THERMODYNAMICS

ME 010 506

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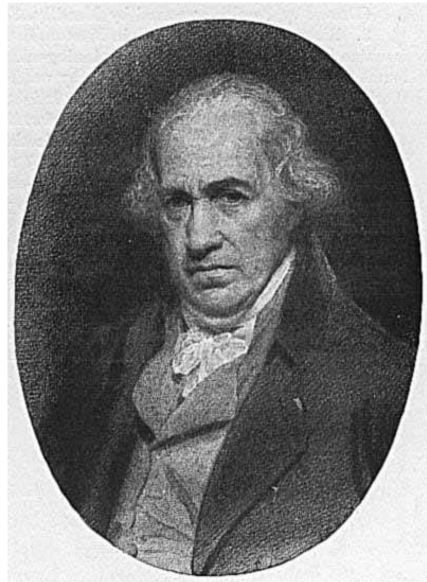
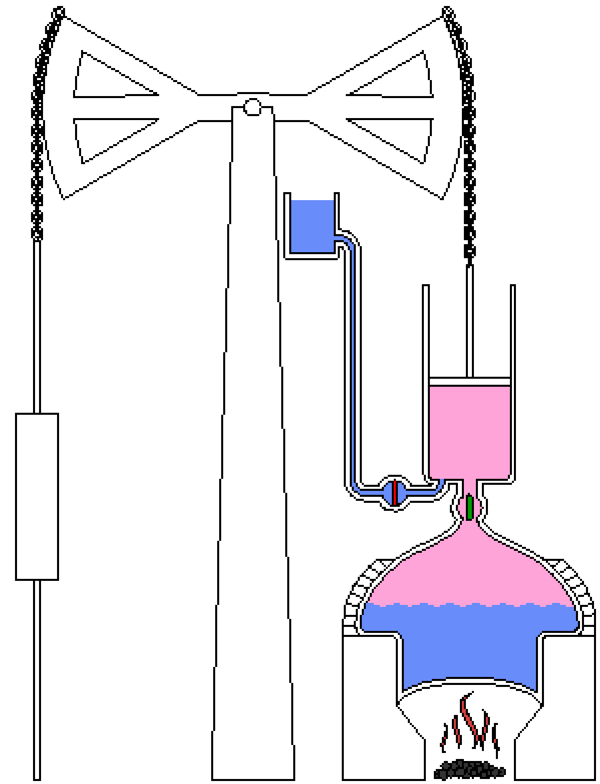
Thomas Savery

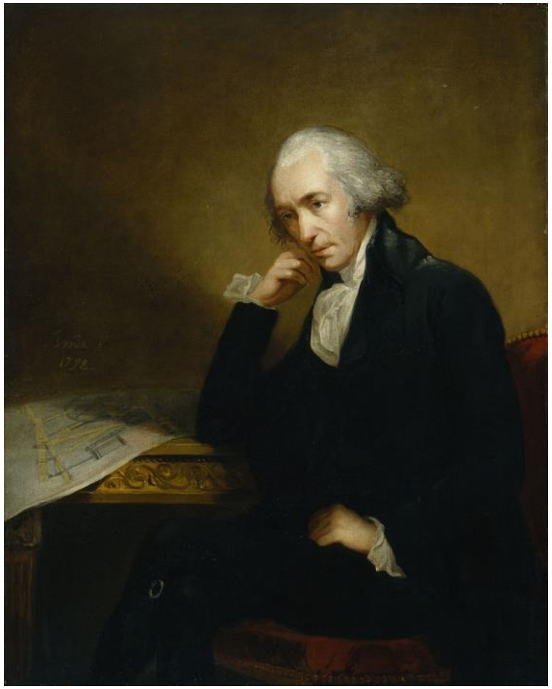


Thomas Newcomen

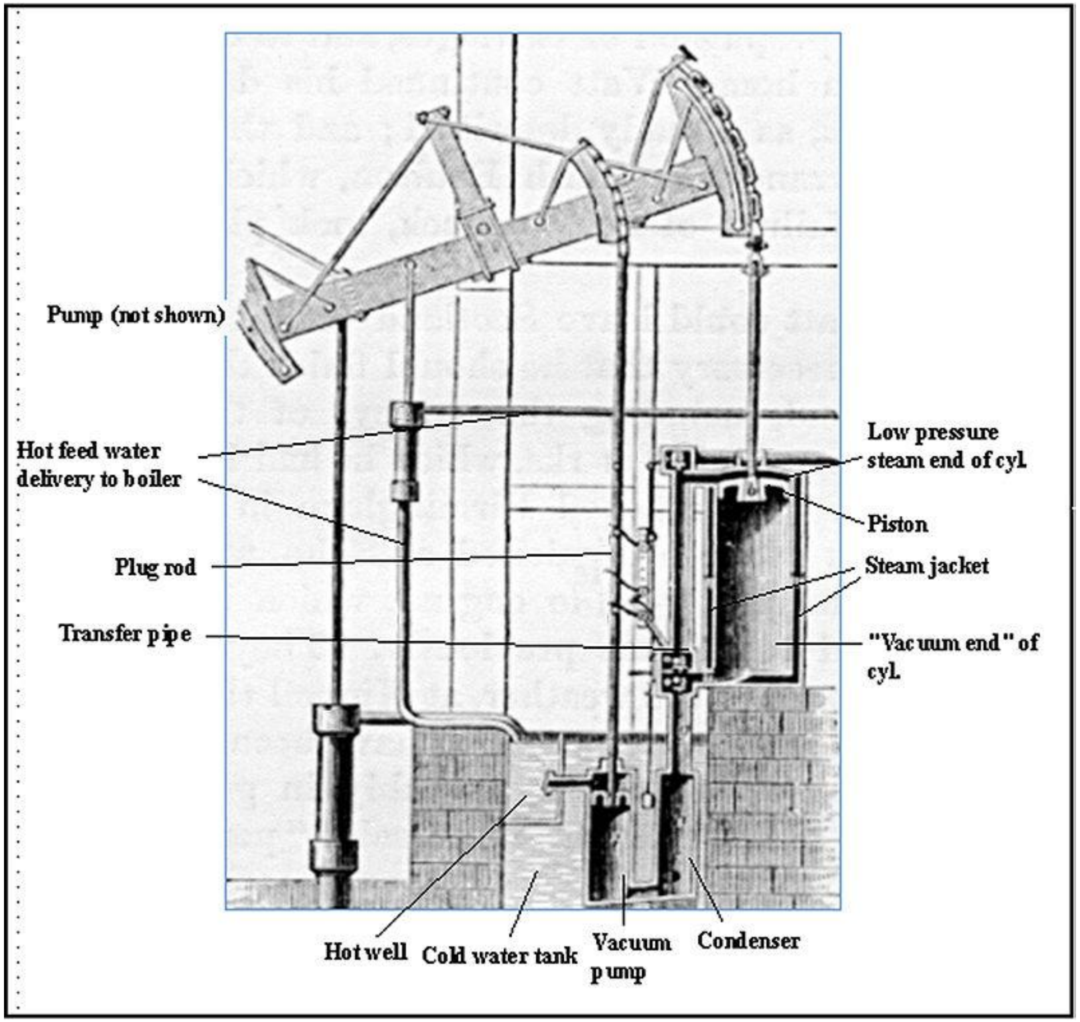


1698, 1712 (England)

