Thermodynamics I

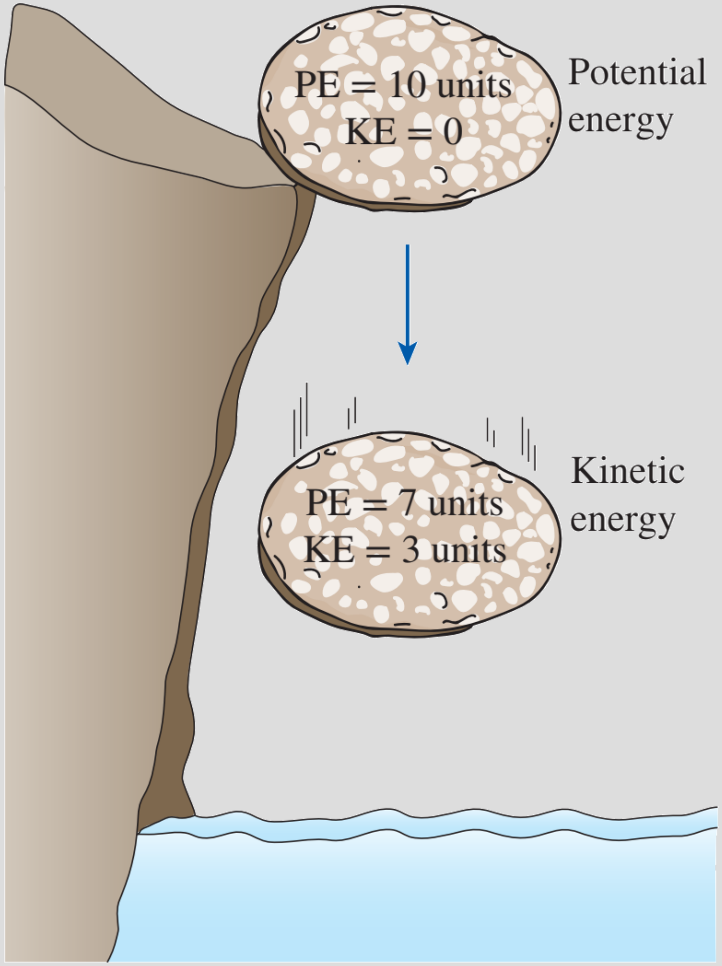
Lecture 1 & 2

Introduction and Basic Concepts (Ch-1)

Dr. Ahmed Rasheed

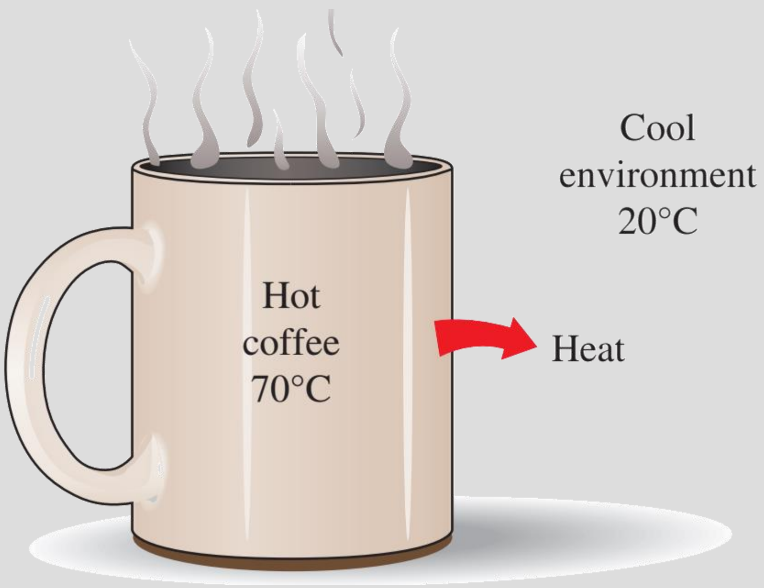
THERMODYNAMICS AND ENERGY

- **Thermodynamics**: The science of *energy.*
- **Energy**: The ability to cause changes.
- The name *thermodynamics* stems from the Greek words *therme* (heat) and *dynamis* (power).
- **Conservation of energy principle**: During an interaction, energy can change from one form to another but the total amount of energy remains constant.
- Energy cannot be created or destroyed.
- **The first law of thermodynamics**: An expression of the conservation of energy principle.
  - The first law asserts that *energy* is a thermodynamic property.



