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Cyclone Gonu


Shirabad Waterfall, Gorgan

Fluid Mechanics

Spring Semester 1402-03 – KNT University of Technology

Session 3

Manjil Windfarm


Hooralazim Marsh System


Bakeri Highway flood control System

Review

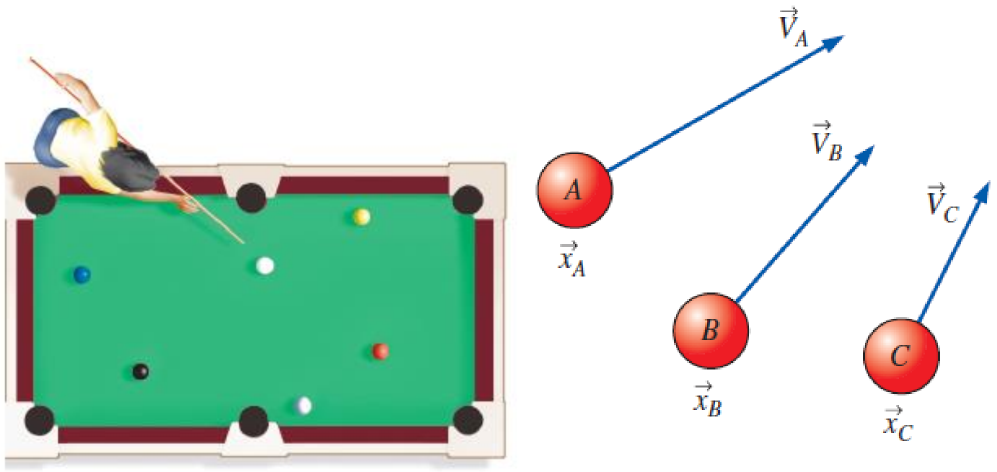
- Compressible vs Incompressible Flow (Mach Number)
- Internal vs External Flow
- Laminar vs Turbulent Flow
- Steady vs Unsteady Flow
- Uniform vs Nonuniform Flow
- Natural vs Forced Flow
- One- , Two-, and Three-Dimensional Flow
- System and Control Volume

Outline

- Review
- Lagrangian and Eulerian Description of Flow
- Dimension and Unit
- Unity Conversion Ratio
- Modeling in Engineering
- Equations and Mass in Fluid Mechanics
- Problem Solving
- Accuracy and Precision

Description of Fluid Flow (Lagrangian and Eulerian)

- **Lagrangian description**
  - ✓ To follow the path of individual objects. This method requires us to track the position and velocity of each individual fluid parcel (fluid particle) and take to be a parcel of fixed identity.



- **Eulerian description**
  - a finite volume called a **flow domain** or **control volume** is defined, through which fluid flows in and out. Instead of tracking individual fluid particles, we define **field variables**, functions of space and time, within the control volume.

- The field variable at a particular location at a particular time is the value of the variable for whichever fluid particle happens to occupy that location at that time.

Dimension and Units

Any physical quantity can be characterized by dimensions.

The magnitudes assigned to the dimensions are called units.

Some basic dimensions such as mass *m*, length *L*, time *t*, and temperature *T* are selected as primary or fundamental dimensions, while others such as velocity *V*, energy *E*, and volume *V* are expressed in terms of the primary dimensions and are called secondary dimensions, or derived dimensions.

Metric SI system: A simple and logical system based on a decimal relationship between the various units.

English system: It has no apparent systematic numerical base, and various units in this system are related to each other rather arbitrarily.

