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.

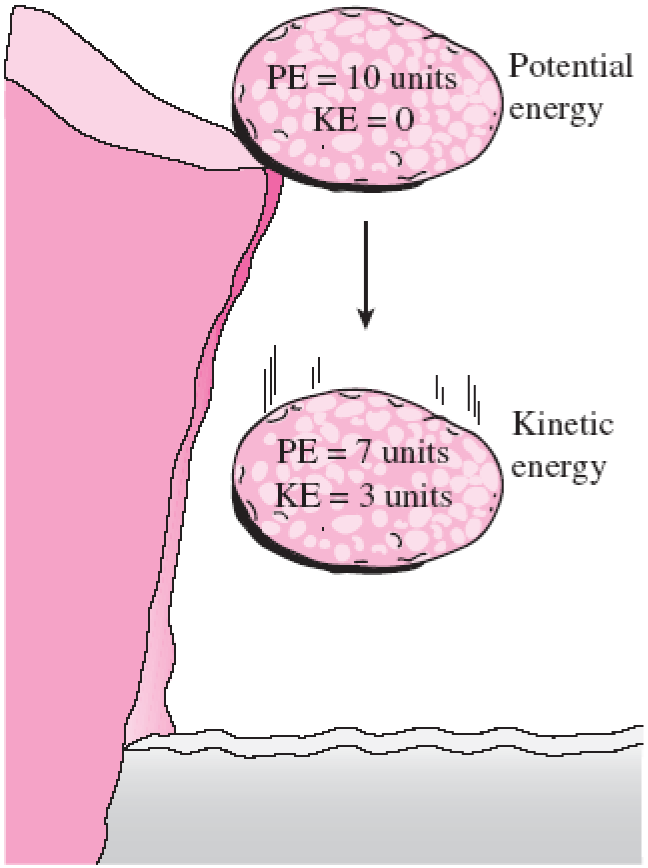


FIGURE 1–1
Energy cannot be created or destroyed; it can only change forms (the first law).

- **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.

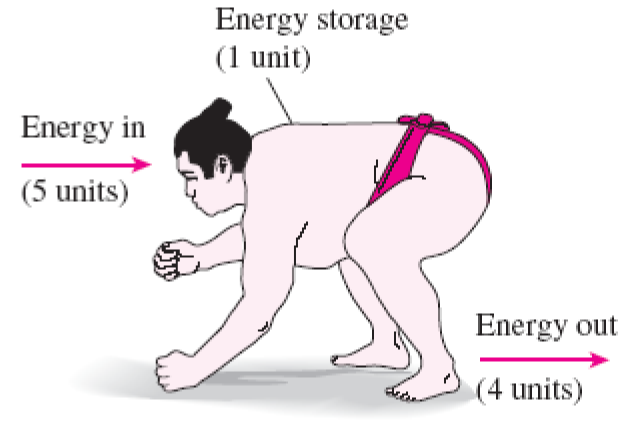


FIGURE 1–2
Conservation of energy principle for the human body.

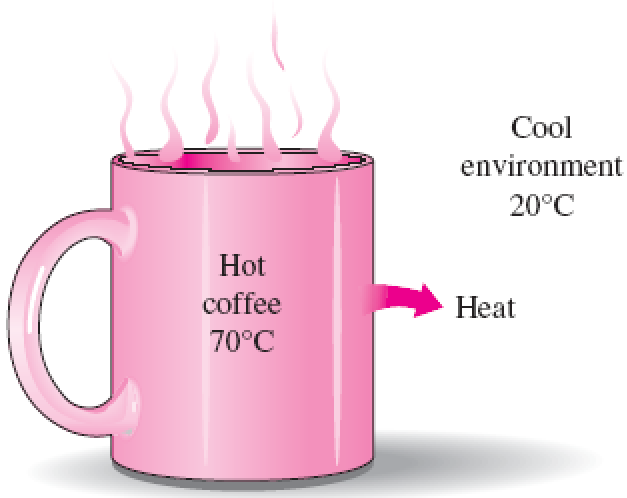


FIGURE 1–3
Heat flows in the direction of decreasing temperature.

