton wheel - Francis turbine - Kaplan and Propeller turbines - - Specific speed - Theory of draft tube - Governing - Performance characteristics - Selection of turbines.		
Module:8	**Contemporary issues**	**2 hours**
	Total Lecture hours:	**45 hours**

Text Books			
1.	Som S K, Gautam Biswas, Chakraborty S, Introduction to Fluid Mechanics and Fluid Machines, 2017, McGraw Hill.		
2.	Fox and McDonald, Introduction to Fluid Mechanics, 2020, 10th Edition, Wiley.		
Reference Books			
1.	Yunus A. Cengel and John. M. Cimbala, Fluid Mechanics: Fundamentals and Applications, 2019, 4th Edition, McGraw Hill.		
Mode of Evaluation: CAT, Written assignment, Quiz, FAT			
Recommended by Board of Studies	09-03-2022		
Approved by Academic Council	No. 65	Date	17-03-2022

FLUID MECHANICS & MACHINES - CURRICULUM

Reference Books

1.	P.N.Modi and S.M.Seth, Hydraulics and Fluid Mechanics including Hydraulic Machines, 17th Edition, 2011.
2.	Yunus A. Çengel, John M. Cimbala, Fluid Mechanics: Fundamentals And Applications, McGraw-Hill, 3rd Edition, 2013.
3.	Dr.R.K.Bansal, A Textbook of Fluid Mechanics and Hydraulic Machines, 5th Edition, Laxmi Publication, 2012.
4.	Donald F. Elger, Barbara C. Williams, Clayton T. Crowe, John A. Roberson, Engineering Fluid Mechanics, John Wiley & Sons, 10th Edition, 2013.
5.	V.L. Streeter, Fluid Mechanics, McGraw Hill Book Co., 2010.
1.	Robert W. Fox, Alan T. McDonald, Philip J. Pirtchard John W. Mitchell, Introduction to Fluid Mechanics, 9th Edition, Wiley Publications, 2015.

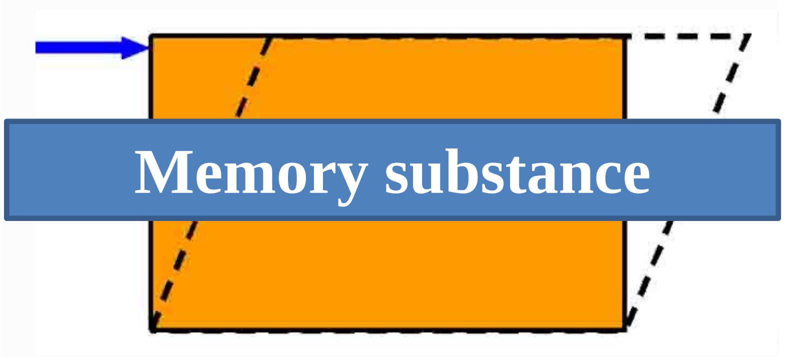
MEE 1004 - FLUID MECHANICS - INSTRUCTIONS

CAT 1 & 2	- 30 marks
Quiz 1	- 10 marks
Quiz 2	- 10 marks
Assignment	- 10 marks
FAT	- 40 marks

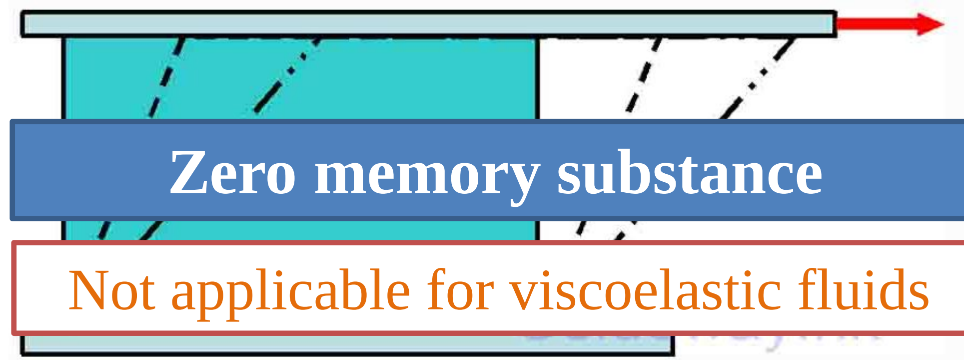
Fluid / Fluids

What is a fluid ?

