# SKMM 2413 Thermodynamics I

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# Synopsis

Thermodynamics is a basic science that deals with energy. This course introduces students to the basic principles of thermodynamics. It will discuss basic concepts and introduces the various forms of energy and energy transfer as well as properties of pure substances. A general relation for the conservation of energy principle will be developed and applied to closed systems and extended to open systems. The second law of thermodynamics will be introduced and applied to cycles, cyclic devices and processes.

# 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.

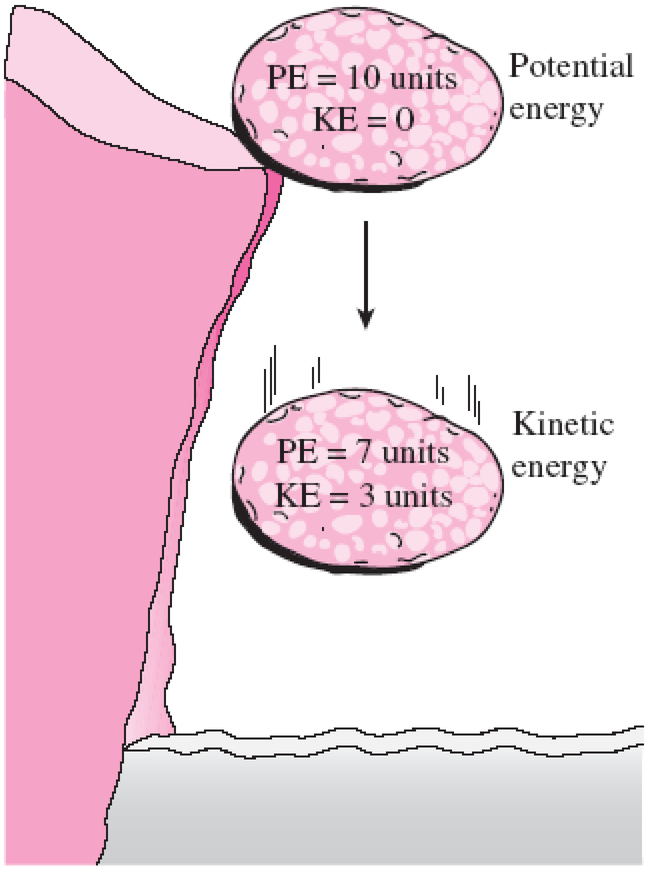



**FIGURE 1–1**
Energy cannot be created or destroyed; it can only change forms (the first law).

- **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.

