Chapter 9

Solids and Fluids
1. Introduction
2. Fluids at Rest
3. Fluid Motion
States of Matter

- Solid
- Liquid
- Gas
- Plasma
Density and Specific Gravity

- What is Density?
- How do I calculate it?
- What are its SI units?
- What is Specific Gravity?
Pressure

- What is pressure?
- How do I calculate it?
- What are its SI units?
Measuring Pressure

- The spring is calibrated by a known force
- The force the fluid exerts on the piston is then measured
Density - Example

1. A water bed is 2.0 m wide and 30.0 cm deep. Find its weight and the pressure that the bed exerts on the floor.
Pressure and Depth

- How do I find pressure at different depths?
Pascal’s Principle

- What is Pascal’s Principle?
- How do I use this principle?
Absolute vs. Gauge Pressure

- What’s the difference?
Pressure Measurements: Manometer

- How does it work?
Blood Pressure

- Blood pressure is measured with a special type of manometer called a sphygmomanometer
- Pressure is measured in mm of mercury
Pressure Measurements:
Barometer

- Invented by Torricelli (1608 – 1647)
- What does it measure?
- How does it work?
Pressure Values in Various Units

- One atmosphere of pressure is defined as the pressure equivalent to a column of mercury exactly 0.76 m tall at 0° C where g = 9.806 65 m/s²
- One atmosphere (1 atm) =
  - 76.0 cm of mercury
  - 1.013 x 10⁵ Pa
  - 14.7 lb/in²
Pascal’s Principle - Example

1. In a car lift used in a service station, compressed air exerts a force on a small piston of circular cross section having a radius of 5.00 cm. This pressure is transmitted by an incompressible liquid to a second piston of radius 15.0 cm. (a) what force must the compressed air exert in order to lift a car weighing 13,300 N? (b) What air pressure will produce this force? (c) Show that the input energy transfer is equal in magnitude to the output energy transfer.
Archimedes

- 287 – 212 BC
- Greek mathematician, physicist, and engineer
- Buoyant force
- Inventor
Archimedes' Principle

- Any object completely or partially submerged in a fluid is buoyed up by a force whose magnitude is equal to the weight of the fluid displaced by the object.
Buoyant Force

- What is a buoyant force?
- How does it occur?
- How do I calculate it?
- What doesn’t affect it?
Totally Submerged Object
Archimedes’ Principle: Floating Object
Archimedes’ Principle - Example

1. A bargain hunter purchases a "gold" crown at a flea market. After she gets home, she hangs it from a scale and finds its weight to be 7.84 N. She then weighs the crown while it is immersed in water of density 1,000 kg/m$^3$, and now the scale reads 6.86 N. Is the crown made of pure gold?
Fluids in Motion: Streamline Flow

- What is a fluid?
- What is Streamline flow?
- What is viscosity?
Characteristics of an Ideal Fluid

- The fluid is nonviscous
  - There is no internal friction between adjacent layers
- The fluid is incompressible
  - Its density is constant
- The fluid motion is steady
  - Its velocity, density, and pressure do not change in time
- The fluid moves without turbulence
  - No eddy currents are present
  - The elements have zero angular velocity about its center
Equation of Continuity

- What is Continuity equation?
- What is flow rate?
- It’s relation to conservation of Mass
Daniel Bernoulli

- 1700 – 1782
- Swiss physicist and mathematician
- Wrote *Hydrodynamica*
- Also did work that was the beginning of the kinetic theory of gases
Bernoulli’s Equation

- Relates pressure to fluid speed and elevation
- Bernoulli’s equation is a consequence of Conservation of Energy applied to an ideal fluid
- Assumes the fluid is incompressible and nonviscous, and flows in a nonturbulent, steady-state manner
Bernoulli’s Equation

- What is it?
- Conservation of Energy
- When can it be used?
Application – Airplane Wing

- The air speed above the wing is greater than the speed below
- The air pressure above the wing is less than the air pressure below
- There is a net upward force
  - Called *lift*
- Other factors are also involved
Application – Airplane Wing

1. When a person inhales, air moves down the bronchus (windpipe) at 15 cm/s. The average flow speed of the air doubles through a constriction in the bronchus. Assuming incompressible flow, determine the pressure drop in the constriction.
Surface Tension

- What is surface Tension?
- How do I find it?
- What are its units?
- What is contact angle?
Surface Tension - Example
Viscosity

- What is Viscosity
- How do I find it?
- What are the units?
- What is Poiseuille’s Law?
- What is Reynolds number?
Motion through a viscous medium

- What is terminal velocity?
- Motion in Air
Terminal Velocity

- The Speed vs. Time Graph for Terminal Velocity
  - $v = 0$, $a$ is $g = 9.8 \text{ m/s}^2$.
  - As $a$ tends to zero, $V$ increases.
  - At $a=0$, $v$ is maximum and this is terminal velocity \( V_t \).
- What is the distance traveled by the object in each time interval with terminal velocity?
Application - Centrifuge

- High angular speeds give the particles a large radial acceleration
  - Much greater than $g$