- A substance that deforms continuously when acted on by a shearing stress of any size.



Memory substance



Zero memory substance

Not applicable for viscoelastic fluids

Solid undergoes a definite deformation – Shear deformation

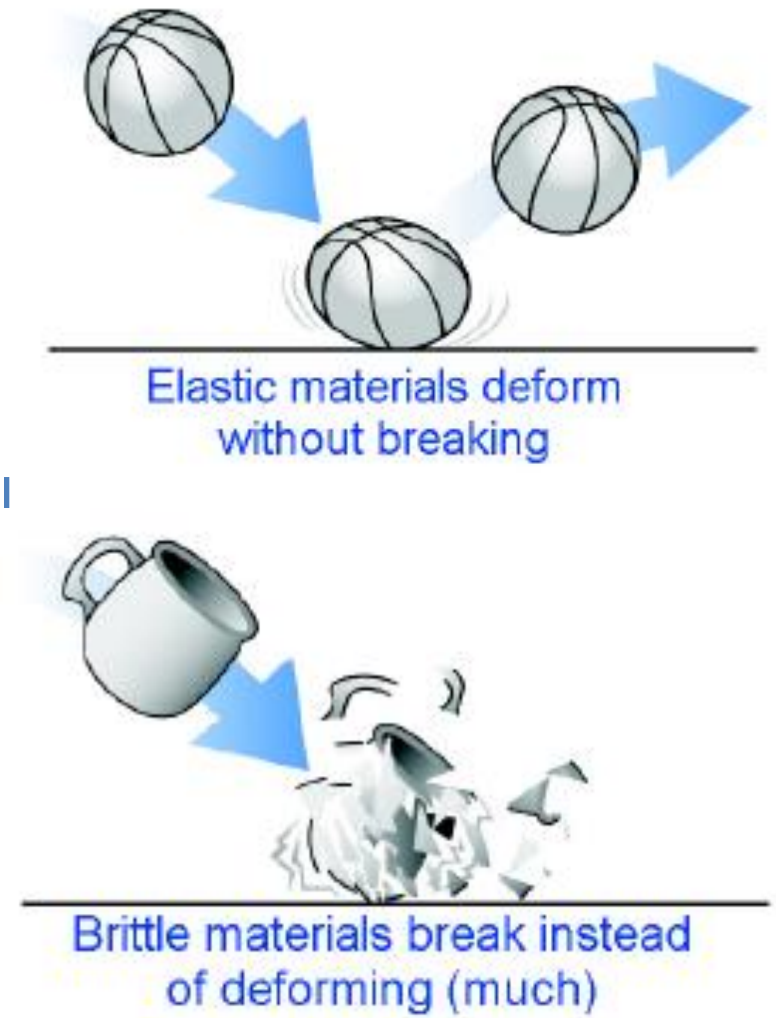
Liquid undergoes a continuous deformation

Solid may or may not regain its original shape

Fluids will not regain its original shape

Properties of solids

- The modulus of elasticity plays the role of the spring constant for solids.
- A material is elastic when it can take a large amount of strain before breaking.
- A brittle material breaks at a very low value of strain.



Distinction Between Solids, Liquids & Gases

- A fluid can be either gas or liquid.
- Solid molecules are arranged in a specific lattice formation and their movement is restricted.
- Liquid molecules can move with respect to each other when a shearing force is applied.
- The spacing of the molecules of gases is much wider than that of either solids or liquids and it is also variable.

Concept of Continuum

Although any matter is composed of several molecules, the concept of continuum assumes a **continuous** distribution of mass within the matter or system with no empty space, instead of the actual **conglomeration** of separate molecules.