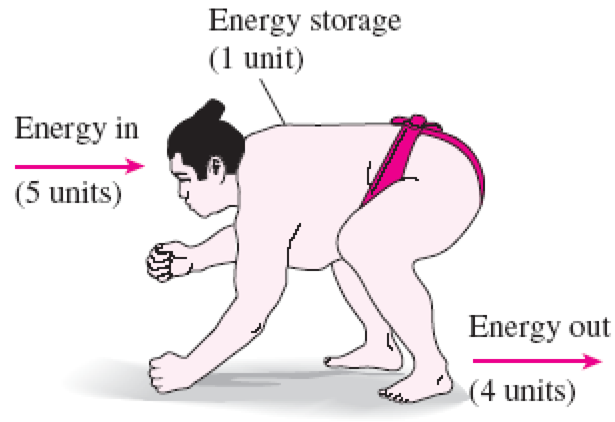



**FIGURE 1–2**
Conservation of energy principle for the human body.

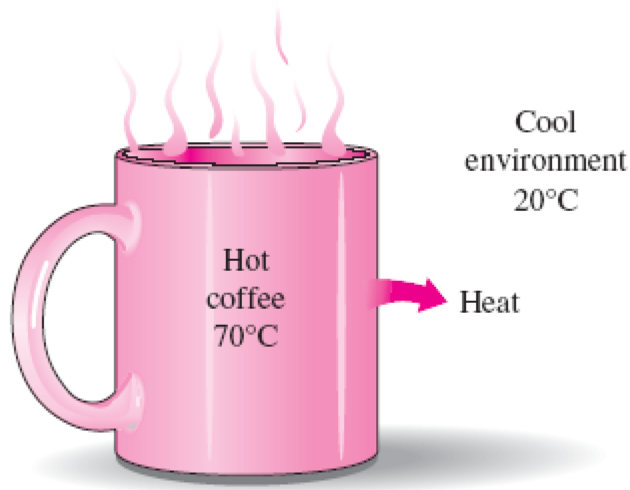



**FIGURE 1–3**
Heat flows in the direction of decreasing temperature.

# Application Areas of Thermodynamics

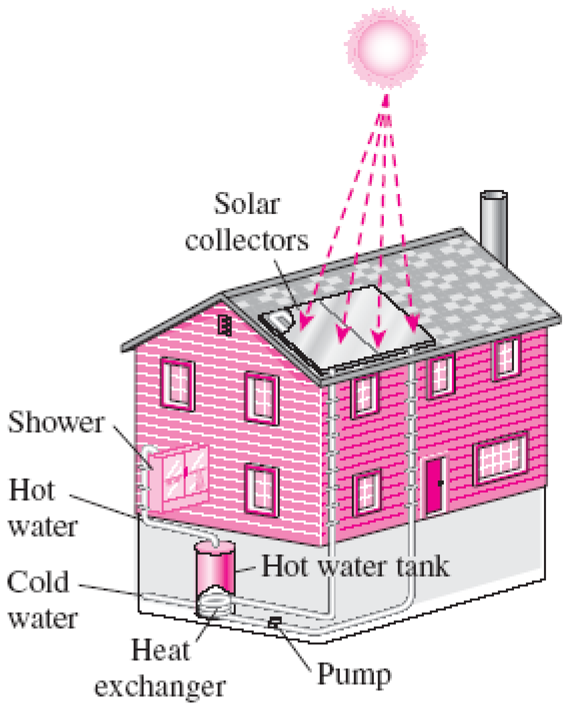



**FIGURE 1–4**
The design of many engineering systems, such as this solar hot water system, involves thermodynamics.

Refrigeration systems

Boats

Aircraft and spacecraft

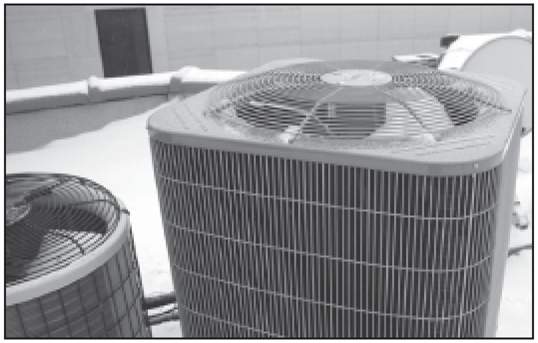
Power plants

All activities in nature involve some interaction between energy and matter; thus, it is hard to imagine an area that does not relate to thermodynamics in some manner.

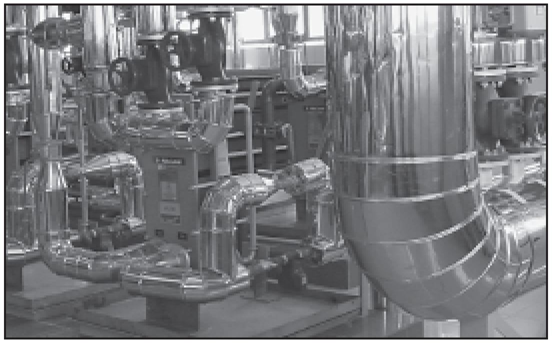
Human body

Cars

Wind turbines



Air conditioning systems



Industrial applications

# UNITS & DIMENSION

Physical Quantity = Dimension
(length, mass, time, temperature, velocity, volume, etc)