- First atmospheric steam engine



James Watt



- 1776

improved efficiency

Father of Thermodynamics

1824

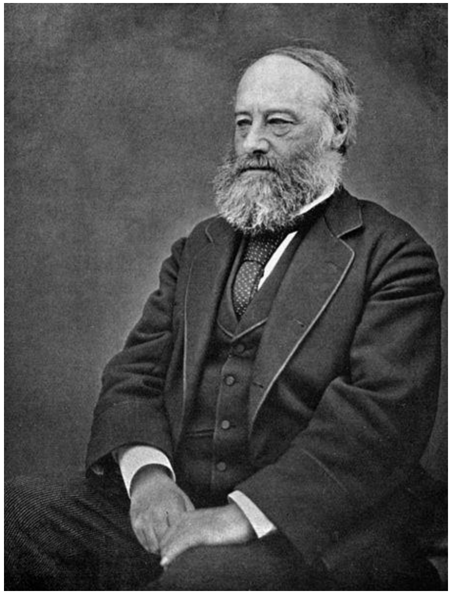
- Nicolas Léonard Sadi Carnot
- motive power of heat

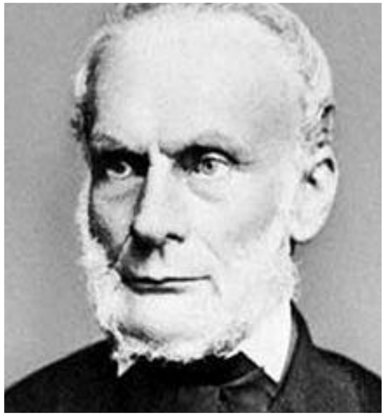
1842

- Julius Robert von Mayer
- conservation of energy

1843

- James Prescott Joule
- Equivalence of heat & mechanical work



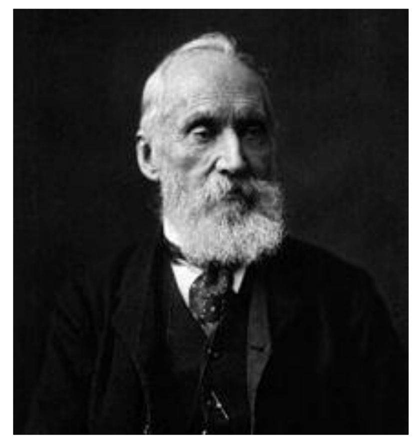


1850

- Rudolph Clausius
- William Rankine
- First Law

1854

- Rudolf Clausius
- Lord Kelvin
- Second Law



- The term **thermo-dynamic** was first used in 1849 by Irish physicist William Thomson (Lord Kelvin), in a paper titled *“An Account of Carnot's Theory of the Motive Power of Heat”*, where he states:

  “A perfect *thermo-dynamic* engine is such that, whatever amount of mechanical effect which it might produce, nothing can be lost in the operations of nature—no energy can be destroyed.”

- *Therme* *<Greek>* → "heat,“
- *Dynamis* *<Greek>* → "power"

- **Thermodynamics:**

  It's the science of energy transfer and its effect on the physical properties of substances.

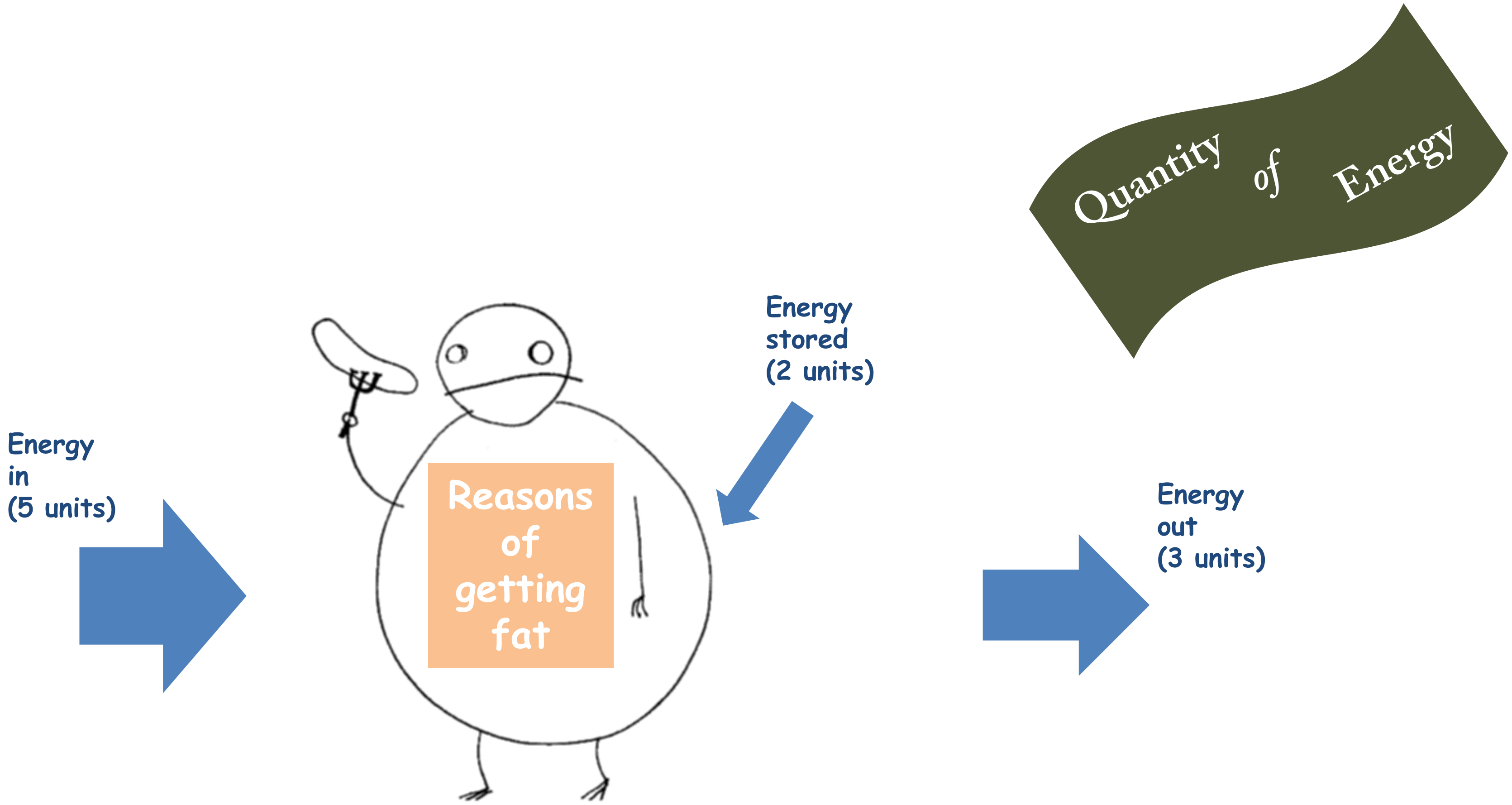
  A branch of physics as well as engineering science.