Energy cannot be created or destroyed; it can only change forms (the first law).

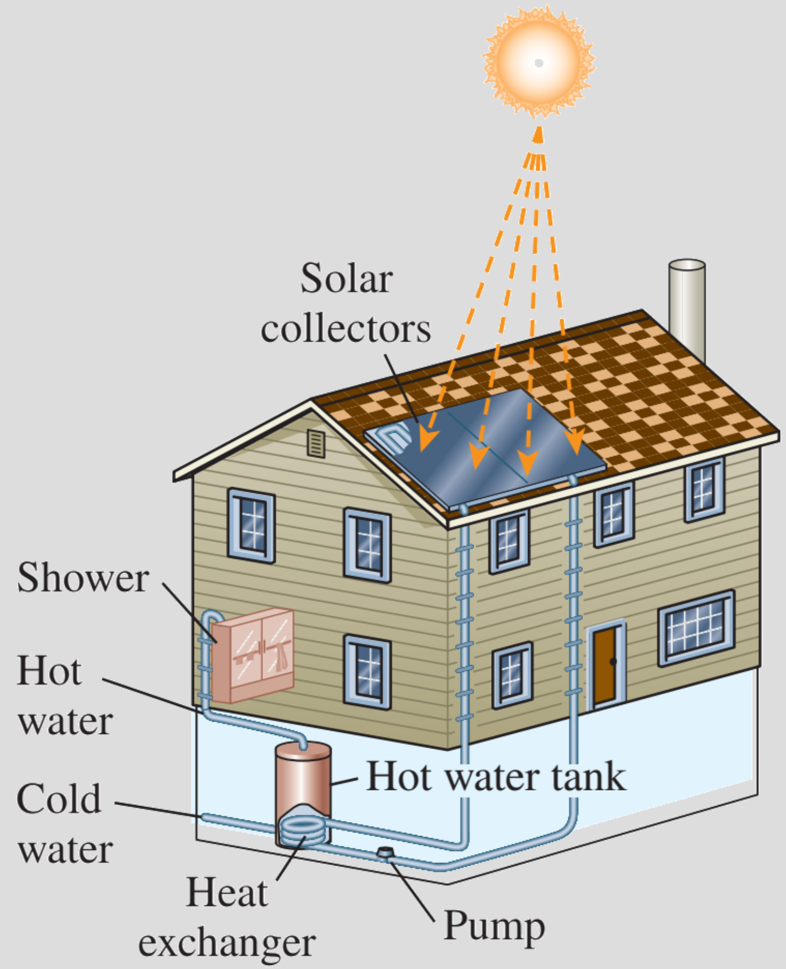
- **The second law of thermodynamics:** It asserts that energy has *quality* as well as *quantity*, and actual processes occur in the direction of decreasing quality of energy.
- **Classical thermodynamics**: A macroscopic approach to the study of thermodynamics that does not require a knowledge of the behavior of individual particles.
- It provides a direct and easy way to the solution of engineering problems and it is used in this text.
- **Statistical thermodynamics**: A microscopic approach, based on the average behavior of large groups of individual particles.
- It is used in this text only in the supporting role.



Heat flows in the direction of decreasing temperature.

Applications of Thermodynamics:

- Electric or gas range Heating and Air Conditioning
- Refrigerator
- Humidifier



On larger scale

- Automotive engines Rockets
- Jet engines
- Conventional or Nuclear PP
- Solar Systems
- Designing from small cars to aero planes

IMPORTANCE OF DIMENSIONS 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.

