CE 1102
FUNDAMENTALS OF CIVIL ENGINEERING

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Your Lecturer:

I am a Civil Engineer/Senior Lecturer/Researcher

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ACADEMIC QUALIFICATIONS

Bachelor of Science in Engineering (Honours)- Specialization: Civil Engineering, Department of Civil Engineering, Faculty of Engineering, University of Peradeniya, Sri Lanka.

M.Sc. (Full Time Research)-Specialization: Environmental Engineering, School of Urban Development, Faculty of Built and Environmental Engineering, Queensland University of Technology (QUT), Australia.

Doctor of Philosophy - Specialization: Hydraulics Engineering, School of Civil, Mining and Environmental Engineering , Faculty of Engineering, University of Wollongong (UOW), Australia.

RECENT ACHIEVEMENTS (Selected)

➢ **Vice-Chancellors Award for Outstanding Contribution to Teaching and Learning (OCTAL) 2020.**

➢ Awarded Fellow Membership of Wollongong Academy for Tertiary Teaching & Learning Excellence (WATTLE) in recognition of contributions to the student learning experience, through teaching and learning practices 2020.

➢ Australian Postgraduate Awards, University of Wollongong, Australia (2015-2019).

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HUMAN LIFE IS PAIN OR PLEASURE ???

Pain / Challenge → Efforts → Pleasure / Achievement
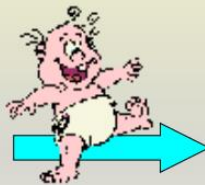
Be happy and make others happy

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Speaking is easy;
Listening is difficult
Speaking is a skill;
Listening is attitude

Please work happily
without sleeping!

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CE 1102 - Fundamentals of Civil Engineering

❖ **Scope of Civil Engineering**
❖ **Fluid mechanics, Hydrostatics**
❖ Hydrodynamics
❖ Flow classification

Week 1-6

❖ Introduction to structural engineering
❖ Building construction & materials
❖ Highway Engineering

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RESOURCES

- **Module Descriptor- Available in LMS**

- **Lesson Plan- Available in LMS**

- **Suggested list of further readings-Available in LMS**

- **Each week Lecture notes- Will be uploaded to LMS before the each week lecture**

- **Lecture recordings for each week- Will be uploaded to LMS after the each week lecture**

- **Any other specific learning materials will be uploaded to the LMS in each week**

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Learning Outcomes

LO2: Estimate the stability of floating bodies and energy associated in moving fluids

This LO will be covered from Chapter 2, Chapter 3 and Chapter 4

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Chapter 2: Fluid mechanics, Hydrostatics
Chapter 2-Part 1- Introduction to Fluid Mechanics and Hydrostatics,
Chapter 2-Part 2- Properties of Fluid
Chapter 2-Part 3-Buoyancy – Stability of Floating Bodies, Metacentre

Chapter 3: Hydrodynamics: Applications of Bernoulli's Equation
Momentum Equation

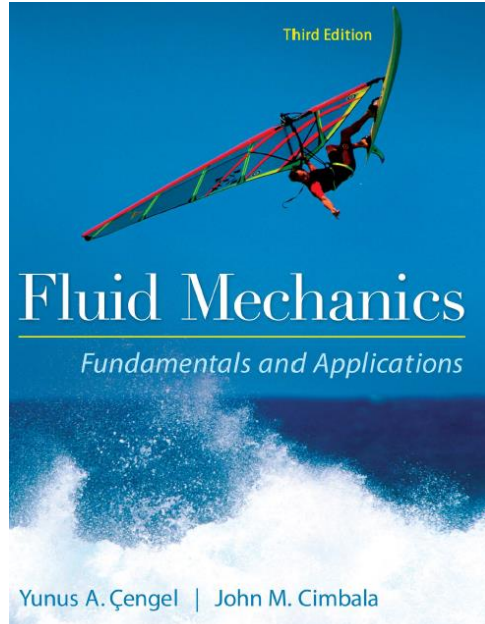**Chapter 4: Flow classification:** Laminar and turbulent flow

