ENVE 2061
BASIC FLUID MECHANICS

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2023 SPRING SEMESTER

TEXTBOOK

Applied
Fluid
Mechanics

Sixth Edition in SI Units

Robert L. Mott
University of Dayton

SI Conversion by

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Prentice Hall

Singapore London New York Toronto Sydney Tokyo Madrid
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Mott, R. L. Applied Fluid Mechanics, 6th Ed., 2005

TOPICS

Week 1	**Absolute and gravitational unit systems, conversion factors; absolute pressure, gage pressure**
Week 2	Properties of fluids@ Density, specific gravity, specific weight, vapor pressure
Week 3	Viscosity, surface tension, modulus of elasticity, temperature dependence of properties
Week 4	Fluid statics : Variation of pressure with elavation in gases and liquids
Week 5	Pressure measurement: manometers, piezometers, pitot tube
Week 6	Forces on plane areas, forces on curved surfaces
Week 7	Forces on plane areas, forces on curved surfaces
Week 8	MIDTERM EXAM (will be announced by Dean’s Office)
Week 9	Buoyancy, stability of submerged and floating bodies
Week 10	Conservation of mass, equation of continuity, mathematics applied to fluid mechanics
Week 11	Basics of fluid flow, laminar flow, turbulent flow, Reynolds number
Week 12	Bernoulli equation and applications
Week 13	Head losses in fluid flow, energy equation
Week 14	Major losses, Colebrook-White equation, Jain equation, Moody diagram, minor losses,
Week 15	Pipe flow problems, applications of energy equation
Week 16	FINAL EXAM (will be announced by Dean’s Office)

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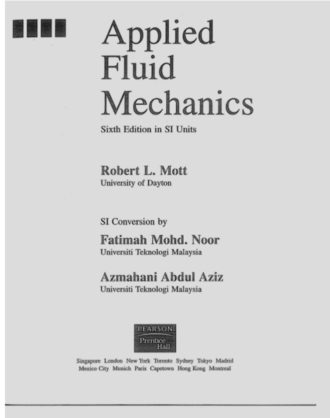

Week 1

CHAPTER 1
THE NATURE OF FLUIDS AND THE STUDY OF FLUID MECHANICS

1.2 OBJECTIVES

After completing this chapter, you should be able to:

TODAY

1. Differentiate between a gas and a liquid.
2. Define *pressure*.
3. Identify the units for the basic quantities of time, length, force, and mass in the SI system (metric unit system).
4. Identify the units for the basic quantities of time, length, force, and mass in the U.S. Customary System.
5. Properly set up equations to ensure consistency of units.
6. Define the relationship between force and mass.
7. Define *density*, *specific weight*, and *specific gravity*.
8. Identify the relationships between specific weight, specific gravity, and density, and solve problems using these relationships.
9. Define *surface tension*.

UNITS

«SI»
The INTERNATIONAL SYSTEM OF UNITS

The SI units for the basic quantities are

length = meter (m)

time = second (s)

mass = kilogram (kg) or $N \cdot s^2/m$

force = newton (N) or $kg \cdot m/s^2$

«U.S.»
The U.S. CUSTOMARY SYSTEM

the U.S. Customary System defines the basic quantities as follows:

length = foot (ft)

time = second (s)

force = pound (lb)

mass = slug or $lb\text{-}s^2/ft$

«SI»
The INTERNATIONAL SYSTEM OF UNITS

TABLE 1.2 SI units for common quantities used in fluid mechanics

Quantity	Basic Definition	Standard SI Units	Other Units Often Used
Length	—	meter (m)	millimeter (mm); kilometer (km)
Time	—	second (s)	hour (h); minute (min)
Mass	Quantity of a substance	kilogram (kg)	$N \cdot s^2/m$
Force or weight	Push or pull on an object	newton (N)	$kg \cdot m/s^2$
Pressure	Force/area	N/m^2 or pascal (Pa)	kilopascals (kPa); bar
Energy	Force times distance	N·m or Joule (J)	$kg \cdot m^2/s^2$
Power	Energy/time	N·m/s or J/s	watt (W); kW
Volume	$(\text{Length})^3$	m^3	liter (L)
Area	$(\text{Length})^2$	m^2	mm^2
Volume flow rate	Volume/time	m^3/s	L/s; L/min; m^3/h
Weight flow rate	Weight/time	N/s	kN/s; kN/min
Mass flow rate	Mass/time	kg/s	kg/h
Specific weight	Weight/volume	N/m^3	$kg/m^2 \cdot s^2$
Density	Mass/volume	kg/m^3	$N \cdot s^2/m^4$

«U.S.»
The U.S. CUSTOMARY SYSTEM

TABLE 1.3 U.S. customary units for common quantities used in fluid mechanics

Quantity	Basic Definition	Standard U.S. Units	Other Units Often Used
Length	—	feet (ft)	inches (in); miles (mi)
Time	—	second (s)	hour (h); minute (min)
Mass	Quantity of a substance	slugs	$lb \cdot s^2/ft$
Force or weight	Push or pull on an object	pound (lb)	kip (1000 lb)
Pressure	Force/area	lb/ft^2 or psf	lb/in^2 or psi; kip/in^2 or ksi
Energy	Force times distance	$lb \cdot ft$	$lb \cdot in$
Power	Energy/time	$lb \cdot ft/s$	horsepower (hp)
Volume	$(Length)^2$	ft^3	gallon (gal)
Area	$(Length)^3$	ft^2	in^2
Volume flow rate	Volume/time	ft^3/s or cfs	gal/min (gpm); ft^3/min (cfm)
Weight flow rate	Weight/time	lb/s	lb/min; lb/h
Mass flow rate	Mass/time	slugs/s	slugs/min; slugs/h
Specific weight	Weight/volume	lb/ft^3	
Density	Mass/volume	$slugs/ft^3$	