  [Energy can be viewed as the ability to cause changes]

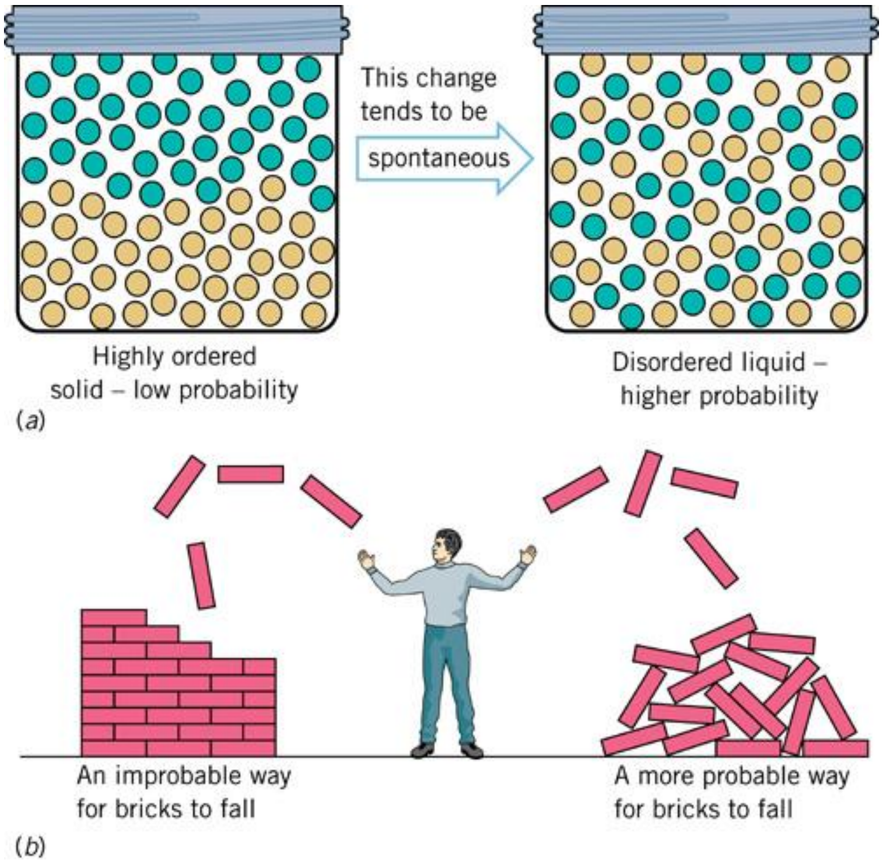
Whole of thermodynamics is founded on four empirical laws that govern energy and its interactions.

- Zeroth Law of Thermodynamics
- First Law of Thermodynamics
- Second Law of Thermodynamics
- Third Law of Thermodynamics

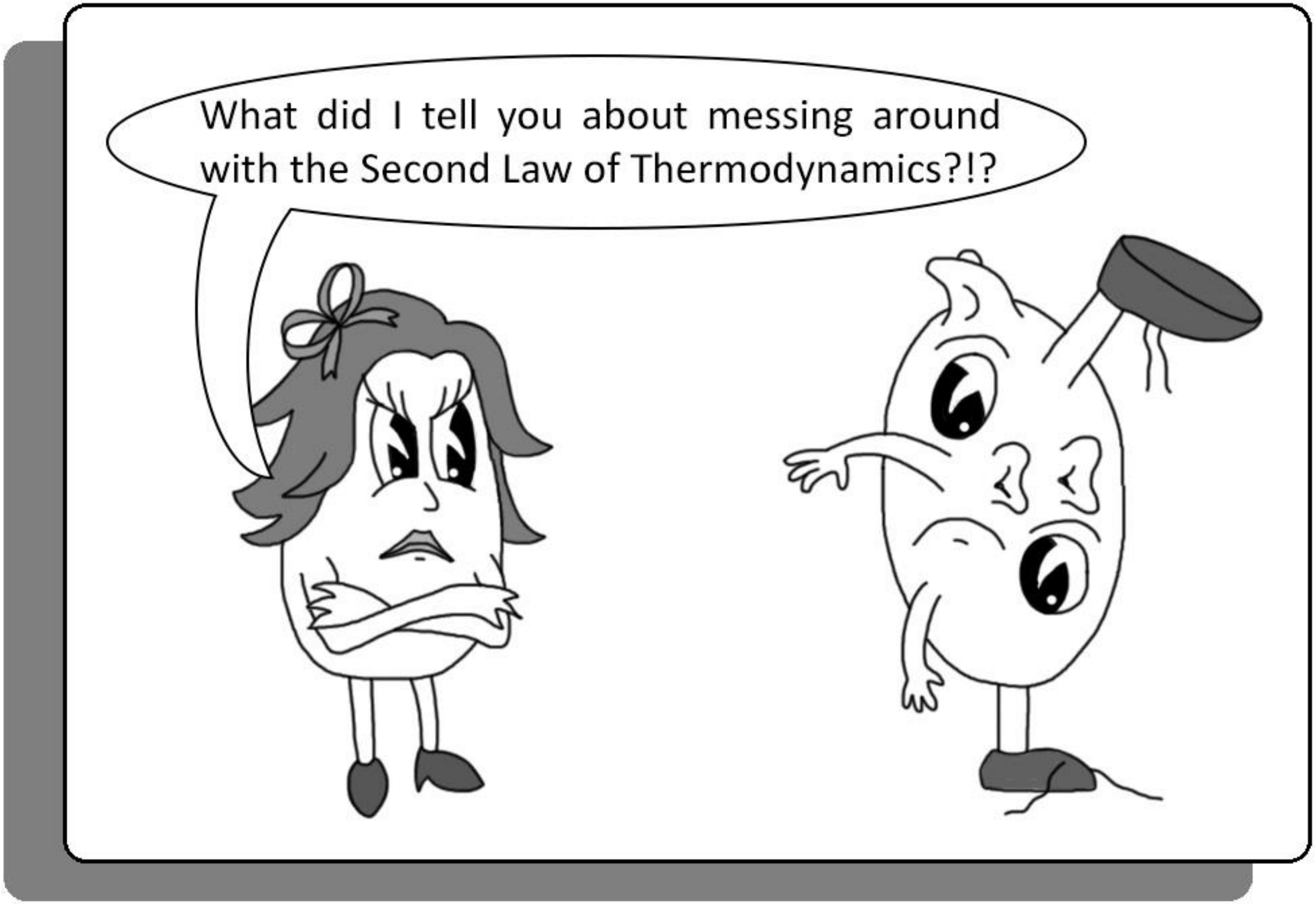
First law: conservation of energy



Second Law: directionality of processes



Quality of Energy


What did I tell you about messing around with the Second Law of Thermodynamics?!?