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Chapter 2: Part I- Fluid Mechanics, Hydrostatics

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Reference

Cengel and Cimbala, Fluid Mechanics, 3rd/4th SI Ed 2020

Third Edition

Fluid Mechanics

Fundamentals and Applications

Yunus A. Çengel | John M. Cimbala

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Introduction

Fluids mechanics applications elsewhere:

breathing, drinking, blood flow, swimming, pumps, fans, turbines, airplanes, ships, rivers, windmills, pipes, icebergs, engines, filters, jets, and sprinklers, reservoirs etc.

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Applications of Fluid Mechanics

☐ In the household
- ✓ Refrigerator
- ✓ Hot water system
- ✓ Sewage
- ✓ Air conditioning
- ✓ Rain water tanks / pumps
- ✓ Fish pond / fountains
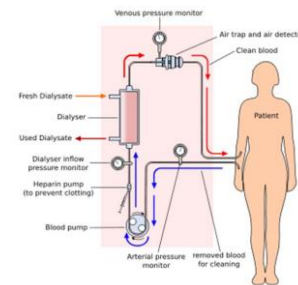- ✓ Swimming pools

☐ Cars
- ✓ Fuel line
- ✓ Fuel pump
- ✓ Fuel injectors
- ✓ Carburettors
- ✓ Air-con + heating
- ✓ Hydraulic brakes
- ✓ Power steering
- ✓ Automatic transmission
- ✓ Lubrication systems
- ✓ Radiator
- ✓ Water pump
- ✓ Aerodynamic design to
- ✓ minimise drag

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Applications of Fluid Mechanics

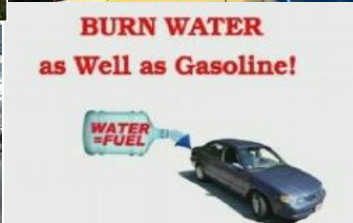Human body
© Ryan McVay/Getty RF

Natural flows and weather
© Glen Allison/Betty RF

Industrial applications
Digital Vision/PunchStock

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When you think about it, almost everything on this planet either is a fluid or moves within or near a fluid.

BURN WATER
as Well as Gasoline!

WATER = FUEL

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Mechanics – deals with stationary and moving bodies

bodies at rest – statics
bodies in motion – dynamics

Subcategory **FLUID MECHANICS**

Fluids at rest – fluid statics
Fluids in motion – fluid dynamics

**Fluid mechanics is also divided into several categories,**

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Fluid Statics

- Fluid static (also called **hydrostatics**) is the <u>science</u> of <u>fluids</u> at rest.

- **Study the pressure forces** throughout a fluid at rest or moving in such a manner that there is no relative motion between adjacent particles and the **pressure forces on finite surface**.

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Fluid mechanics is also divided into several categories

- Hydrodynamics (practically incompressible fluids e.g. water)
  - ➢ Hydraulics (liquid flows in pipes and open channels)

- Gas dynamics
- Aerodynamics
- Meteorology
- Oceanography
- Hydrology

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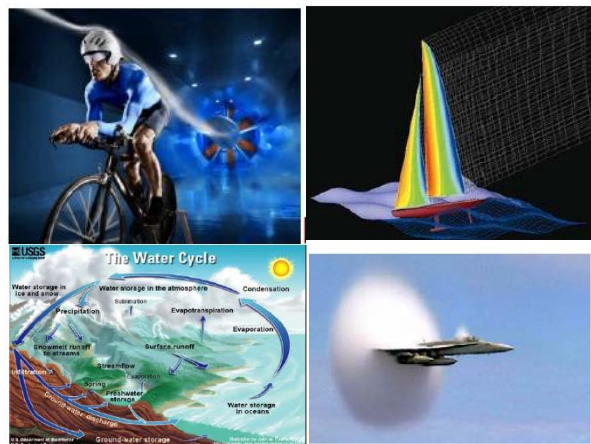
What is a Fluid ?