Measurement of Dimension = Unit
(meter, kg, seconds, …) *SI system*

Dimension
- Primary - length (m)
  - mass (kg)
  - time (s)
  - temperature (K)
- Secondary (Derived)

e.g Volume = length3

Velocity = $\frac{\text{length}}{\text{time}}$

## Unit Addition

- all terms must have the same dimension, unit, & factor (dimensional homogeneity)

## Unit Conversion

Quantities are multiplied with ***1*** (conversion factor)

(Quantities unchanged, but units have changed)

*Except temperature conversion since it involves addition*

# SI Prefix

| *FACTOR* | in full | in words | SI PREFIX | SI SYMBOL |
|---|---|---|---|---|
| 1.0E+24 | 1 000 000 000 000 000 000 000 000 | septillion | yotta- | Y |
| 1.0E+21 | 1 000 000 000 000 000 000 000 | sextillion | zetta- | Z |
| 1.0E+18 | 1 000 000 000 000 000 000 | quintillion | exa- | E |
| 1.0E+15 | 1 000 000 000 000 000 | quadrillion | peta- | P |
| 1.0E+12 | 1 000 000 000 000 | trillion | tera- | T |
| 1.0E+9 | 1 000 000 000 | billion | giga- | G |
| 1.0E+6 | 1 000 000 | million | mega- | M |
| 1.0E+3 | 1 000 | thousand | kilo- | k |
| 1.0E+2 | 100 | hundred | hecto- | h |
| 1.0E+1 | 10 | ten | deca- | da |
| 1.0E-1 | 0.1 | tenth | deci- | d |
| 1.0E-2 | 0.01 | hundredth | centi- | c |
| 1.0E-3 | 0.001 | thousandth | milli- | m |
| 1.0E-6 | 0.000 001 | millionth | micro- | µ |
| 1.0E-9 | 0.000 000 001 | billionth | nano- | n |
| 1.0E-12 | 0.000 000 000 001 | trillionth | pico- | p |
| 1.0E-15 | 0.000 000 000 000 001 | quadrillionth | femto- | f |
| 1.0E-18 | 0.000 000 000 000 000 001 | quintillionth | atto- | a |
| 1.0E-21 | 0.000 000 000 000 000 000 001 | sextillionth | zepto- | z |
| 1.0E-24 | 0.000 000 000 000 000 000 000 001 | septillionth | yocto- | y |

# Greek Alphabets

| Capital | Lowercase | Name | Pronunciation |
|---|---|---|---|
| Α | α | ALPHA | AL-fuh |
| Β | β | BETA | BAY-tuh |
| Γ | γ | GAMMA | GAM-uh |
| Δ | δ | DELTA | DEL-tuh |
| Ε | ε ϵ | EPSILON | EP-sil-on |
| Ζ | ζ | ZETA | ZAY-tuh |
| Η | η | ETA | AY-tuh |
| Θ | θ | THETA | THAY-tuh |
| Ι | ι | IOTA | eye-OH-tuh |
| Κ | κ | KAPPA | KAP-uh |
| Λ | λ | LAMBDA | LAM-duh |
| Μ | μ | MU | MYOO |

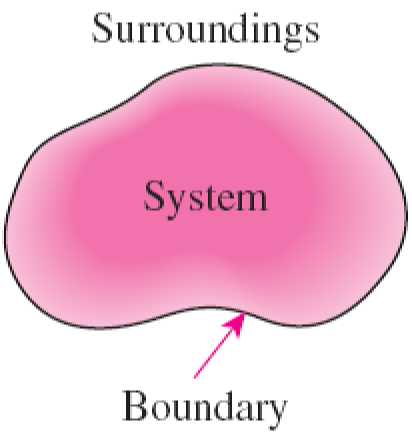
| Capital | Lowercase | Name | Pronunciation |
|---|---|---|---|
| Ν | ν | NU | NOO |
| Ξ | ξ | XI | KS-EYE |
| Ο | ο | OMICRON | OM-i-KRON |
| Π | π ϖ | PI | PIE |
| Ρ | ρ | RHO | ROW |
| Σ | σ ς | SIGMA | SIG-muh |
| Τ | τ | TAU | TAU |
| Υ | υ | UPSILON | OOP-si-LON |
| Φ | ϕ φ | PHI | FEE |
| Χ | χ | CHI | K-EYE |
| Ψ | ψ | PSI | SIGH |
| Ω | ω | OMEGA | oh-MAY-guh |