The first three laws, each paves way for a new property,

0^{th} law – **TEMPERATURE**

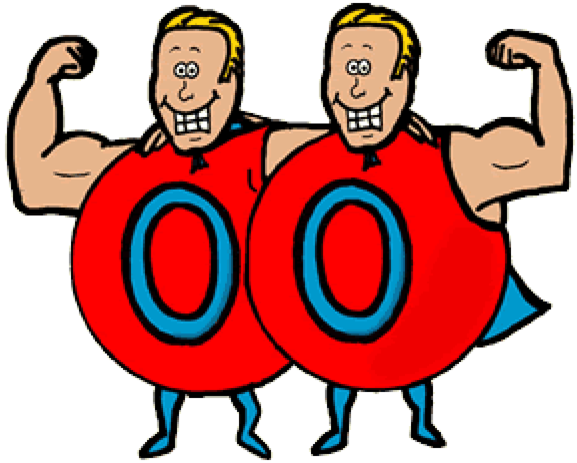
1^{st} law – **ENERGY**

2^{nd} law – **ENTROPY**

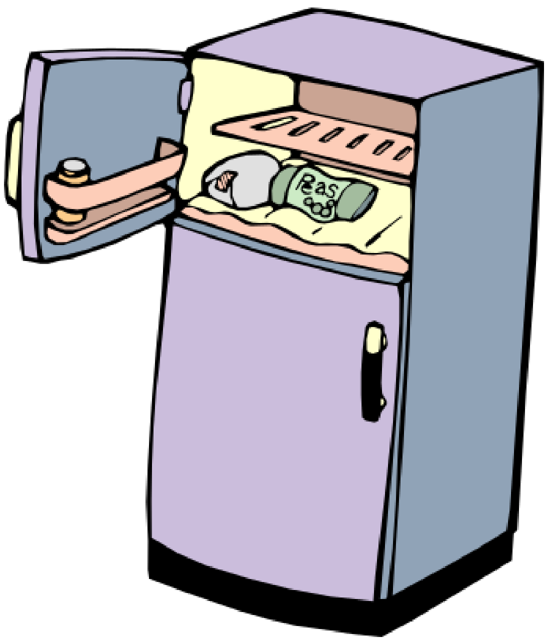
Applications?

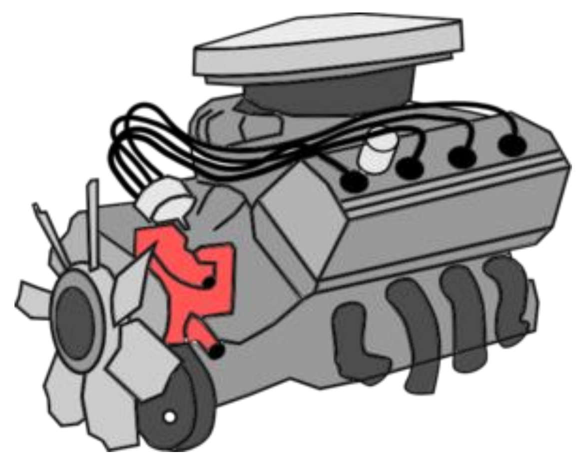
- All energy interactions are governed by thermodynamic laws
- So wherever there is energy interaction…is potentially a new frontier for thermodynamics..

Chemistry



Atro physics





Mechanical Systems

& even ECONOMICS
(Thermo-economics)

ME010 506 Thermodynamics

(Common with PE 010 506 and AU010 506)

Teaching scheme **Credits:** 4

3 hours lecture and 1 hour tutorial per week

Objectives

- *To impart the basic concepts of Thermodynamics*

Pre-requisites: *Knowledge required to study this subject (especially any subject previously studied)*

Module I (10 hours)

Fundamentals concepts – scope and limitations of thermodynamics. Thermodynamic systems – different types of systems – macroscopic and microscopic analysis – continuum – Properties – state – processes. Thermodynamics equilibrium – Equation of state of an ideal gas – PVT system – Real gas relations – Compressibility factor – Law of corresponding states.

Module II (15 hours)

Laws of thermodynamics- Zeroth law of thermodynamics – Thermal equilibrium – Concept of temperature – Temperature scales – Thermometry – Perfect gas temperature scales. – Thermometry – Perfect gas temperature scales. Work and heat – First law of thermodynamics – Concept of energy _ First law for closed and open systems – Specific heats – internal energy and enthalpy – Steady flow energy equations _ Jule Thompson effect.

Module III (15 hours)

Second law of thermodynamics- Various statements and their equivalence_ Reversible process and reversible cycles- Carnot cycles- Corollaries of the second law – thermodynamics temperature scales – Clausis inequality- Concept of entropy – Calculation of change in entropy in various thermodynamic processes – Reversibility and irreversibility – Available and unavailable energy – Third law of thermodynamics.

Module IV (10 hours)

Thermodynamic relations – Combined first and second law equations – Hemholtz and gibbs functions – Maxwell relations- Equations for specific heats, internal energy, enthalpy and entropy – Clausius Clapeyron equations _ applications of thermo dynamic relations.

Module V (10 hours)

Properties of pure substances – PVT, PT and TS diagrams, Mollier diagrams- Mixture of gases and vapours- mixture of ideal gases – Dalton's law – Gibbs law- Thermodynamic properties of mixtures

Text Book:

P K Nag; *Engineering Thermodynamics*

Steam Tables:

C.P. Kothandaraman

Reference Books:

Sonntag, Borgnakke, Van Wylen; Fundamentals of Thermodynamics

Moran, Shapiro; Fundamentals of Engineering Thermodynamics

Cengel, Boles; Thermodynamics - an Engineering Approach

Some Basic Concepts:

System

Macroscopic & Microscopic *point of view*

Continuum

Properties, State, Processes, Equilibrium

Specific Volume, Pressure, Temperature

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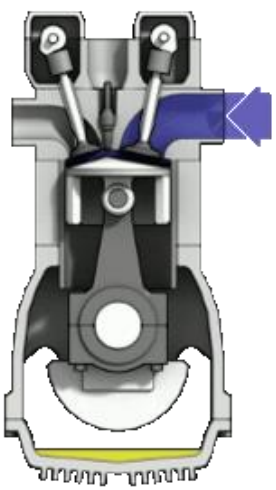
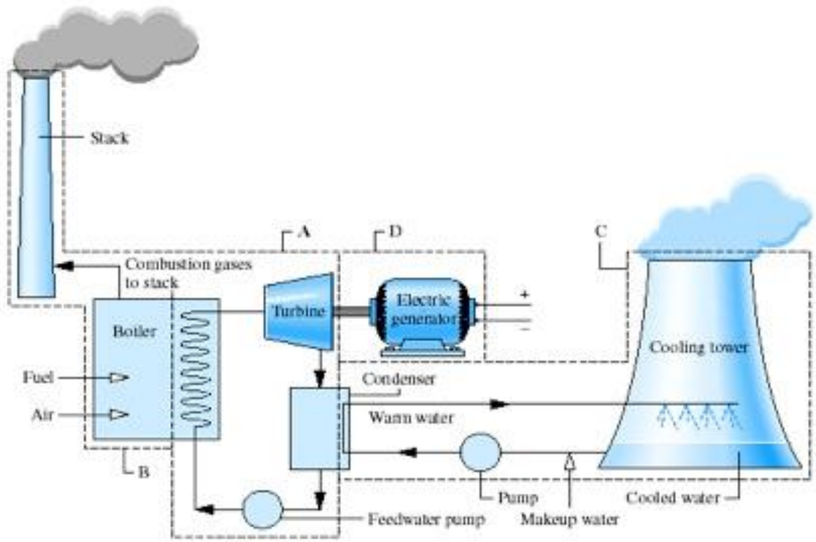
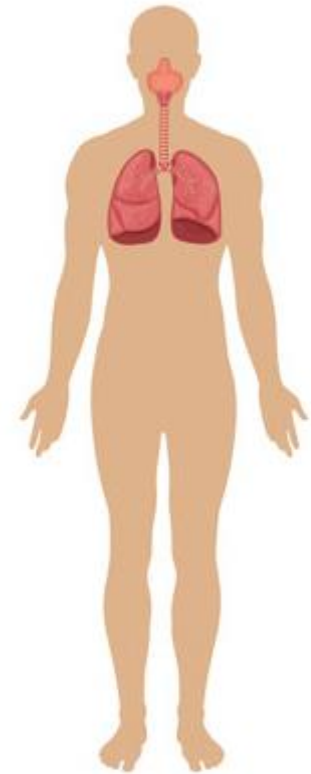
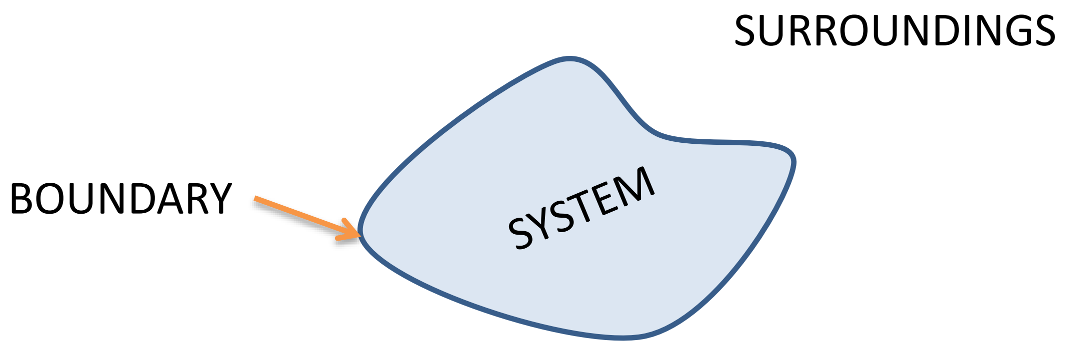
Whatever we want to study

1



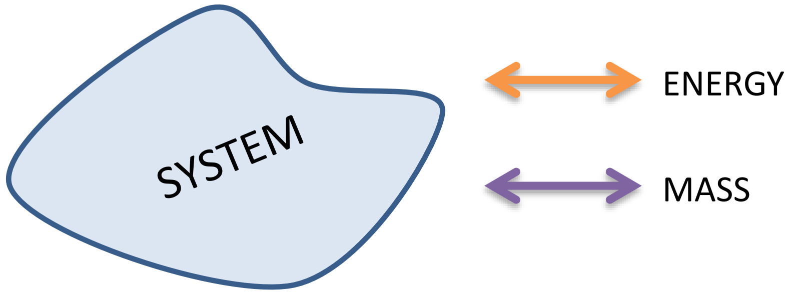


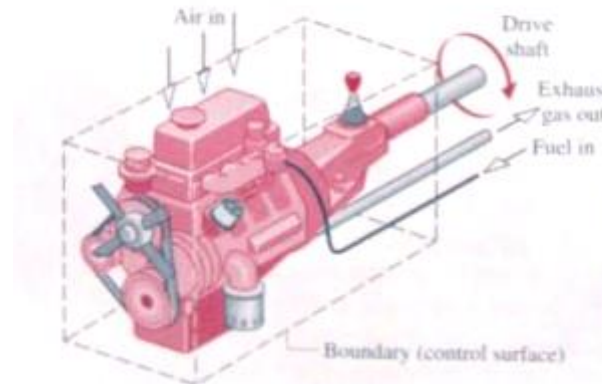



SURROUNDINGS
BOUNDARY
SYSTEM

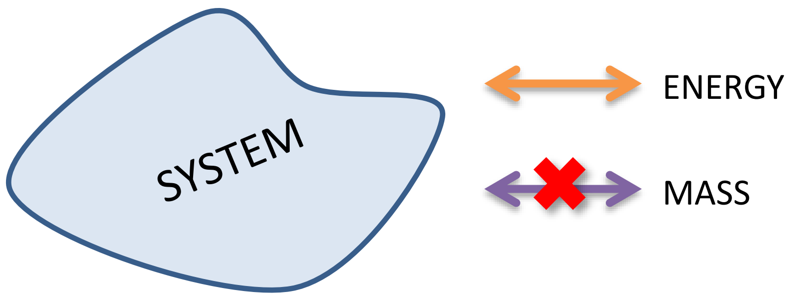
INTERACTION

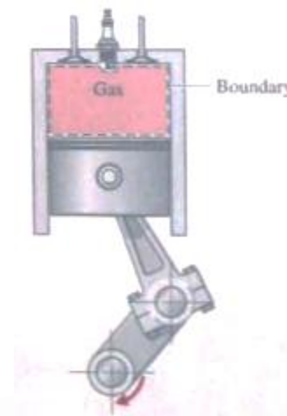
OPEN SYSTEM
(CONTROL VOLUME)



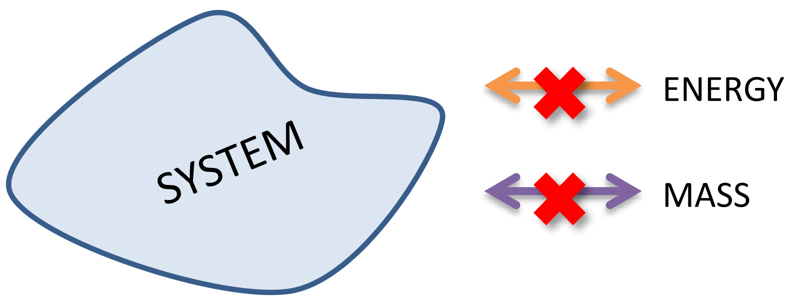


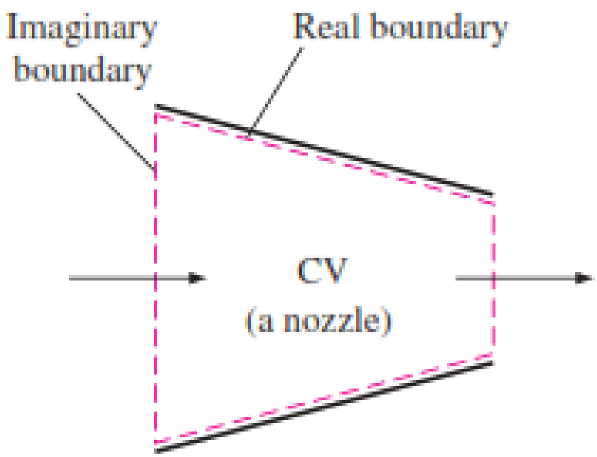
CLOSED SYSTEM
(CONTROL MASS)