A liquid takes the shape of the container it is in and forms a free surface in the presence of gravity

Q: What will happen if:
- the beaker is tilted ?
- the walls are removed ?

A gas expands until it encounters the walls of the container and fills the entire available space. Gases cannot form a free surface.

The terms <u>gas</u> and <u>vapour</u> are interchangeable.
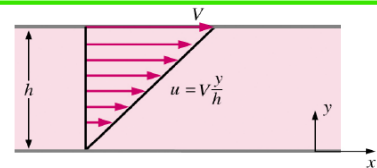
Free surface

Liquid

Gas
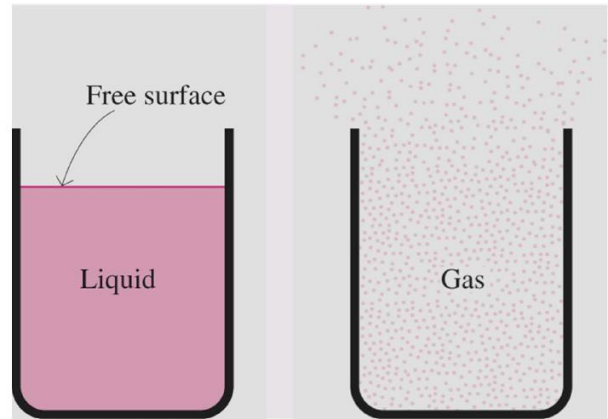
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What is a Fluid ?

A substance in the liquid or gas phase is referred to as a **fluid.**

❖ Distinction between a solid and a fluid is made on the basis of the substance's ability to resist an applied shear (or tangential) stress that tends to change its shape.

❖ A solid can resist an applied shear stress by deforming, whereas a fluid deforms continuously under the influence of shear stress, no matter how small.

In solids, stress is proportional to *strain* Applying a constant shear force, a solid eventually stops deforming at a fixed strain angle.
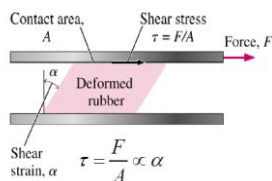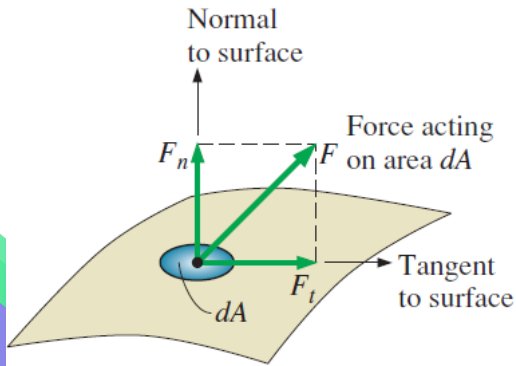
BUT in fluids stress is proportional to strain rate a fluid never stops deforming and approaches a certain rate of strain.

Contact area, A Shear stress $\tau = F/A$ Force, F

α

Deformed rubber

Shear strain, α $\tau = \dfrac{F}{A} \propto \alpha$

V

h $u = V\dfrac{y}{h}$ y

x

$$\tau = \frac{F}{A} \propto \dot{\alpha} \propto \mu \frac{du}{dy} = \mu \frac{V}{h}$$

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What is a Fluid ?