**System**: A quantity of matter or a region in space chosen for study.

**Surroundings**: The mass or region outside the system

**Boundary**: The real or imaginary surface that separates the system from its surroundings.

The boundary of a system can be *fixed* or *movable.*
Systems may be considered to be *closed* or *open.*



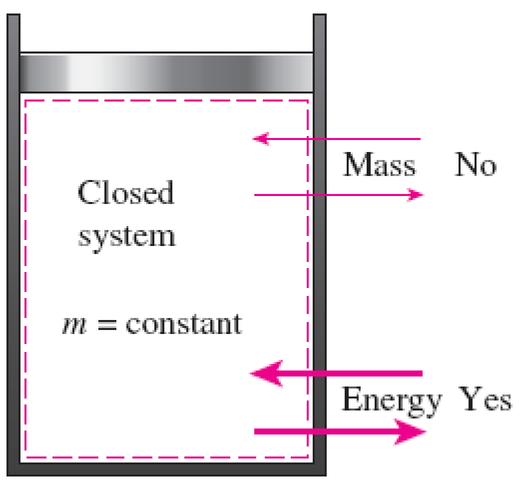
**Closed system (Control mass):** A fixed amount of mass. Energy can cross the boundary, but no mass can

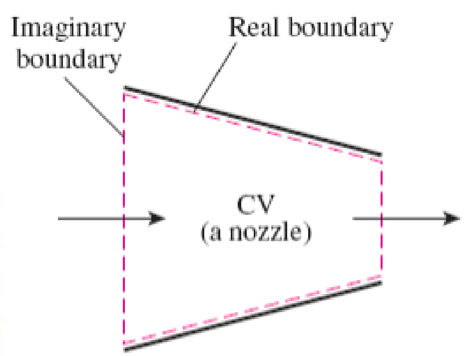
**Open system (control volume)**: A properly selected region in space.

It usually encloses a device that involves mass flow such as a compressor, turbine, or nozzle.

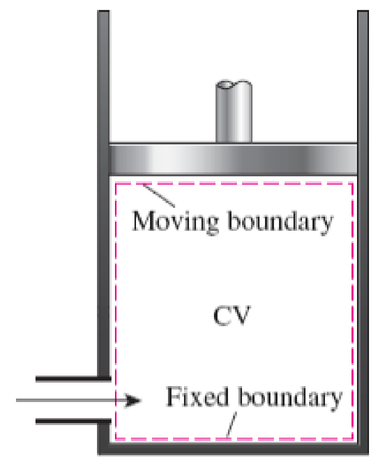
Both mass and energy can cross the boundary of a control volume.

**Control surface**: The boundaries of a control volume. It can be real or imaginary.




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




(*b*) A control volume with fixed and moving boundaries

# Property

*Properties* are characteristics of a system (e.g. Mass, volume, temperature, energy, pressure etc.)

Types of property

- Extensive
  - The value depends on the size of the system (*additive*) (Volume V, mass m, Energy E, Internal Energy U)
- Intensive
  - The value does not depend on the size of the system (not additive) (Temperature T, Pressure P)
  - Specific Property (Independent of size)
    - Specific Property = (Extensive Property) / (Mass)
    - ex. Specific Volume v, Specific Energy e