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)

Units

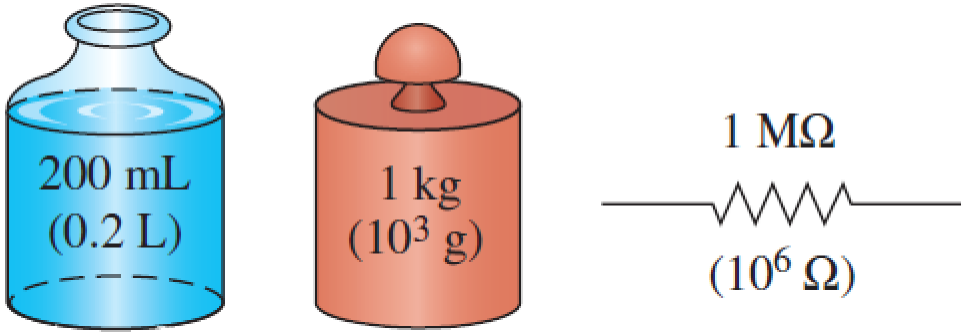
1 lbm = 0.45359 kg

1 ft = 0.3048 m

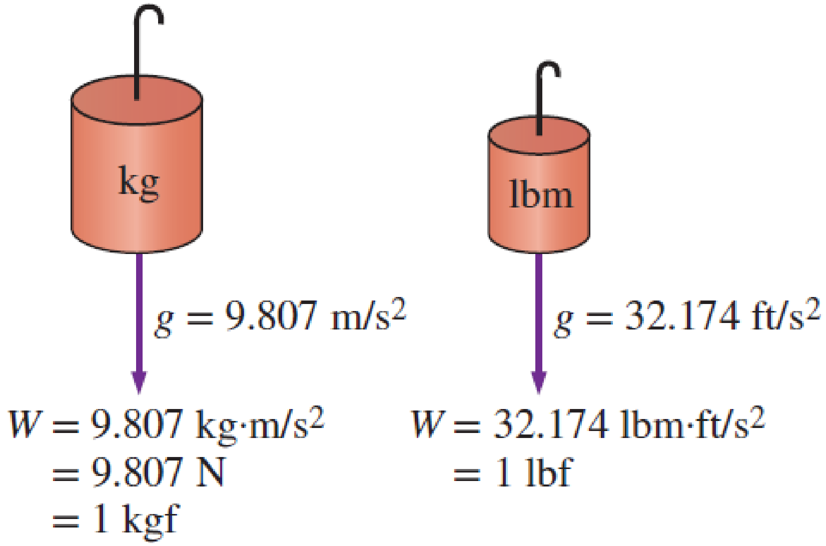
Work = Force × Distance
1 J = 1 N·m
1 cal = 4.1868 J
1 Btu = 1.0551 kJ

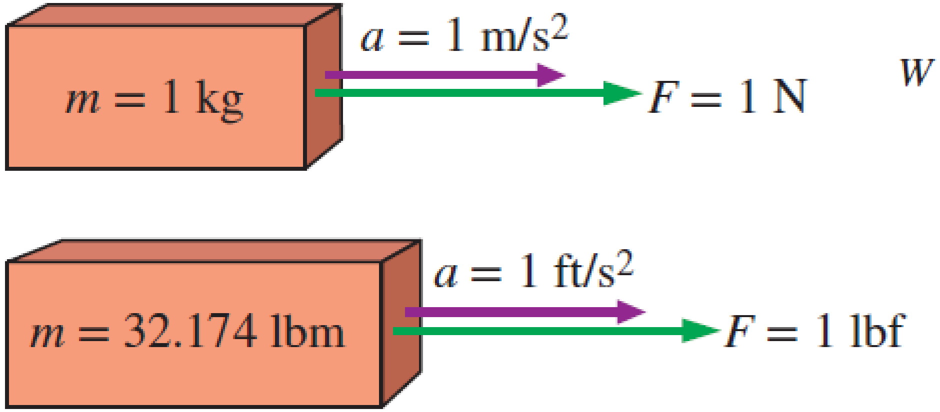
Force = (Mass) (Acceleration)

$F = ma$



The SI unit prefixes are used in all branches of engineering.





1 N = 1 kg·m/s^2

1 lbf = 32.174 lbm·ft/s^2

The definition of the force units.