Mechanics

- Categories of Mechanics

  - Rigid bodies

    - Statics

    - Dynamics

  - Deformable bodies

  - Fluids

Mechanical vibrations

Deformation of solids
Bending of Beams

Mechanics of Fluids and measurements
Turbines and Pumps

SOLIDS: Strain is related to stress. For Hookean or linear elastic solids

$\sigma = E\varepsilon$, where

ε is strain
E is Young's modulus
σ is stress (force/area)

FLUIDS: Strain *rate* is related to shear stress.

For Newtonian fluids

$\tau = \mu\, du/dy$, where

τ is shear stress,
μ is viscosity
du/dy is velocity gradient

Fluid Mechanics / Mechanics of Fluids

Fluid mechanics is the branch of physics which involves the study of fluids (liquids, gases, and plasmas) and the forces on them.

Fluid Statics

mechanics of fluids at rest

Fluid Kinematics

deals with velocities and streamlines w/o considering forces or energy

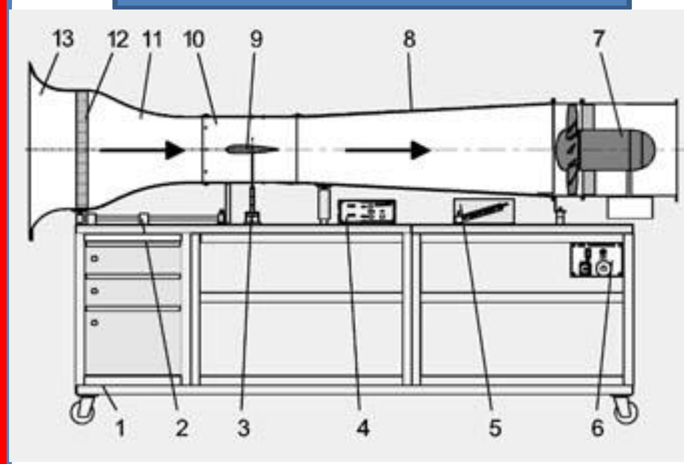
Fluid Dynamics

deals with the relations between velocities and accelerations and forces exerted by or upon fluids in motion

Fluid Dynamics- Applications

Analytical Fluid Dynamics	Experimental Fluid Dynamics	Computational Fluid Dynamics
AFD	EFD	CFD

Control volume, Exact solutions for simple geometry and conditions, Approximate solutions for practical applicationsa Empirical relations using EFD data



Continuity	$\frac{\partial \rho}{\partial t}+\frac{\partial}{\partial x_i}(\rho u_i)=0$
Momentum	$\frac{\partial}{\partial t}(\rho u_i)+\frac{\partial}{\partial x_j}(\rho u_i u_j)=-\frac{\partial P}{\partial x_i}+\frac{\partial \tau_{ij}}{\partial x_j}$
Energy	$\frac{\partial}{\partial t}(\rho h_{tot})+\frac{\partial}{\partial x_j}(\rho h_{tot} u_j)=\frac{\partial P}{\partial t}+\frac{\partial}{\partial x_j}(u_i \tau_{ij}+\lambda \frac{\partial T}{\partial x_j})$

where $\tau_{ij}=\mu\left(\frac{\partial u_i}{\partial x_j}+\frac{\partial u_j}{\partial x_i}+\frac{2}{3}\delta_{ij}\frac{\partial u_i}{\partial x_i}\right)$ $\quad h_{tot}=h+\frac{1}{2}u_i^2$

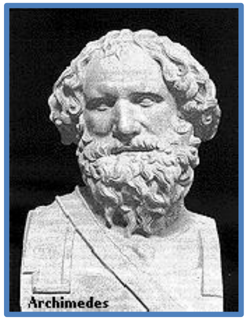
Scope of the Study

- Flow in pipes and channels
- Air and blood in body
- Air resistance or drag
- wind loading
- Projectile motion
- jets, shock waves
- Lubrication
- Combustion
- Irrigation
- Sedimentation
- Meteorology
- Oceanography