TABLE 1–1

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)

TABLE 1–2

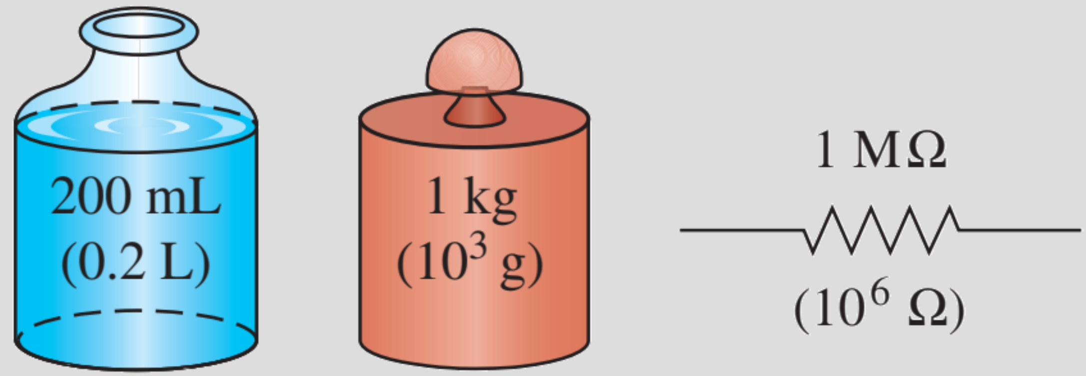
Standard prefixes in SI units

Multiple	Prefix
10^{24}	yotta, Y
10^{21}	zetta, Z
10^{18}	exa, E
10^{15}	peta, P
10^{12}	tera, T
10^{9}	giga, G
10^{6}	mega, M
10^{3}	kilo, k
10^{2}	hecto, h
10^{1}	deka, da
10^{-1}	deci, d
10^{-2}	centi, c
10^{-3}	milli, m
10^{-6}	micro, μ
10^{-9}	nano, n
10^{-12}	pico, p
10^{-15}	femto, f
10^{-18}	atto, a
10^{-21}	zepto, z
10^{-24}	yocto, y

Some SI and English Units

$$1 \text{ lbm} = 0.45359 \text{ kg}$$

$$1 \text{ ft} = 0.3048 \text{ m}$$



Work = Force × Distance

1 J = 1 N·m

1 cal = 4.1868 J

1 Btu = 1.0551 kJ

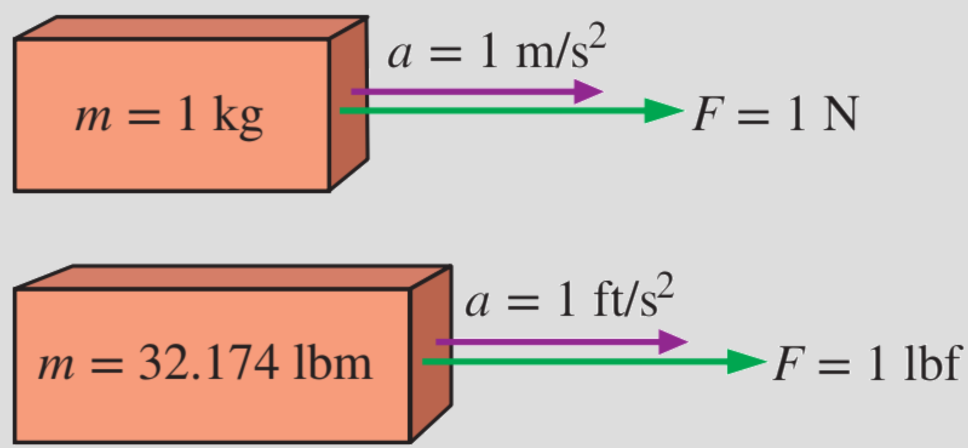
The SI unit prefixes are used in all branches of engineering.