e.g. Specific volume = Volume / mass

$v\ [m^3/kg] = V\ [m^3]\ /\ m\ [kg]$

# State

A state is described by the system properties at that instant

If even only 1 of the properties changed; the state has changed

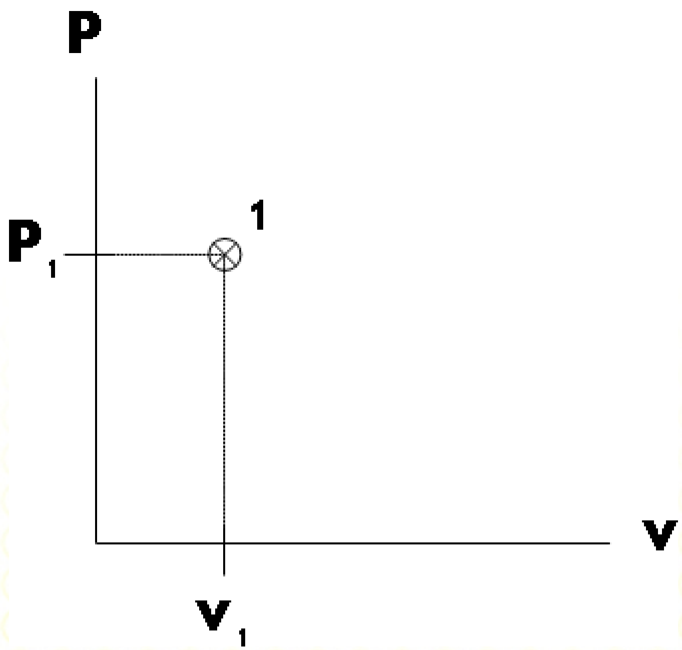
If all properties does not change with time; it is called *steady state*

If the properties at two different times are the same; both states are the same

# State Postulate

“The **state** of a simple, compressible system can be completely described by knowing only **2 properties** which are intensive and independent” (other properties can be determined from other relations)

State can be shown on a **property diagram**



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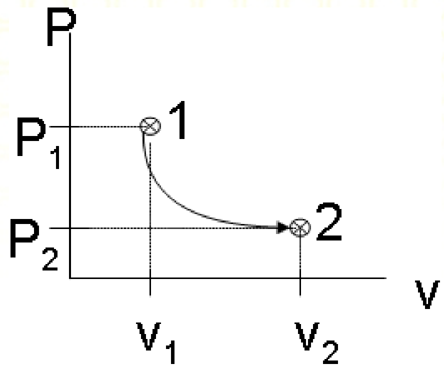
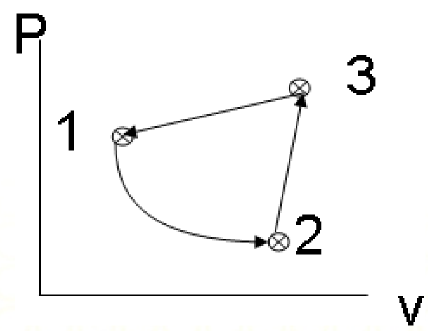
# Process

When state changes; the system has undergone a **process**




If several processes occurred in series until it reaches the initial condition; the system has undergone a **cycle** *(net change of any property = 0 after a cycle)*



# Constant Property Process

When the value of a property is constant during the process

| Example properties that is constant | Process Name |
|---|---|
| Temperature | Isothermal, const. temperature |
| Pressure | isobaric, const. pressure |
| Volume | isometric, isochoric, const. volume |
| Entropy | isentropic |
| Enthalpy | isenthalpic |

# Property (continued)

A quantity is a *property* iff (if and only if) the difference between 2 *states* is not dependent on the *process* between those states (point function).