Application Areas of Thermodynamics

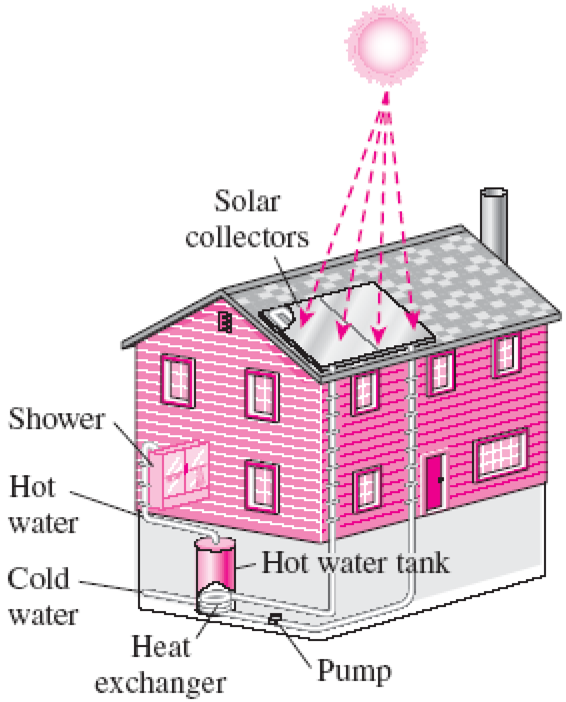


FIGURE 1–4
The design of many engineering systems, such as this solar hot water system, involves thermodynamics.

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

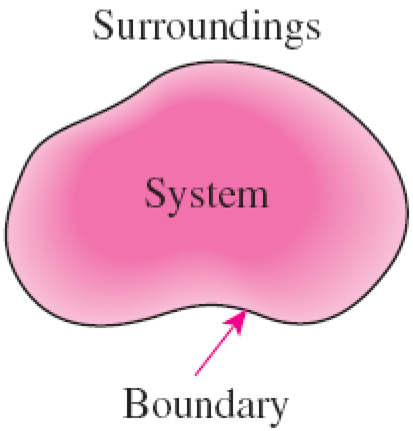
Capital	Lowercase	Name	Pronunciation
Ν	ν	NU	NOO
Ξ	ξ	XI	KS-EYE
Ο	ο	OMICRON	OM-i-KRON
Π	π ϖ	PI	PIE
Ρ	ρ	RHO	ROW
Σ	σ ς	SIGMA	SIG-muh
Τ	τ	TAU	TAU
Υ	υ	UPSILON	OOP-si-LON
Φ	ϕ φ	PHI	FEE
Χ	χ	CHI	K-EYE
Ψ	ψ	PSI	SIGH
Ω	ω	OMEGA	oh-MAY-guh

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.*



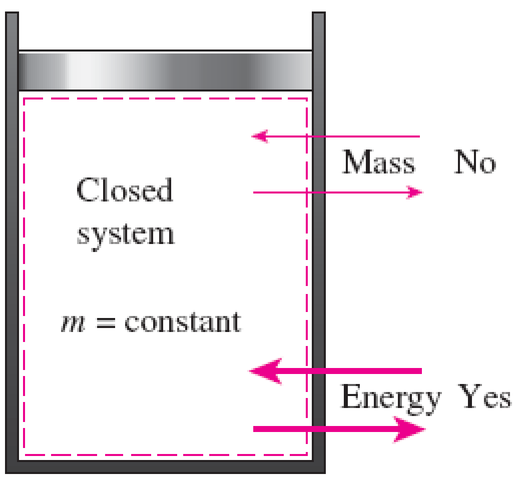
Closed system (Control mass): A fixed amount of mass. Energy can cross the boundary, but no mass can

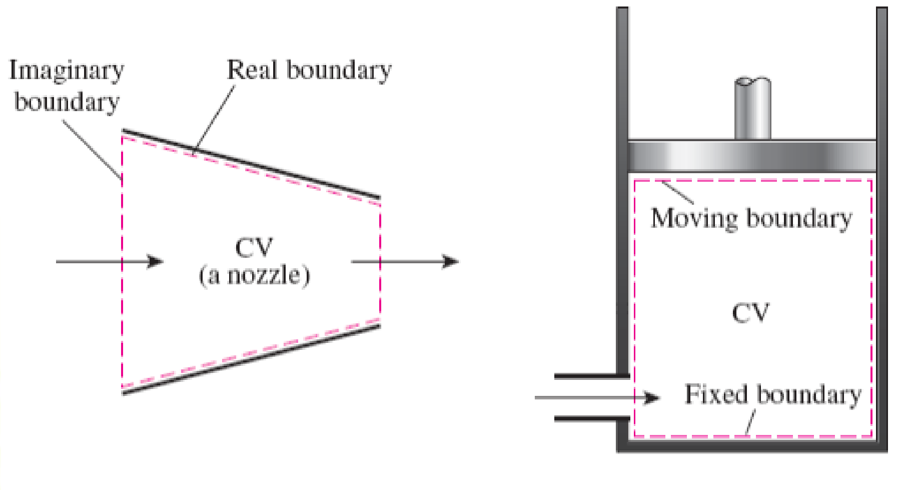
Open system (control volume): A properly selected region in space.