$$\text{Force} = (\text{Mass})(\text{Acceleration})$$

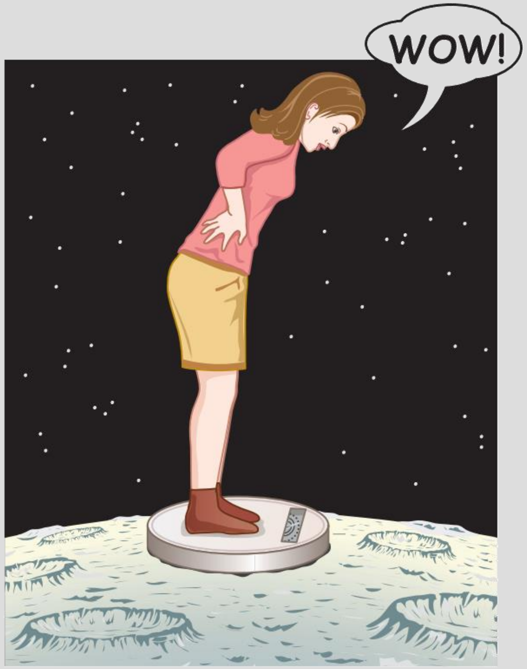
$$F = ma$$

$$1 \text{ N} = 1 \text{ kg} \cdot \text{m/s}^2$$

$$1 \text{ lbf} = 32.174 \text{ lbm} \cdot \text{ft/s}^2$$



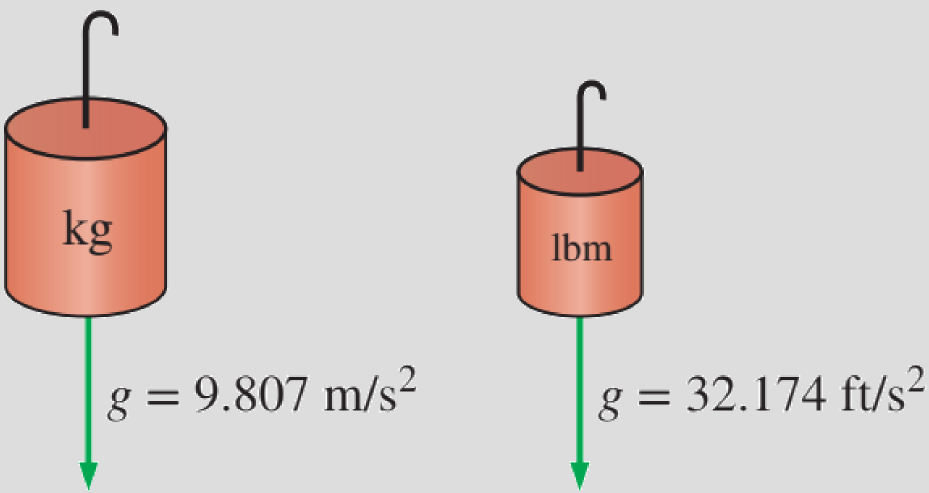
The definition of the force units.