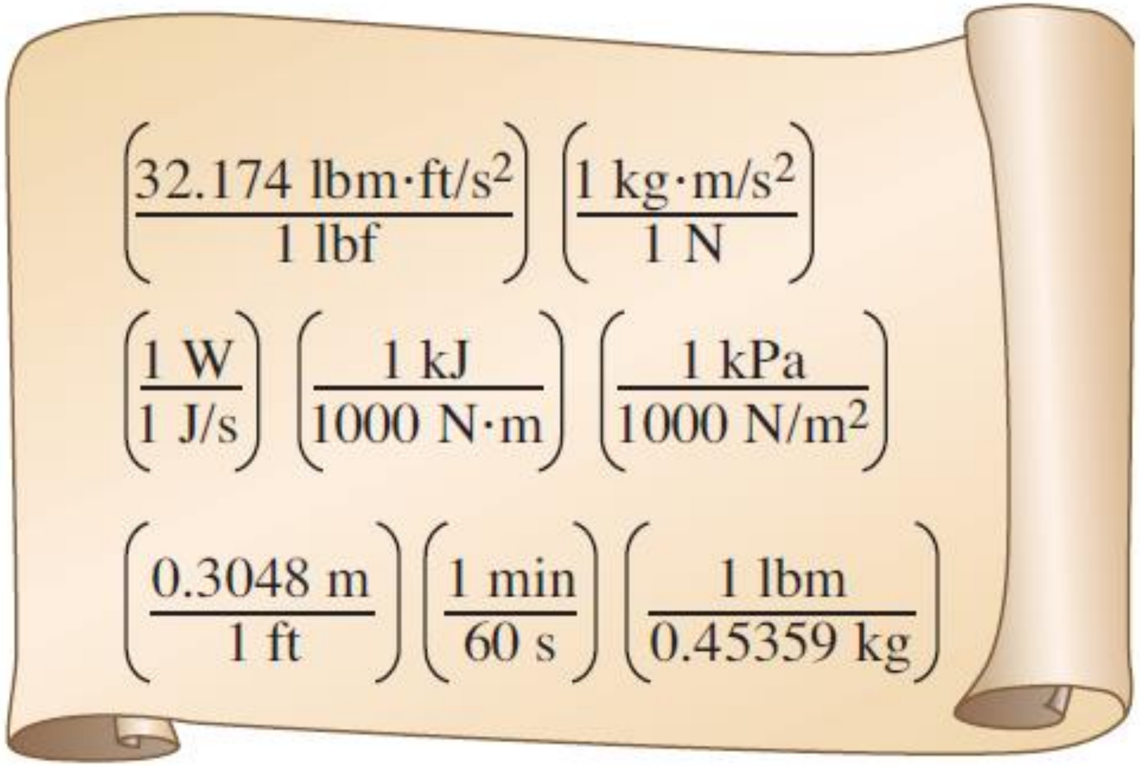
Unity Conversion Ratios

*All **nonprimary units** (secondary units) can be formed by combinations of **primary units**.*

$$\mathrm{N} = \mathrm{kg}\,\frac{\mathrm{m}}{\mathrm{s}^2} \qquad \text{and} \qquad \mathrm{lbf} = 32.174\,\mathrm{lbm}\,\frac{\mathrm{ft}}{\mathrm{s}^2}$$

Some unity conversion ratios

$$\frac{\mathrm{N}}{\mathrm{kg \cdot m/s^2}} = 1 \qquad \text{and} \qquad \frac{\mathrm{lbf}}{32.174\,\mathrm{lbm \cdot ft/s^2}} = 1$$