If the difference of a function **y** is an *exact differential* (**dy**), that function is a *thermodynamic property.*

*Work*, *heat* depends on the path (process), and thus not an exact differential, and not a property (path function)

# Summary

We are studying a **system**

Ex. Gas inside a piston-cylinder device

Gas = **system**

Surrounded by **surrounding**

Separated by a **boundary** (inside surface of cylinder)

System has **properties** (T,p,v)

Properties describe the **state** of the system (*State Postulate*)

State can be shown on a **property diagram**

When state changes; the system underwent a **process**

If it returns to the initial state; the system underwent a cycle

# Phase and Pure Substances

<u>**Phase**</u> - – a <u>uniform</u> amount of matter

- Physical structure (solid, liquid, gas)
- Chemical composition

<u>Pure Substance</u> – *system* with a uniform chemical composition

# Equilibrium

When there's no more change on any property

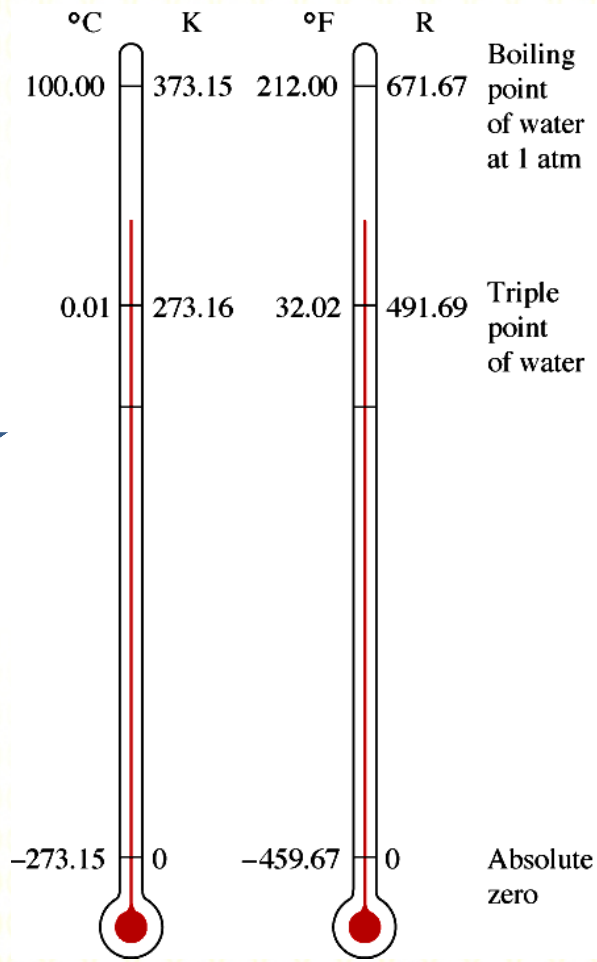
- 4 things have to be in equilibrium
  - Thermal equilibrium
  - Phase equilibrium
  - Mechanical Equilibrium
  - Chemical equilibrium

Equilibrium Process - System always in equilibrium during process (process drawn as solid line on property diagram)

Quasistatic Process = quasiequilibrium (quasi = almost)

# Temperature

A fundamental quantity – a measure of molecular activity




$$T(K) = T(°C) + 273.15$$

$$\Delta T(K) = \Delta T(C)$$

$$T(R) = T(°F) + 459.67$$

$$\Delta T(R) = \Delta T(F)$$

$$T(°C) = T(K) - 273.15$$
$$T(°R) = 1.8T(K)$$
$$T(°F) = T(°R) - 459.67$$
$$T(°F) = 1.8T(°C) + 32$$

# The Zeroth Law

Two systems in thermal equilibrium with a third system are in thermal equilibrium with each other.