$$W = mg \quad \text{(N)}$$

W weight
m mass
g gravitational acceleration

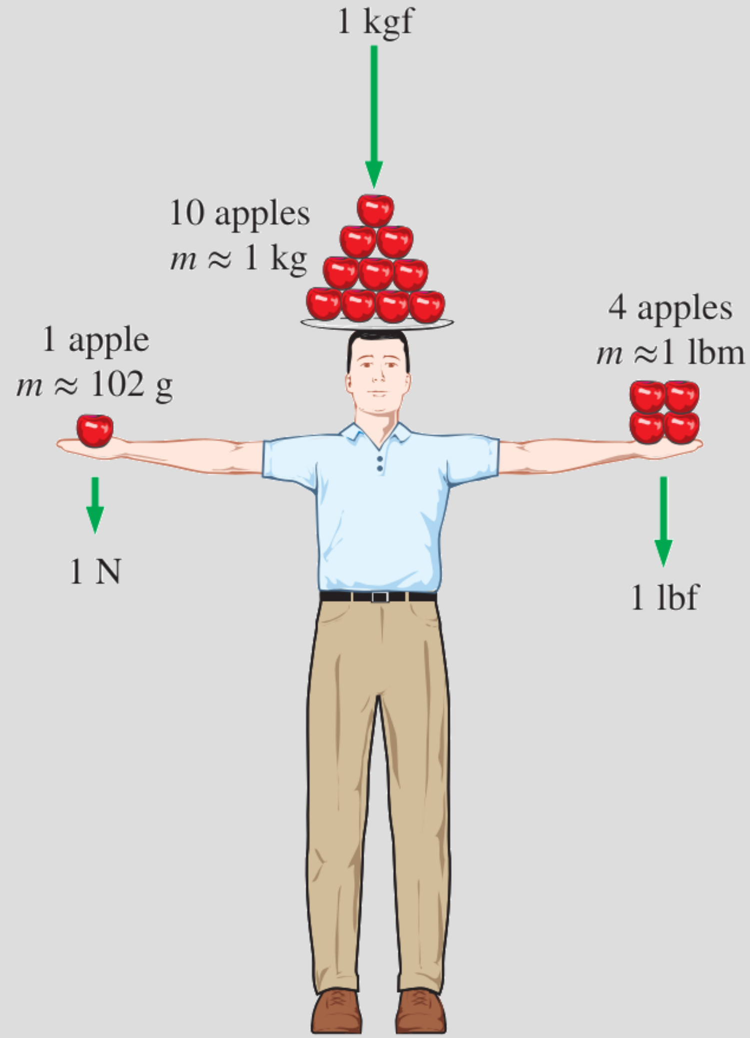
A body weighing 60 kgf on earth will weigh only 10 kgf on the moon.



$$\begin{aligned} W &= 9.807\ \text{kg·m/s}^2 \\ &= 9.807\ \text{N} \\ &= 1\ \text{kgf} \end{aligned}$$

$$\begin{aligned} W &= 32.174\ \text{lbm·ft/s}^2 \\ &= 1\ \text{lbf} \end{aligned}$$

The weight of a unit mass at sea level.



The relative magnitudes of the force units newton (N), kilogram-force (kgf), and pound-force (lbf).

DENSITY AND SPECIFIC GRAVITY

Density

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

Specific volume

$$v = \frac{V}{m} = \frac{1}{\rho}$$

$$V = 12\ \mathrm{m}^3$$
$$m = 3\ \mathrm{kg}$$
$$\Downarrow$$
$$\rho = 0.25\ \mathrm{kg/m}^3$$
$$v = \frac{1}{\rho} = 4\ \mathrm{m^3/kg}$$

Density is mass per unit volume; specific volume is volume per unit mass.

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.

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

TABLE 1–3

Specific gravities of some substances at 0°C

Substance	SG
Water	1.0
Blood	1.05
Seawater	1.025
Gasoline	0.7
Ethyl alcohol	0.79
Mercury	13.6
Wood	0.3–0.9
Gold	19.2
Bones	1.7–2.0
Ice	0.92
Air (at 1 atm)	0.0013

Dimensional homogeneity

All equations must be dimensionally **homogeneous**.

Unity Conversion Ratios

All nonprimary units (secondary units) can be formed by combinations of primary units.
Force units, for example, can be expressed as

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

They can also be expressed more conveniently as **unity conversion ratios** as

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

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.

To be dimensionally homogeneous, all the terms in an equation must have the same unit.

Examples

$$\left(\frac{32.174\ \text{lbm}\cdot\text{ft/s}^2}{1\ \text{lbf}}\right) \left(\frac{1\ \text{kg}\cdot\text{m/s}^2}{1\ \text{N}}\right)$$

$$\left(\frac{1\ \text{W}}{1\ \text{J/s}}\right) \left(\frac{1\ \text{kJ}}{1000\ \text{N}\cdot\text{m}}\right) \left(\frac{1\ \text{kPa}}{1000\ \text{N/m}^2}\right)$$

$$\left(\frac{0.3048\ \text{m}}{1\ \text{ft}}\right) \left(\frac{1\ \text{min}}{60\ \text{s}}\right) \left(\frac{1\ \text{lbm}}{0.45359\ \text{kg}}\right)$$