UNIT CANCELLATION PROCEDURE

The analyses required in fluid mechanics involve the algebraic manipulation of several terms. The equations are often complex, and it is extremely important that the results be dimensionally correct. That is, they must have their proper units. Indeed, answers will have the wrong numerical value if the units in the equation are not consistent. Tables 1.2 and 1.3 summarize standard and other common units for the quantities used in fluid mechanics.

A simple straightforward procedure called *unit cancellation* will ensure proper units in any kind of calculation, not only in fluid mechanics but also in virtually all your technical work. The six steps of the procedure are listed below.

UNIT CANCELLATION PROCEDURE

1. Solve the equation algebraically for the desired term.
2. Decide on the proper units for the result.
3. Substitute known values, including units.
4. Cancel units that appear in both the numerator and denominator of any term.
5. Use conversion factors to eliminate unwanted units and obtain the proper units as decided in Step 2.
6. Perform the calculation.

PRACTICE PROBLEMS

Conversion Factors

1.1 Convert 1250 millimeters to meters.

1.2 Convert 1600 square millimeters to square meters.

1.3 Convert 3.65×10^3 cubic millimeters to cubic meters.

1.4 Convert 2.05 square meters to square millimeters.

1.5 Convert 0.391 cubic meters to cubic millimeters.

1.6 Convert 55.0 gallons to cubic meters.

1.7 An automobile is moving at 80 kilometers per hour. Calculate its speed in meters per second.

1.8 Convert a length of 25.3 feet to meters.

1.9 Convert a distance of 1.86 miles to meters.

1.10 Convert a length of 8.65 inches to millimeters.

1.11 Convert a distance of 2580 feet to meters.

1.12 Convert a volume of 480 cubic feet to cubic meters.

1.13 Convert a volume of 7390 cubic centimeters to cubic meters.

1.14 Convert a volume of 6.35 liters to cubic meters.

1.15 Convert 6.0 feet per second to meters per second.

1.16 Convert 2500 cubic feet per minute to cubic meters per second.

Consistent Units in an Equation

A body moving with constant velocity obeys the relationship $s = vt$, where s = distance, v = velocity, and t = time.

1.17 A car travels 0.50 km in 10.6 s. Calculate its average speed in m/s.

1.18 In an attempt at a land speed record, a car travels 1.50 km in 5.2 s. Calculate its average speed in km/h.

1.19 A car travels 304.8 m in 14 s. Calculate its average speed in km/h.

1.20 In an attempt at a land speed record, a car travels 1 km in 5.7 s. Calculate its average speed in km/h.

A body starting from rest with constant acceleration moves according to the relationship $s = \frac{1}{2}at^2$, where s = distance, a = acceleration, and t = time.

1.21 If a body moves 3.2 km in 4.7 min while moving with constant acceleration, calculate the acceleration in m/s^2.

1.22 An object is dropped from a height of 13 m. Neglecting air resistance, how long would it take for the body to strike the ground? Use $a = g = 9.81\ m/s^2$.

1.23 If a body moves 3.2 km in 4.7 min while moving with constant acceleration, calculate the acceleration in m/s^2.

1.24 An object is dropped from a height of 1.35 m. Neglecting air resistance, how long would it take for the body to strike the ground? Use $a = g = 9.81\ m/s^2$.

The formula for kinetic energy is $KE = \frac{1}{2}mv^2$, where m = mass and v = velocity.

1.25 Calculate the kinetic energy in N·m of a 15-kg mass if it has a velocity of 1.20 m/s.

1.26 Calculate the kinetic energy in N·m of a 3600-kg truck moving at 16 km/h.

1.27 Calculate the kinetic energy in N·m of a 75-kg box moving on a conveyor at 6.85 m/s.

1.28 Calculate the mass of a body in kg if it has a kinetic energy of 38.6 N·m when moving at 31.5 km/h.

1.29 Calculate the mass of a body in g if it has a kinetic energy of 94.6 N·m when moving at 2.25 m/s.

1.30 Calculate the velocity in m/s of a 12-kg object if it has a kinetic energy of 15 N·m.

1.31 Calculate the velocity in m/s of a 175-g body if it has a kinetic energy of 212 mN·m.

One measure of a baseball pitcher's performance is earned run average, or ERA. It is the average number of earned runs allowed if all the innings pitched were converted to equivalent nine-inning games. Therefore, the units for ERA are runs per game.

1.32 If a pitcher has allowed 39 runs during 141 innings, calculate the ERA.

1.33 A pitcher has an ERA of 3.12 runs/game and has pitched 150 innings. How many earned runs has the pitcher allowed?

1.34 A pitcher has an ERA of 2.79 runs/game and has allowed 40 earned runs. How many innings have been pitched?

1.35 A pitcher has allowed 49 earned runs during 123 innings. Calculate the ERA.