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

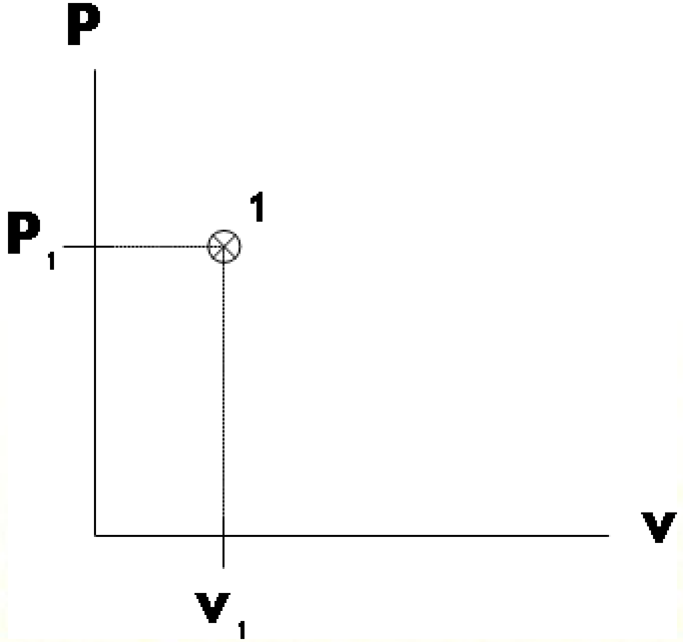
If all properties does not change with time; it is called *steady state*

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

State Postulate

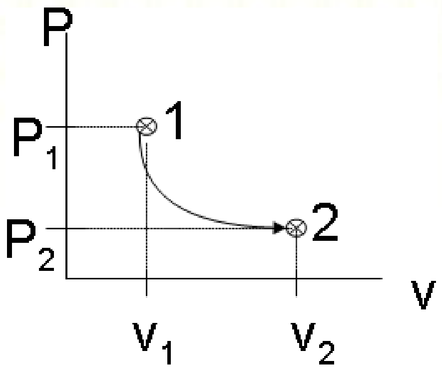
"The **state** of a simple, compressible system can be completely described by knowing only **2 properties** which are intensive and independent" (other properties can be determined from other relations)

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

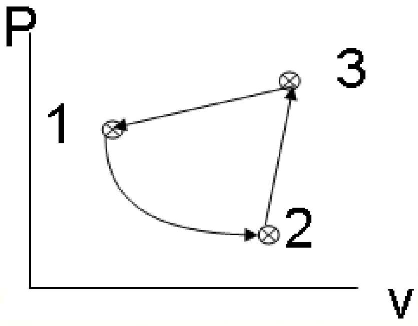


Process

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 <u>*property*</u> iff (if and only if) the difference between 2 <u>*states*</u> is not dependent on the <u>*process*</u> between those states (point function).

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

<u>*Work*</u>, <u>*heat*</u> 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

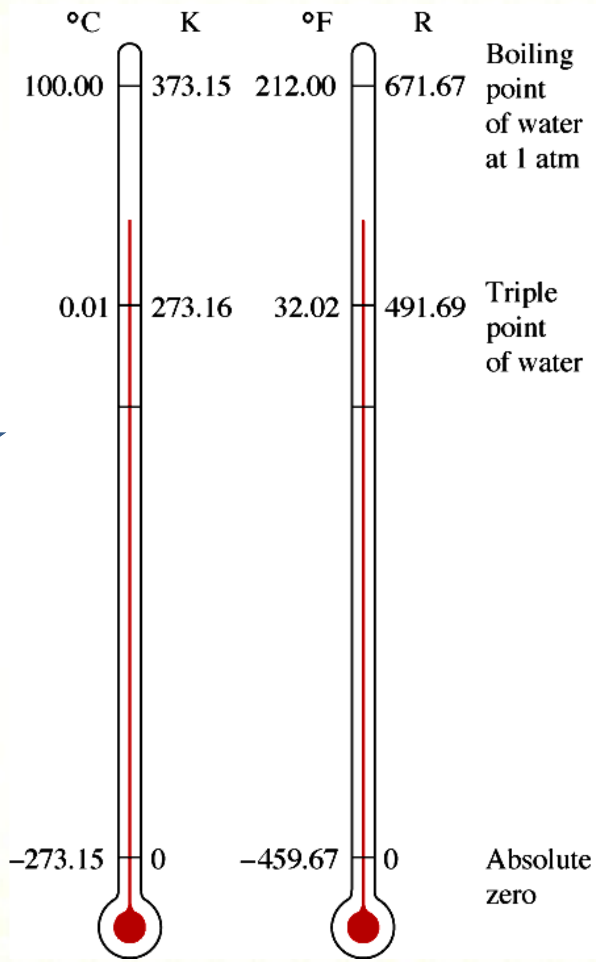
- 4 things have to be in equilibrium
  - Thermal equilibrium
  - Phase equilibrium
  - Mechanical Equilibrium
  - Chemical equilibrium