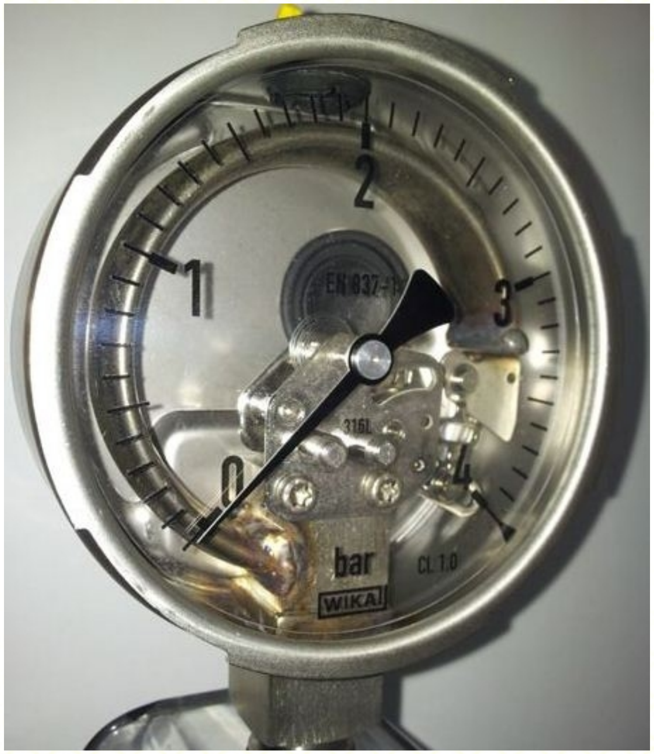
# Pressure

**Pressure**: A normal force exerted by a fluid per unit area

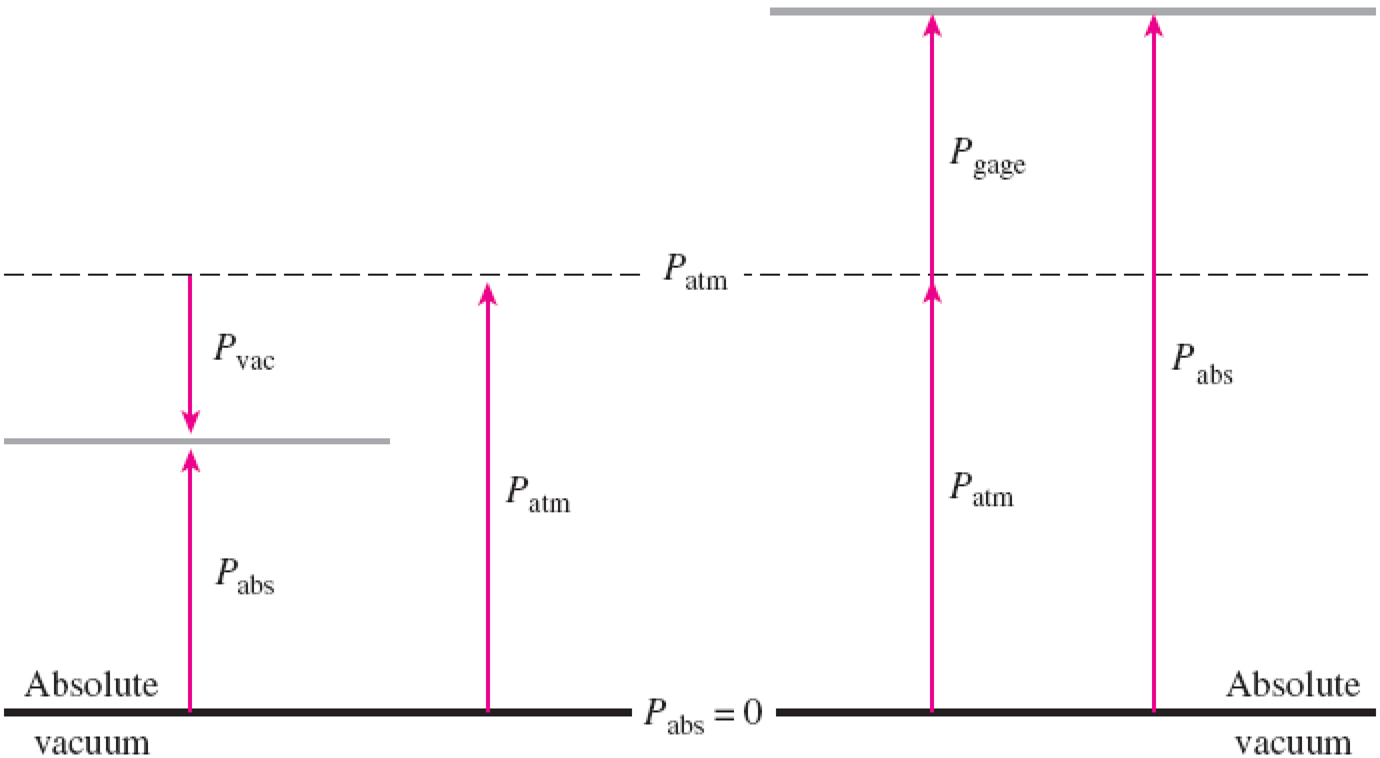
$$1 \text{ Pa} = 1 \text{ N/m}^2$$

Variation of pressure with depth

$$\Delta P = \rho g h$$