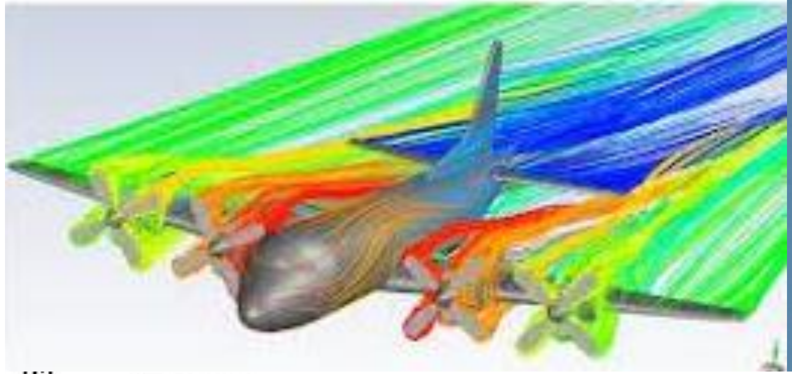
Unity conversion ratios are identically equal to 1 and are unitless, and thus such ratios (or their inverses) can be inserted conveniently into any calculation to properly convert units.

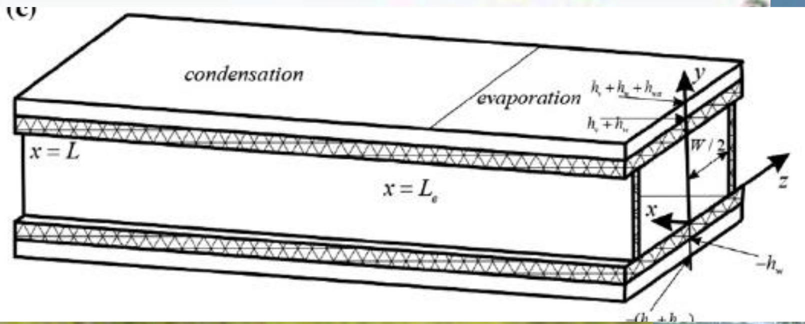
Modeling in Engineering

An engineering device or process can be studied either *experimentally* (testing and taking measurements) or *analytically* (by analysis or calculations).

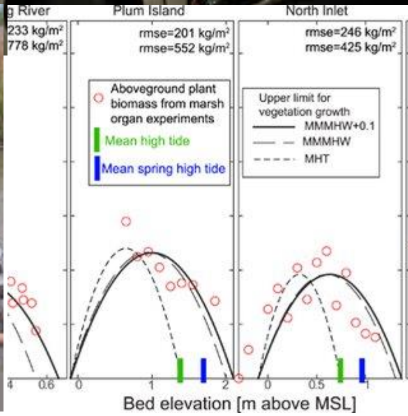
The **experimental approach** has the advantage that we deal with the actual physical system, and the desired quantity is determined by measurement, within the limits of experimental error. However, this approach is **expensive**, **time-consuming**, and often **impractical**.

The **analytical approach** (including the **numerical approach**) has the advantage that it is **fast** and **inexpensive**, but the results obtained are subject to the accuracy of the **assumptions**, **approximations**, and **idealizations** of the analysis.







Equations and Math in Fluid Mechanics

Why do we need mathematical equations? The descriptions of most scientific problems involve equations that relate the changes in some key variables to each other.

In the limiting case of infinitesimal or differential changes in variables, we obtain ***differential equations*** that provide precise mathematical formulations for the **physical principles and laws** by representing the rates of change as ***derivatives***.

Differential equations are used to investigate a wide variety of problems in sciences and engineering.