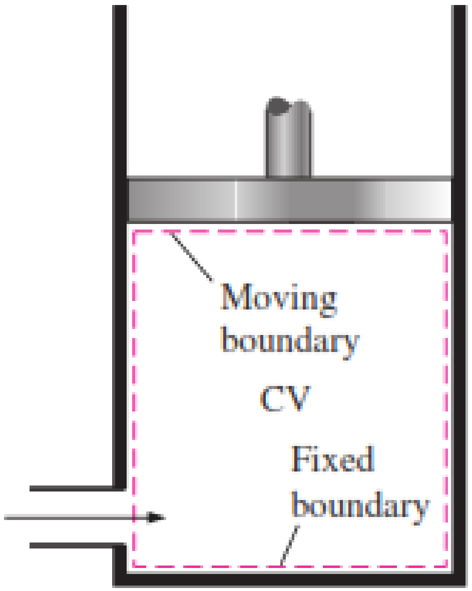




ISOLATED SYSTEM




Imaginary
boundary
Real boundary
CV
(a nozzle)


Moving
boundary
CV
Fixed
boundary

Some Basic Concepts:

System

Macroscopic & Microscopic *point of view*

Continuum

Properties, State, Processes, Equilibrium

Specific Volume, Pressure, Temperature

Macroscopic Approach (Classical Thermodynamics)

- Classical way
- Defines properties as perceivable effect measureable by instruments

Microscopic Approach (Statistical Thermodynamics)

- Rationalization of the effects based on molecular theory
- Defines properties like pressure temperature etc. as time averaged influence of molecular motion
- Makes use of statistics & probability theory

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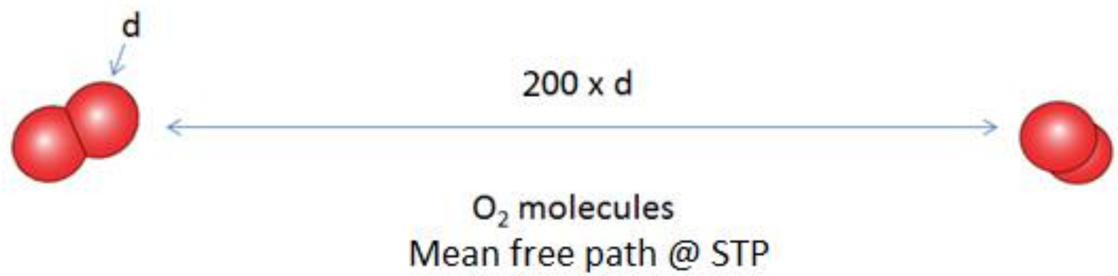
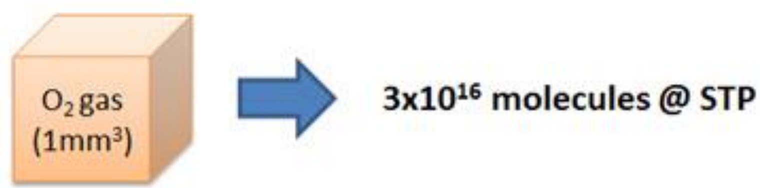
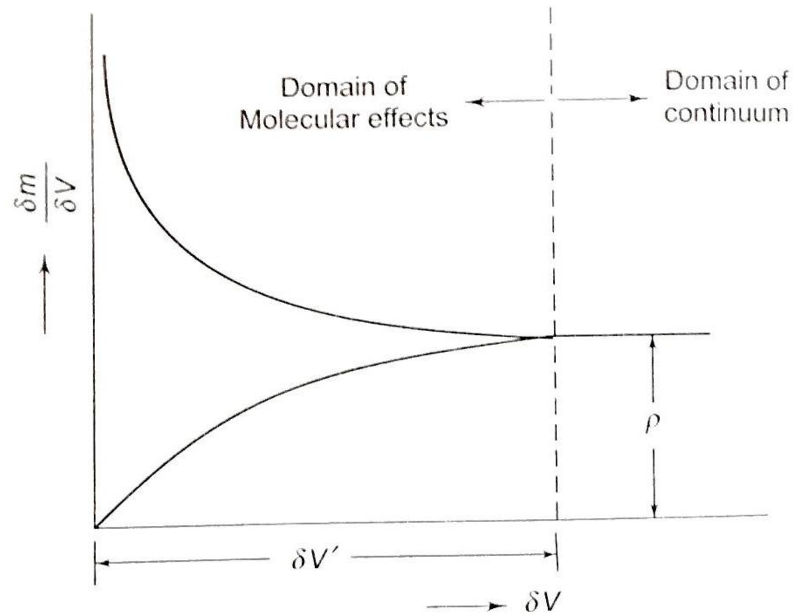
- Macroscopic approach of disregarding molecular theory and treating the substance as being continuous is the *continuum assumption*.



But,



- Only a convenient *'assumption'*.
- Loses validity at high vacuum, high altitude flight etc.



Definition of the macroscopic property, *density*

$$\rho = \lim_{\delta V \to \delta V'} \left(\frac{\delta m}{\delta V} \right)$$

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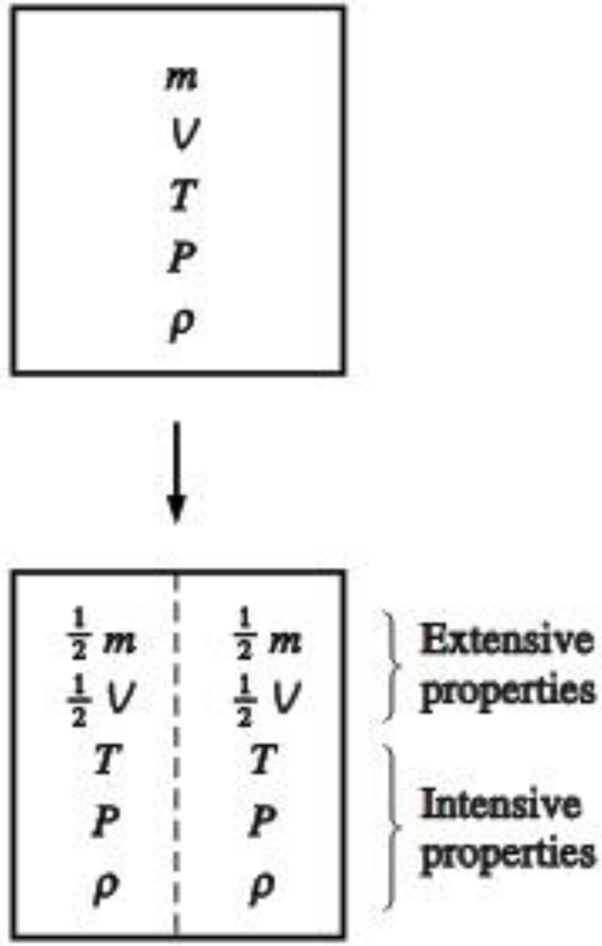
- Any characteristics of the system → *Property*