Measuring Physical Quantities: Units

Unity conversion ratios

$$W = p(V_2 - V_1) = (1.049 \text{ bar})(.045 \text{ m}^2)\left|\frac{10^5 \text{ N/m}^2}{1 \text{ bar}}\right|\left|\frac{1 \text{ kJ}}{10^3 \text{ N}\cdot\text{m}}\right| = 4.72 \text{ kJ}$$

EXAMPLE 1–1 Spotting Errors from Unit Inconsistencies

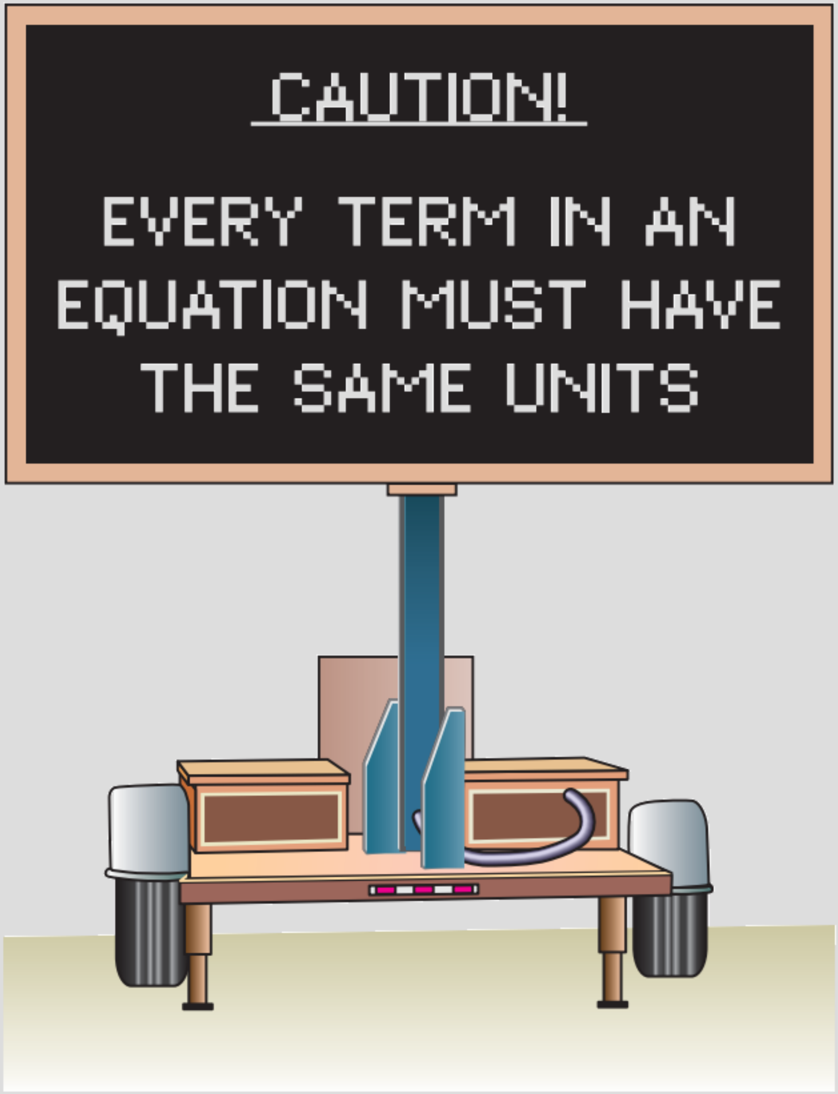
While solving a problem, a person ended up with the following equation at some stage:

$$E = 25 \text{ kJ} + 7 \text{ kJ/kg}$$

where E is the total energy and has the unit of kilojoules. Determine how to correct the error and discuss what may have caused it.

EXAMPLE 1–2 Obtaining Formulas from Unit Considerations

A tank is filled with oil whose density is $\rho = 850 \text{ kg/m}^3$. If the volume of the tank is $V = 2 \text{ m}^3$, determine the amount of mass m in the tank.



End of Lecture