Normal stress: $\sigma = \dfrac{F_n}{dA}$

Shear stress: $\tau = \dfrac{F_t}{dA}$

- Stress is defined as the force per unit area

- Normal component: normal stress
  – In a fluid at rest, the normal stress is called **pressure**

- Tangential component: shear stress

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No-slip Condition

❖ No-slip condition: A fluid in direct contact with a solid "sticks" to the surface due to viscous effects

❖ Responsible for generation of wall shear stress, τ_w surface drag $D=\int \tau_w dA$, and the development of the boundary layer
❖The fluid property responsible for the no-slip condition is **viscosity**

❖Important boundary condition in formulating initial boundary value problem (IBVP) for analytical and computational fluid dynamics analysis
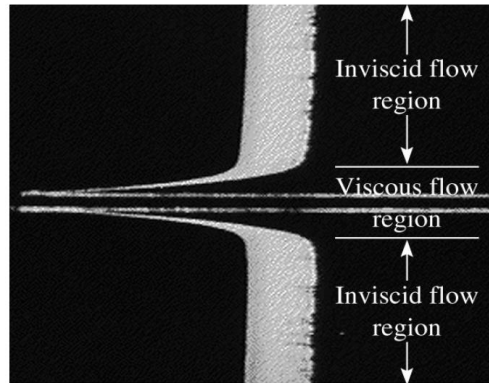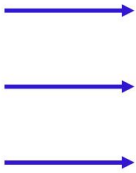

PLAY!

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http://www.youtube.com/watch?v=cUTkqZeiMow
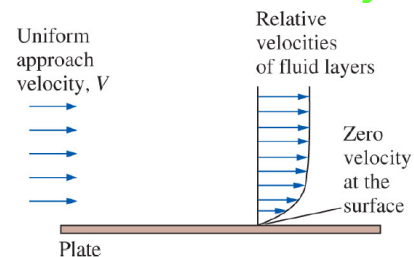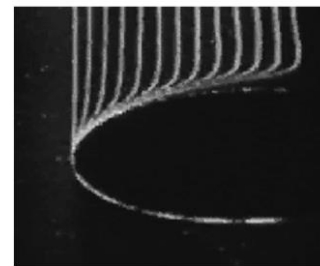
Viscous vs. Inviscid Regions of Flow

❑Regions where frictional effects are significant are called viscous regions. They are usually close to solid surfaces.
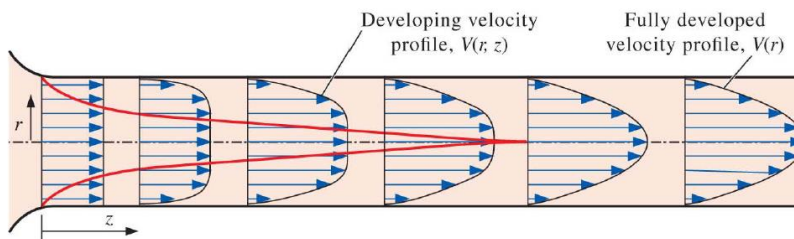
FLOW DIRECTION

Inviscid flow region

Viscous flow region

Inviscid flow region

❑Regions where frictional forces are small compared to inertial or pressure forces are called inviscid.

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Internal Flow

Developing velocity profile, V(r, z)

Fully developed velocity profile, V(r)

r

z

• Flow in a pipe or duct is internal flow IF the fluid is completely bounded by solids surfaces

• If the duct is only partially filled, this is referred to as open-channel flow (e.g. water in rivers)

• Internal flows are dominated by the influence of viscosity throughout the flow field
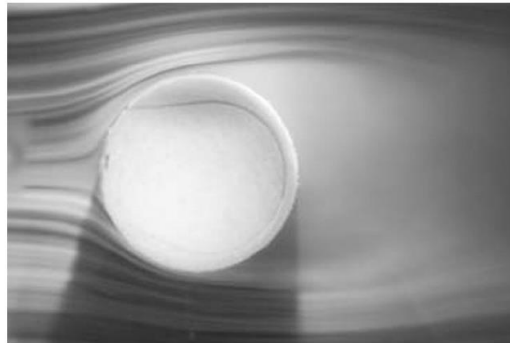
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External Flow

This is the flow of unbounded fluid over a surface (e.g. plate, wire, pipe)

For external flows, viscous effects are limited to the boundary layer and wake downstream of the bodies.