  ex: P, v, T

- Unique value of a property to define a system
  - No property gradient within or external to the system so that property doesn't change with time
  - system in *Equilibrium*
    - $\frac{dp}{dt} = 0$ --> mechanical eq.
    - $\frac{dT}{dt} = 0$ --> thermal eq.
    - no change of chemical composition w.r.t. time --> chemical eq.
    - no change of phase composition w.r.t. time --> phase eq.

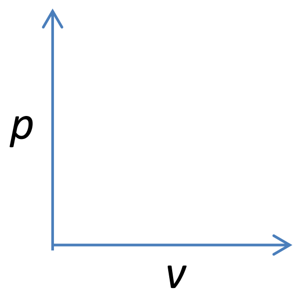
    } **Thermodynamic Equillibrium**

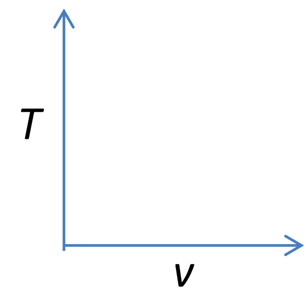

m
V
T
P
ρ
½ m
½ V
T
P
ρ
½ m
½ V
T
P
ρ
Extensive properties
Intensive properties

- When all properties have a definite value, the system is said to exist at a definite *State*
- The state is described by the properties (properties are the coordinates to describe the state)
- Conversely property is something that depends on the state of a system (state/point function)
- State is always an equilibrium condition

- State Postulate

The state of a simple compressible system is completely specified by two independent, intensive properties.

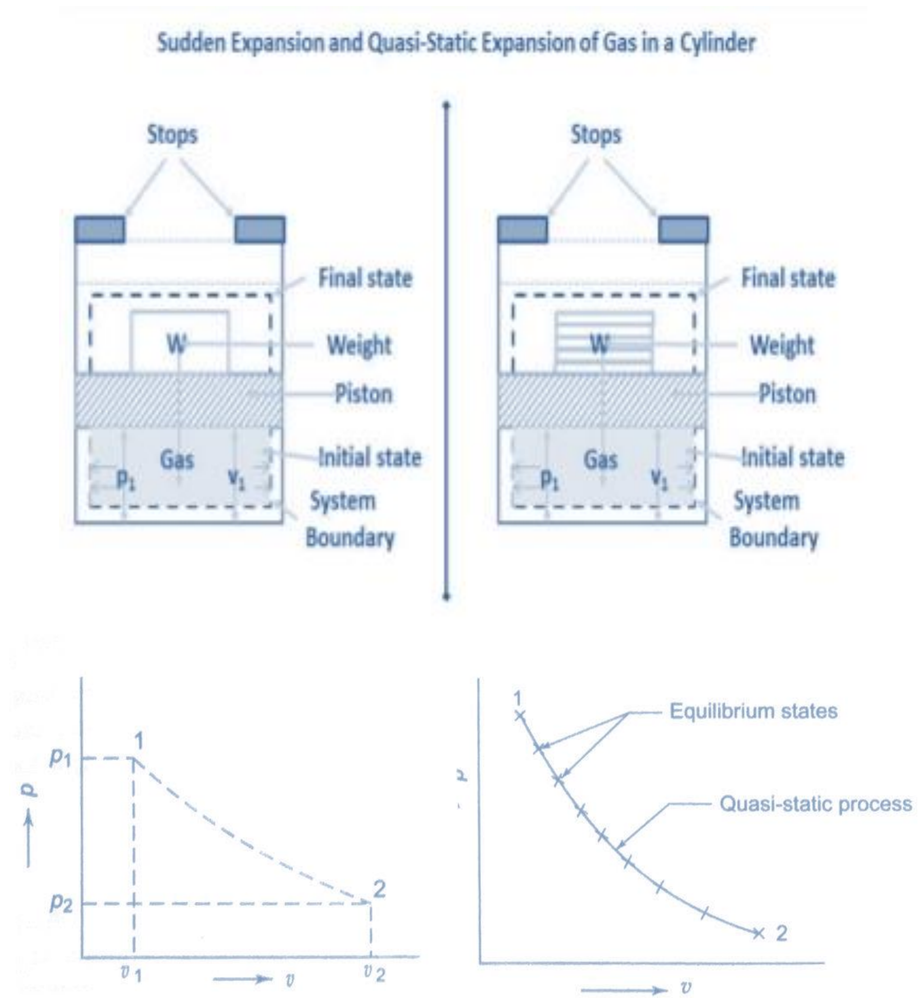




A state can thus be represented as a point on a property diagram (state space)

Other properties can be determined by thermodynamic relations

- Process → Change of state
- Path (process path) → succession of states passed through during a change of state
- Quasi- Static process (Equilibrium process)



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Specific Volume, Pressure, Temperature

- Specific Volume

$$v = \lim_{\delta V \to \delta V'} \left(\frac{\delta V}{\delta m} \right) = \frac{1}{\rho}$$