Complex model

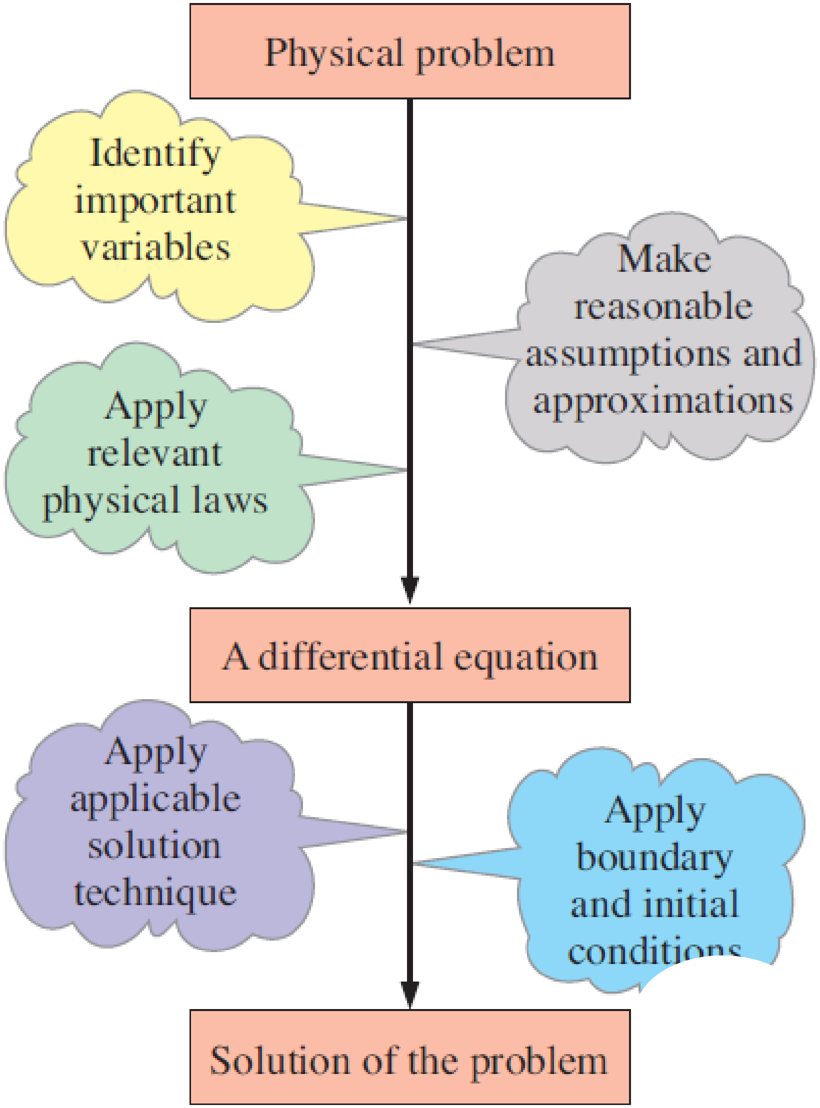
(very accurate)

vs.

Simple model

(not-so-accurate)

The right choice is usually the simplest model that yields satisfactory results.



Ideal Gas

Equation of state:

Ideal-gas equation of state: The simplest and best-known equation of state for substances in the gas phase.

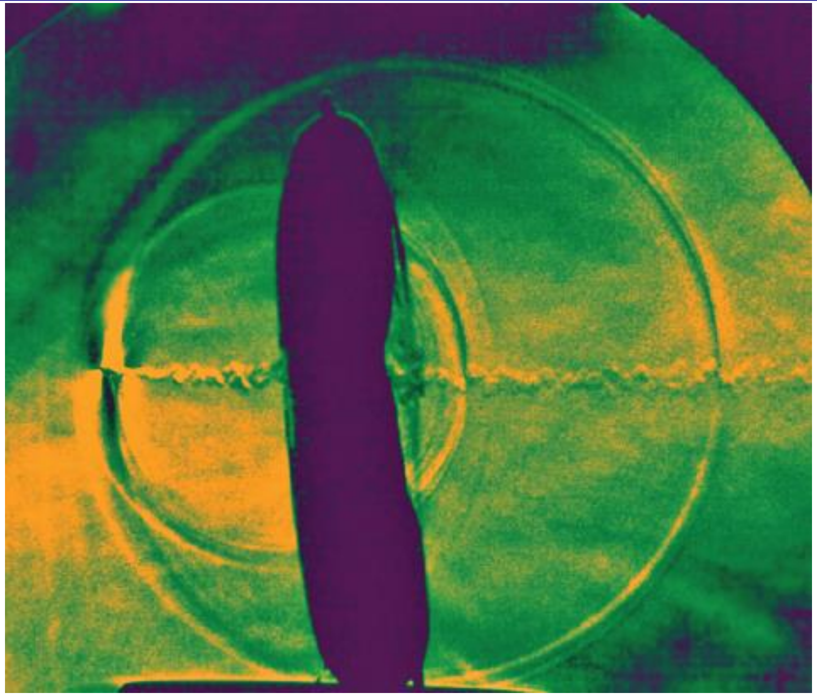
$$Pv = RT \quad \text{or} \quad P = \rho RT$$