History of Fluid Mechanics

- Fluids essential to life
  - Human body 65% water
  - Earth’s surface is 2/3 water
  - Atmosphere extends 17km above the earth’s surface
- History shaped by fluid mechanics
  - Geomorphology
  - Human migration and civilization
  - Modern scientific and mathematical theories and methods
  - Warfare
- Affects every part of our lives

History of Fluid Mechanics

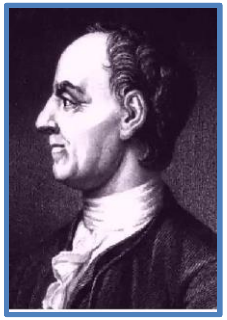


Archimedes
(C. 287-212 BC)

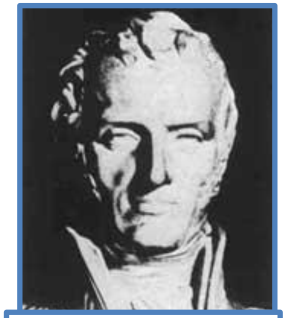
Newton
(1642-1727)

Leibniz
(1646-1716)

Bernoulli
(1667-1748)



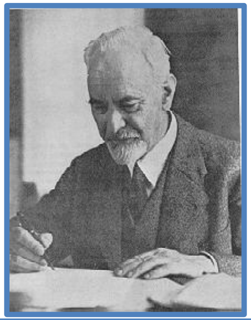
Euler
(1707-1783)



Navier
(1785-1836)

Stokes
(1819-1903)

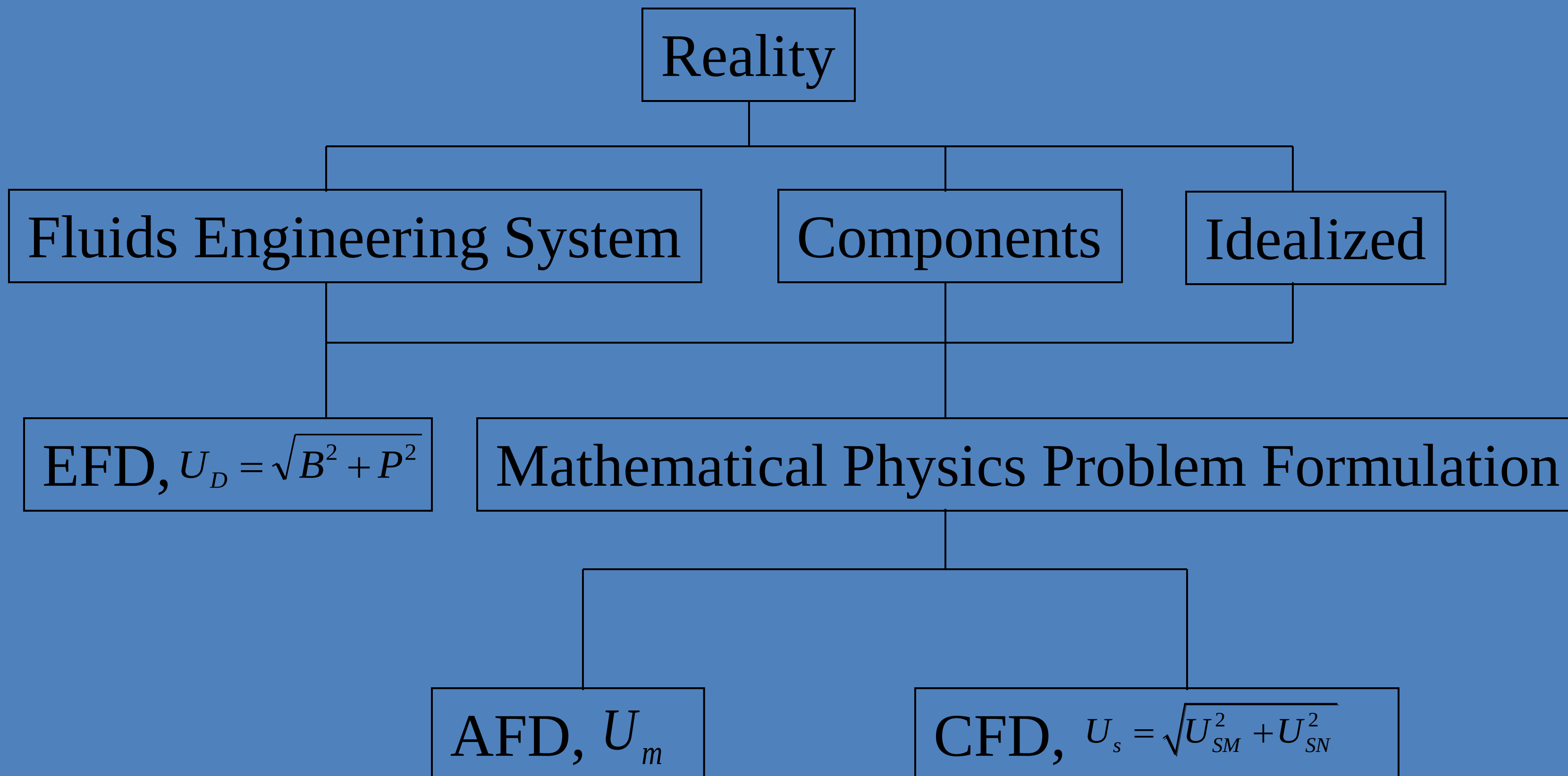
Reynolds
(1842-1912)