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.

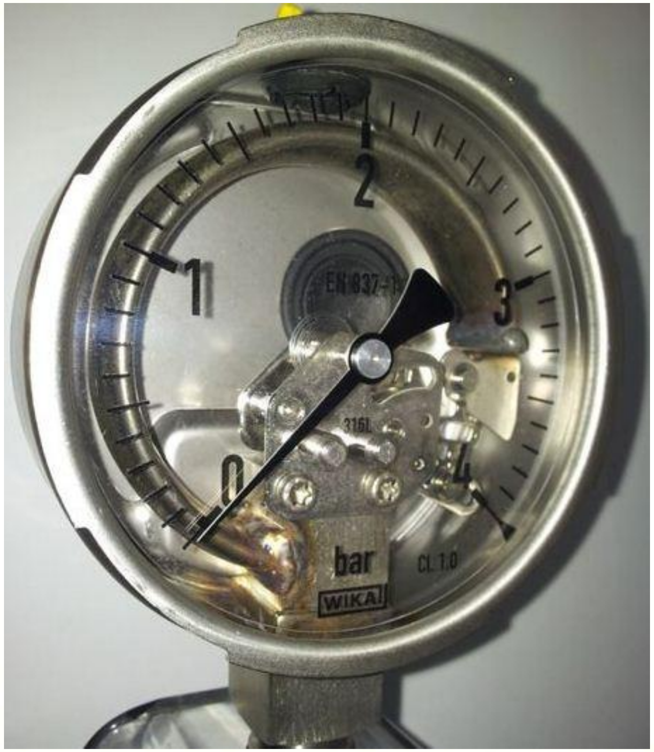
Pressure

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

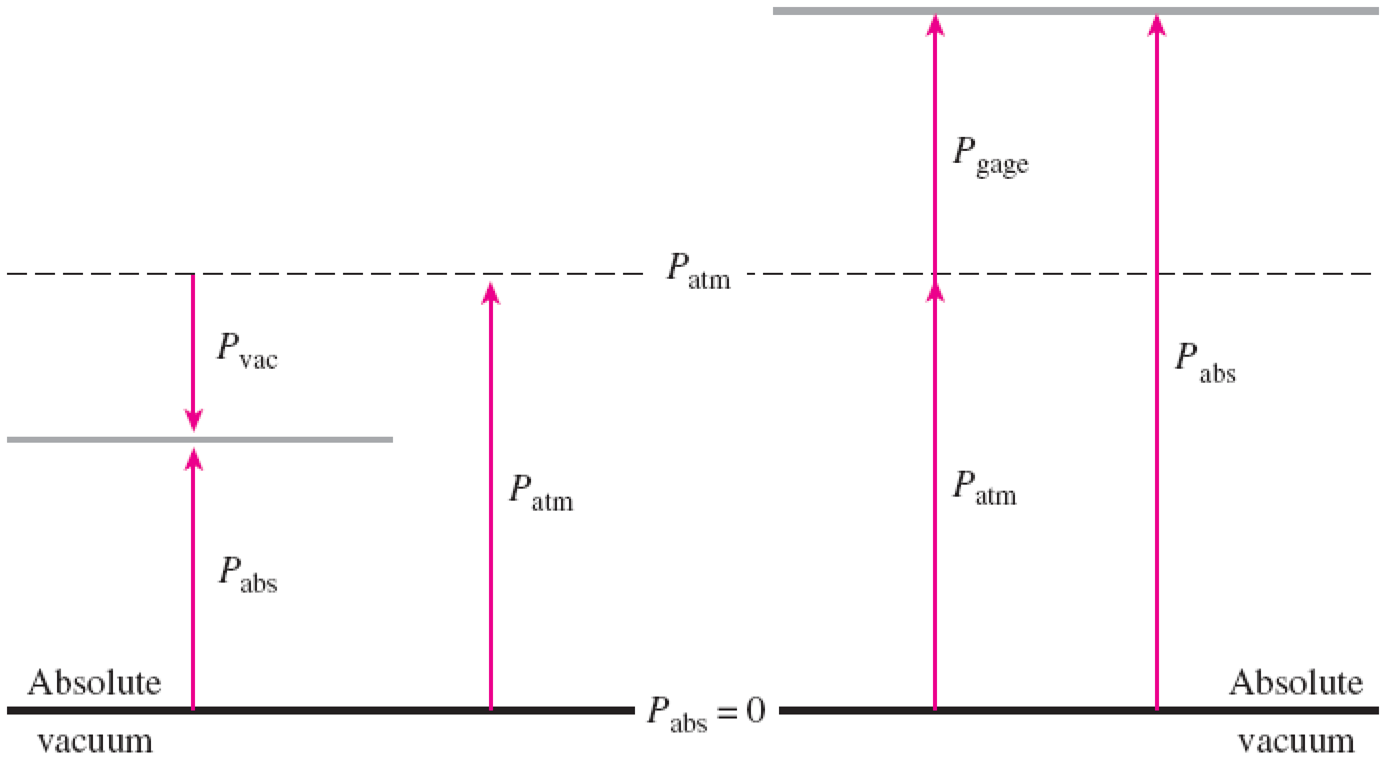
$$1 \text{ Pa} = 1 \text{ N/m}^2$$

Variation of pressure with depth

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