$$R = R_u / M \qquad R_u = 8.314 \text{ kj/kmol} \cdot \text{K}$$ The universal gas constant

$$PV = mRT \text{ or } PV = NR_u T$$

$T(\text{K}) = T(°\text{C}) + 273.15 = T(\text{R})/1.8$
$T(\text{R}) = T(°\text{F}) + 459.67 = 1.8T(\text{K})$

$$P_1V_1/T_1 = P_2V_2/T_2$$ For a fixed mass



- At low pressures and high temperatures, the density of a gas decreases and the gas behaves like an ideal gas.
- In the range of practical interest, many familiar gases such as air, nitrogen, oxygen, hydrogen, helium, argon, neon, and carbon dioxide can be treated as ideal gases with negligible error.

Problem-Solving

Step 1: Problem Statement

Step 2: Schematic

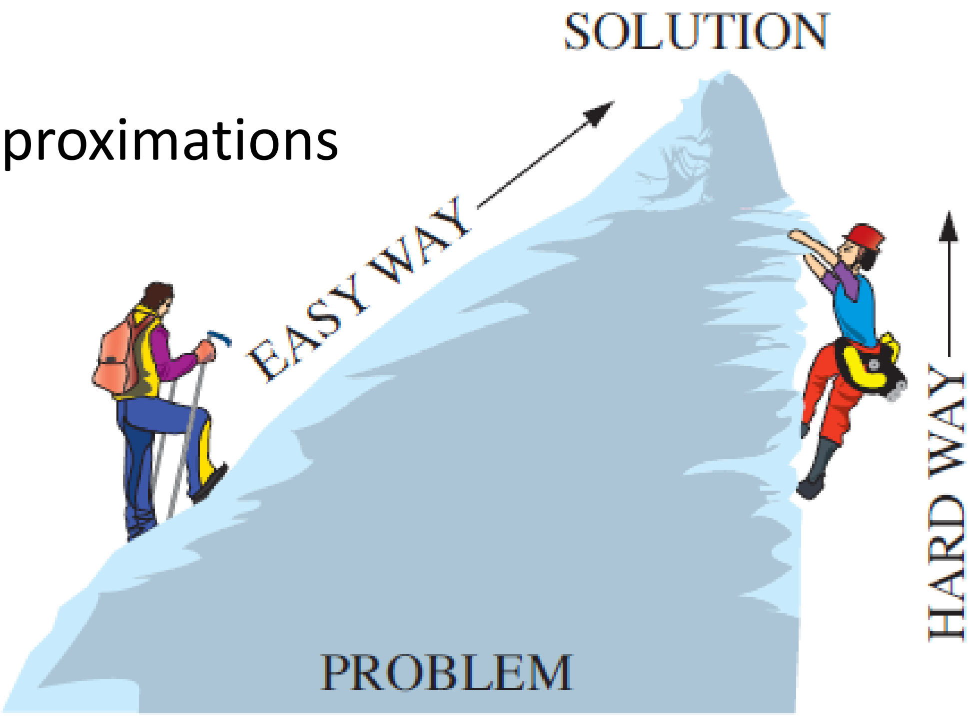
Step 3: Assumptions and Approximations

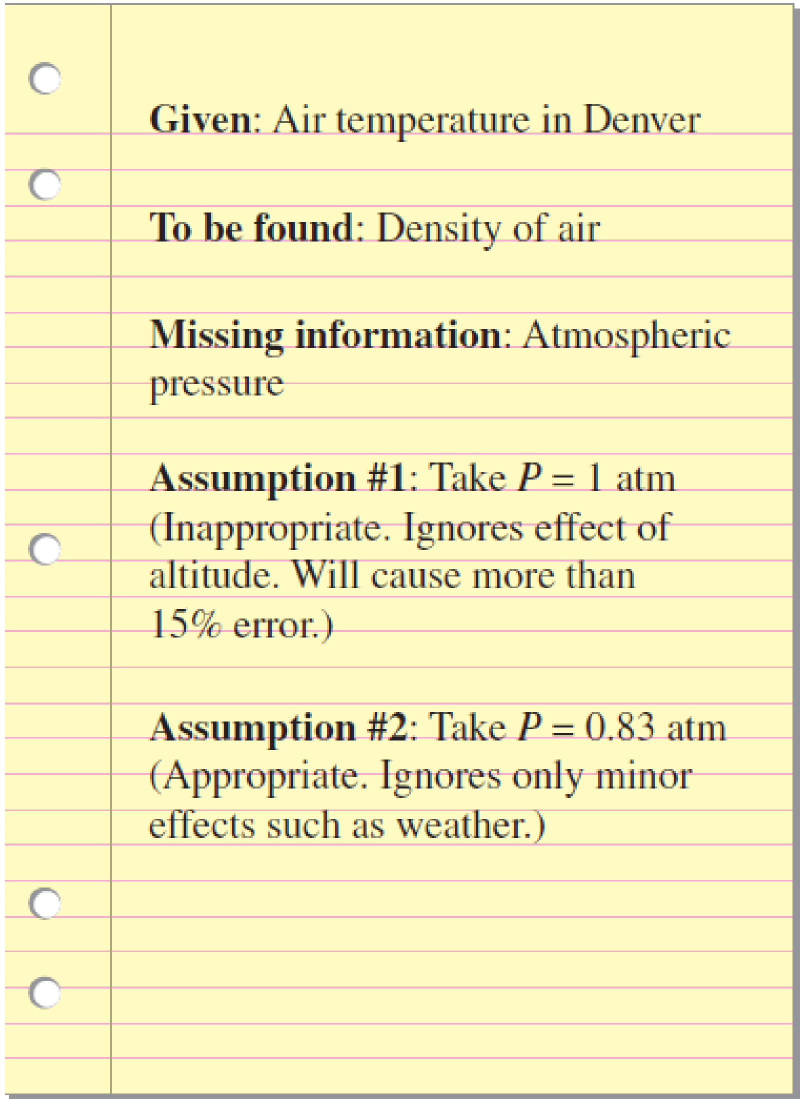
Step 4: Physical Laws

Step 5: Properties

Step 6: Calculations

Step 7: Reasoning, Verification, and Discussion





Accuracy, Precision, and Significant Digits

Accuracy error (*inaccuracy*): The value of one reading minus the true value. In general, accuracy of a set of measurements refers to the closeness of the average reading to the true value. Accuracy is generally associated with repeatable, fixed errors.

Precision error: The value of one reading minus the average of readings. In general, precision of a set of measurements refers to the fineness of the resolution and the repeatability of the instrument. Precision is generally associated with unrepeatable, random errors.

Given: Volume: $V = 3.75$ L

Density: $\rho = 0.845$ kg/L

(3 significant digits)

Also, $3.75 \times 0.845 = 3.16875$

Find: Mass: $m = \rho V = 3.16875$ kg

Rounding to 3 significant digits:

$m = 3.17$ kg

Intensive and Extensive Properties

Property: Any characteristic of a system.

Some familiar properties are pressure *P*, temperature *T*, volume *V*, and mass *m*.

Properties are considered to be either *intensive* or *extensive*.