FLOW DIRECTION

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Compressible vs Incompressible

❖ A flow is classified as incompressible if the density remains   nearly constant.

❖ Liquid flows are typically incompressible.

❖ Apply 210 atm of pressure to liquid water at 1 atm … there is   only a 1% change in density

❖ BUT apply 0.01 atm of pressure to atmospheric air causes a   1% change in density

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Compressible vs Incompressible

❖Gas flows are often compressible, especially for high speeds
  (e.g. rockets, space craft)

❖Mach number, Ma = V/c is a good indicator of whether or not compressibility effects   are important.

❑ Ma < 0.3 : Incompressible
❑ Ma < 1 : Subsonic
❑Ma = 1 : Sonic
❑Ma > 1 : Supersonic
❑Ma >> 1 : Hypersonic

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Laminar vs Turbulent Flow

❖Laminar: highly ordered fluid motion with smooth streamlines.

❖Turbulent: highly disordered fluid motion characterized by velocity fluctuations   and eddies.

❖Transitional: a flow that contains both laminar and turbulent regions

❖Reynolds number, Re= $\rho Vd/\mu$ is the key parameter in   determining whether or not a flow is laminar or turbulent (Ch 8)
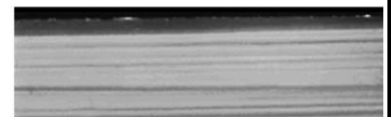
Laminar
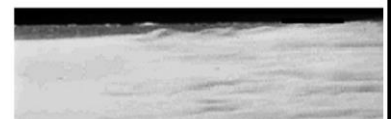
Transitional

Turbulent

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Natural vs. Forced Flow

❖ A fluid flow is said to be natural or forced, depending on how the fluid motion is initiated.

❖In **forced flow, a fluid is forced to flow over a surface or in a** pipe by external means such as a pump or a fan.

❖In **natural flows, any fluid motion is due to natural means such** as the buoyancy effect, which manifests itself as the rise of the warmer (and thus lighter) fluid and the fall of cooler (and thus denser) fluid

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Steady vs. Unsteady Flow

❖ Steady implies no change at a point with time.
❖Unsteady is the opposite of steady.
❖ Transient usually describes a starting, or developing flow e.g. a rocket firing up   – pressure builds up, flow accelerates then steadies

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One-, Two-, and Three-Dimensional Flows

❖ Typical flow involves 3D geometry and velocity may vary in all directions

❖ Velocity vector,
  o Rectangular coordinates **V(x,y,z)**
  o Cylindrical coordinates **V(r,ɵ,z)**

❖ Variation in some directions may be small with respect to other directions, e.g. a long pipe of small diameter, therefore can be modelled easier as 1 or 2 dimensional.

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One-, Two-, and Three-Dimensional Flows

Example: for fully-developed pipe flow, velocity *V(r)* is a function of
radius *r* and pressure *p(z)* is a function of distance z along the pipe.
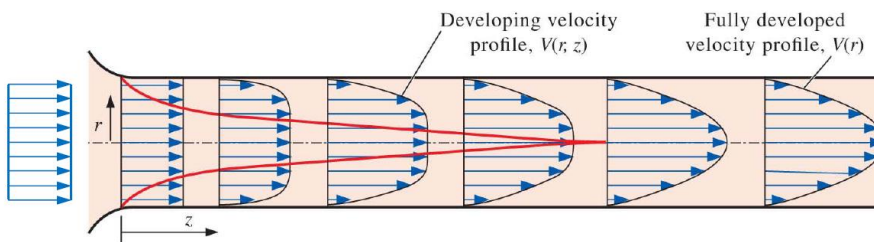
Two-dimensional at entrance and becomes one-dimensional when the velocity profile fully develops

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System and Control Volume

❖ A **system is defined as a** quantity of matter or a region in space chosen for study.