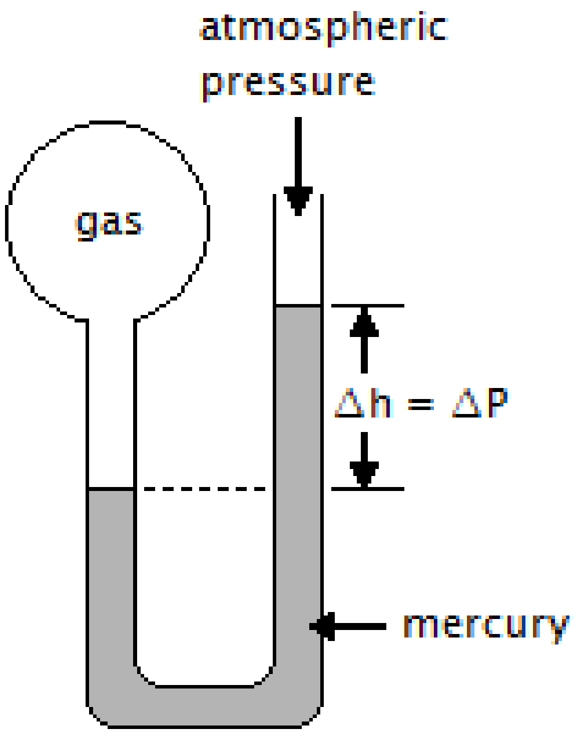
# Absolute, Gauge, and Vacuum Pressures

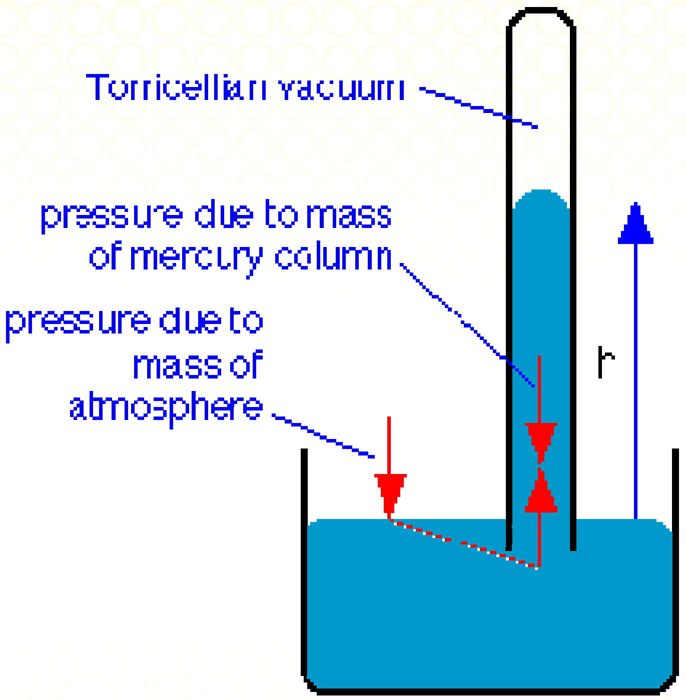



$$P_{gage} = P_{abs} - P_{atm}$$

$$P_{vac} = P_{atm} - P_{abs}$$

# Manometer & Barometer



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