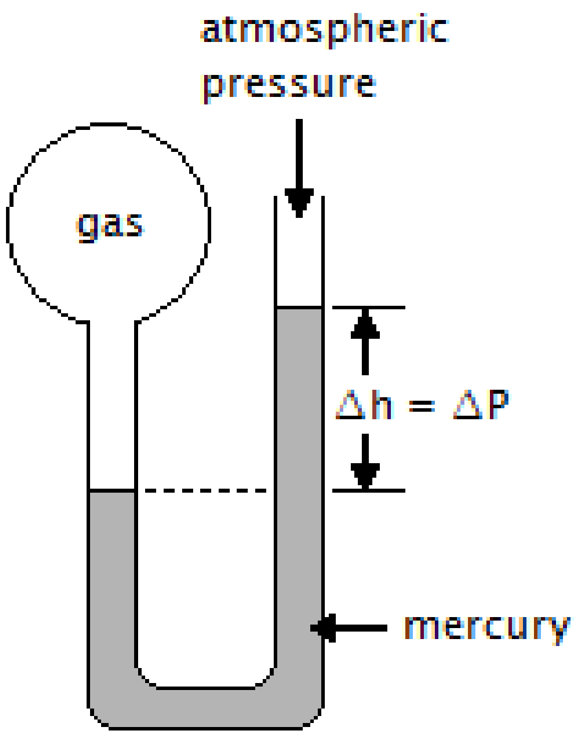
Absolute, Gauge, and Vacuum Pressures

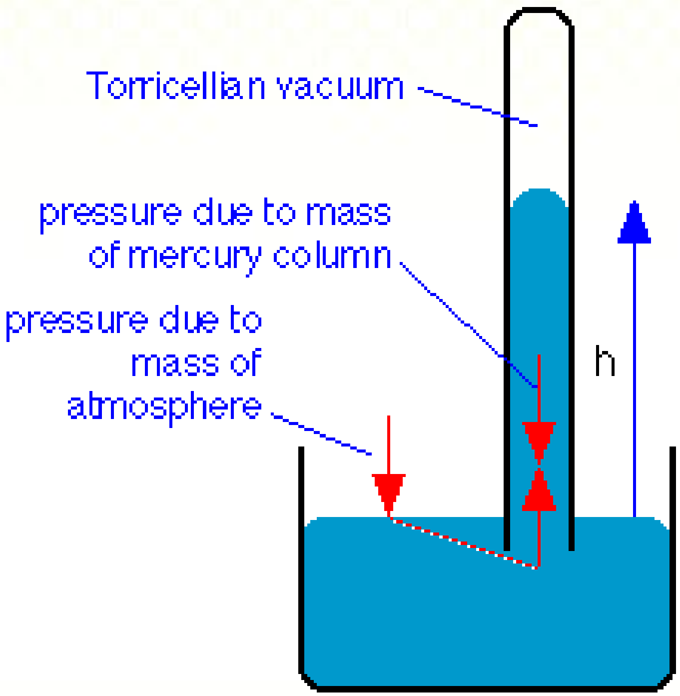


$$P_{gage} = P_{abs} - P_{atm}$$

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

Manometer & Barometer





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