❖The mass or region outside the system is the **surroundings**.

❖The real or imaginary surface separating the system from the surroundings in called the **boundary**.

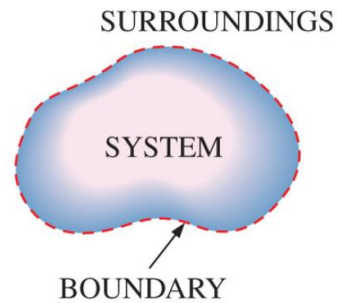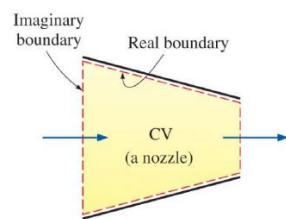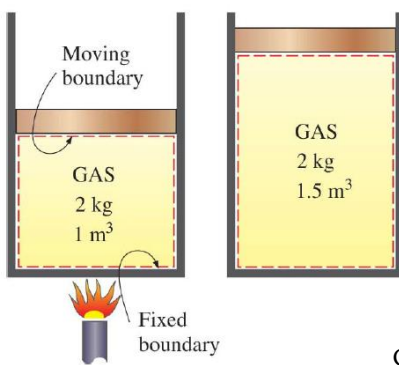**SURROUNDINGS**

SYSTEM

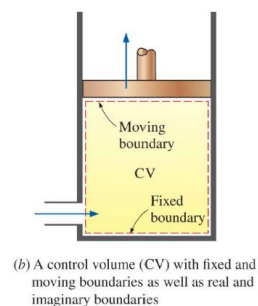**BOUNDARY**

FIGURE 1–23
System, surroundings, and boundary.

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System and Control Volume

❖A closed system consists of a fixed amount of mass
❖No mass can cross the boundary
❖Energy (heat, work) can cross the boundary
❖The volume does not have to be fixed

Moving boundary

GAS
2 kg
1 m³

Fixed boundary

GAS
2 kg
1.5 m³

Imaginary boundary   Real boundary

CV
(a nozzle)

(a) A control volume (CV) with real and imaginary boundaries

Moving boundary

CV

Fixed boundary

(b) A control volume (CV) with fixed and moving boundaries as well as real and imaginary boundaries

Control volumes detailed in Chapter 6

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Dimensions and Units

❑ Primary dimensions (or fundamental dimensions) include:

Length (m), Mass (kg), Time (s), Temperature (K)

❑ Secondary dimensions (derived dimensions) can be expressed in terms of primary dimensions and include:

velocity *V*, *energy E, and volume V.*

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Dimensions and Units

❖We all know that **Weight *W* is a force. It is the gravitational force applied to a** body, and its magnitude is determined from Newton's second law, **W = mg (N)**

❖The weight of a unit volume of a substance is the **specific weight, *γ* and is** determined from **γ** = ρg, where ρ is density, units N/m^3.

❖ Water has a density of 1000 kg/m^3 @ 4°C, which is equivalent to a specific gravity, **SG = 1 and is unitless. All other substances are a ratio based on water.**

❖Relative Density and specific gravity mean the same thing, both unitless.

Dimensional homogeneity is a valuable tool in checking for errors. Make sure every term in an equation has the same units.
Penalties will apply in the tutorial quizzes, in exam if no units
(or incorrect units) accompany the final answer(s).
E = 25 kJ + 7 kJ/kg

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Summary

Covered Chapter 2-part 1
❖Intro – looked a the big picture, where fluid mechanics fits in   Defined a fluid, forces and stress/pressure
❖Examples and applications
❖Terminologies and explanations
❖Dimensions and units

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"You've got to get up every morning with determination if you're going to go to bed with satisfaction."

– George Lorimer

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KEEP HAPPY
AND
SEE YOU SOON

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