Prandtl
(1875-1953)

Taylor
(1886-1975)

Fluids Dynamics



UNIT SYSTEMS

SI UNITS

In the SI system, the unit of force, the *Newton*, is derived unit. The meter, second and kilogram are base units.

MKS

In the US Customary system, the unit of mass, the *slug*, is a derived unit. The foot, second and pound are base unit.

Basic Unit System & Units

The SI system consists of six **primary** units, from which all quantities may be described but in fluid mechanics we are generally only interested in the top four units from this table.

Quantity	SI Unit	Dimension
length	metre, m	L
mass	kilogram, kg	M
time	second, s	T
temperature	Kelvin, K	θ
current	ampere, *A*	I
luminosity	candela	Cd

Derived Units

Derived Units

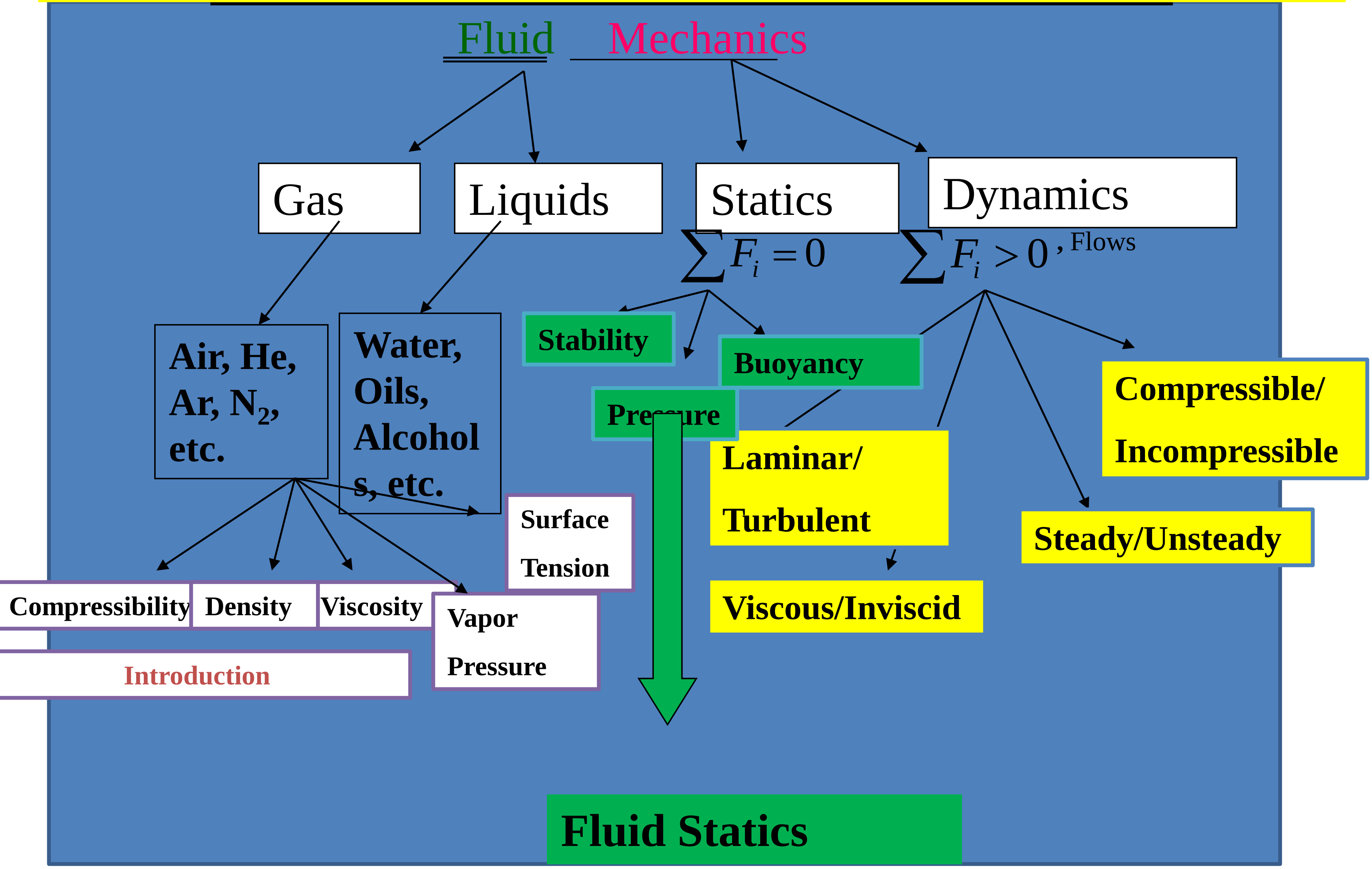
Quantity	SI Unit		Dimension
velocity	m/s	ms^{-1}	LT^{-1}
acceleration	m/s^2	ms^{-2}	LT^{-2}
force	N $kg\ m/s^2$	$kg\ ms^{-2}$	$M\ LT^{-2}$