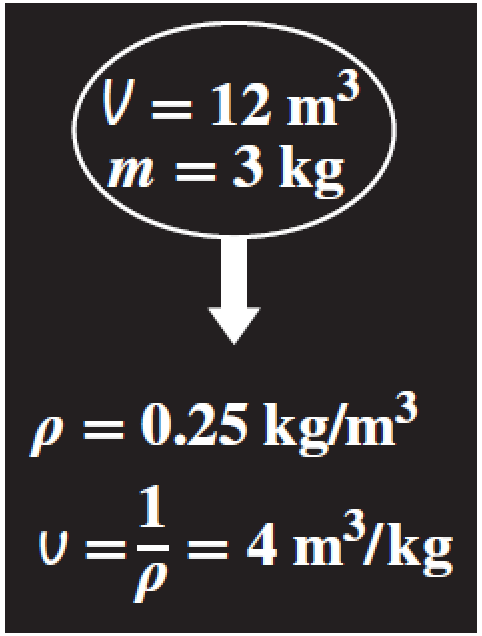
Intensive properties: Those that are independent of the mass of a system, such as temperature, pressure, and density.

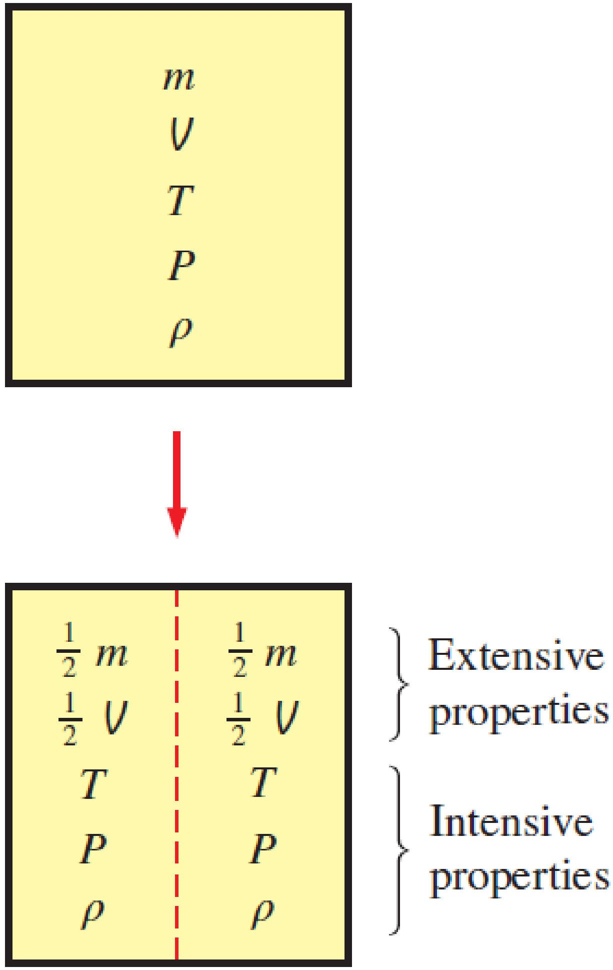
Extensive properties: Those whose values depend on the size—or extent—of the system.

Specific properties: Extensive properties per unit mass.

$$v = V/m = 1/\rho$$ **Specific volume**

Density $$\rho = \frac{m}{V} \quad (\mathrm{kg/m^3})$$





Specific Gravity and Weight

Specific gravity: The ratio of the density of a substance to the density of some standard substance at a specified temperature (usually water at 4°C).

$$\mathrm{SG} = \frac{\rho}{\rho_{\mathrm{H_2O}}}$$

Specific weight: The weight of a unit volume of a substance.

$$\gamma_s = \rho g \quad \left(\mathrm{N/m^3}\right)$$

Substance	SG
Water	1.0
Blood (at 37°C)	1.06
Seawater	1.025
Gasoline	0.68
Ethyl alcohol	0.790
Mercury	13.6
Balsa wood	0.17
Dense oak wood	0.93
Gold	19.3
Bones	1.7–2.0
Ice (at 0°C)	0.916
Air	0.001204

Wrap-up

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