energy (or work)	Joule J N m, $kg\ m^2/s^2$	$kg\ m^2s^{-2}$	ML^2T^{-2}
power	Watt W N m/s $kg\ m^2/s^3$	Nms^{-1} $kg\ m^2s^{-3}$	ML^2T^{-3}
pressure (or stress)	Pascal P, N/m^2, $kg/m/s^2$	Nm^{-2} $kg\ m^{-1}s^{-2}$	$ML^{-1}T^{-2}$
density	kg/m^3	$kg\ m^{-3}$	ML^{-3}
specific weight	N/m^3 $kg/m^2/s^2$	$kg\ m^{-2}s^{-2}$	$ML^{-2}T^{-2}$
relative density	a ratio no units		1 no dimension
viscosity	$N\ s/m^2$ kg/m s	$N\ sm^{-2}$ $kg\ m^{-1}s^{-1}$	$M\ L^{-1}T^{-1}$
surface tension	N/m $kg\ /s^2$	Nm^{-1} $kg\ s^{-2}$	MT^{-2}

Table summarizes these unit systems.

Name	Length	Time	Mass	Force
International System of Units (SI)	meter (m)	second (s)	kilogram (kg)	newton* (N) $\left(\frac{kg \cdot m}{s^2}\right)$
U.S. Customary (FPS)	foot (ft)	second (s)	slug* $\left(\frac{lb \cdot s^2}{ft}\right)$	pound (lb)

*Derived unit.

Fluid Mechanics / Mechanics of Fluids




Any Comments / Questions ?