- Pressure

$$p = \lim_{\delta A \to \delta A'} \left(\frac{\delta F_n}{\delta A} \right)$$

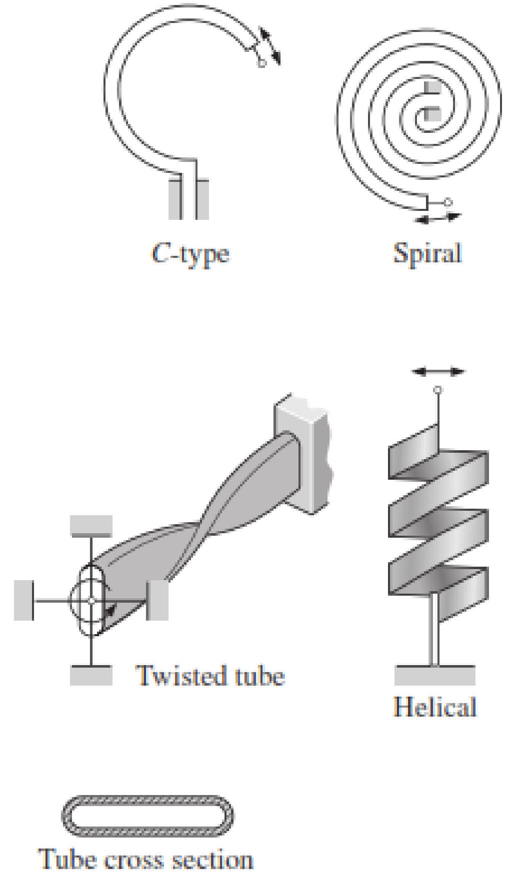
Units of pressure

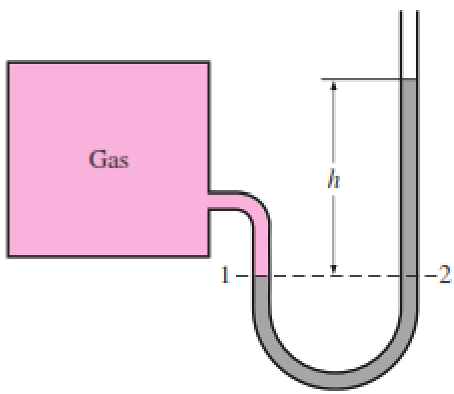
SI Unit: 1 Pa (Pascal) = 1 N/m^2

- 1 mmHg (torr) = 133 Pa
- 1 psi = 6894.75 Pa
- 1 bar = 10^5 Pa
- 1 atm (Atmosphere) = 1.01325 x 10^5 Pa
- 1 kgf/cm^2 = 0.9807 x 10^5 Pa

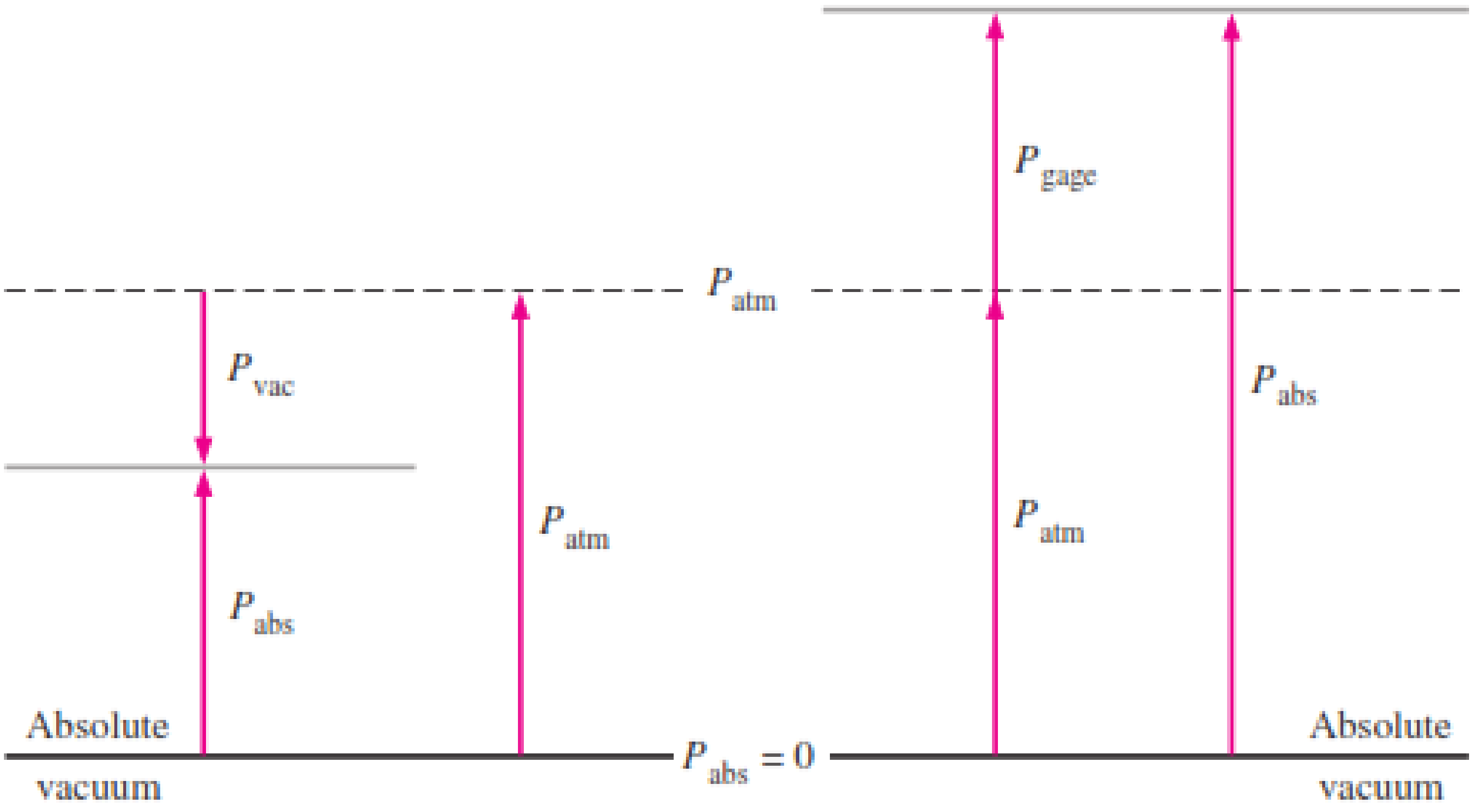
Pressure Measurement

- Pressure transducers
  - Piezo-electric transducers
  - Strain-gage pressure transducers
- Bourdon Tube
- Manometer





- Absolute, Gauge & Vacuum pressures



Example 1.1 The pressure of gas in a pipe line is measured with a mercury manometer having one limb open to the atmosphere (Fig. Ex. 1.1). If the difference in the height of mercury in the two limbs is 562 mm, calculate the gas pressure. The barometer reads 761 mm Hg, the acceleration due to gravity is 9.79 m/s^2, and the density of mercury is 13,640 kg/m^3.

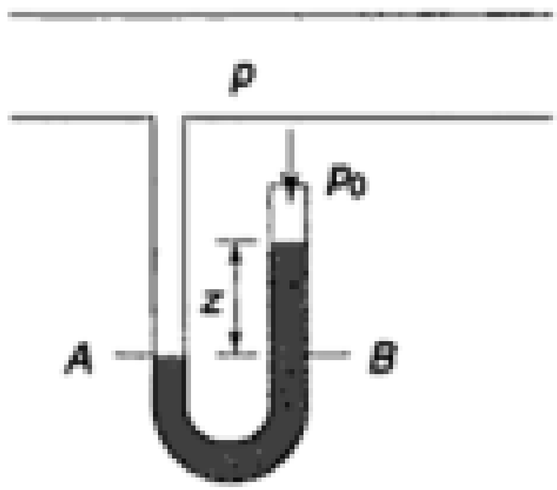


Fig. Ex. 1.1

- **Convert the following readings of pressure to kPa, assuming that the barometer reads 760 mmHg:** (a) 90 cmHg gauge (b) 40 cmHg vacuum (c) 1.2 m H_2O gauge (d) 3.1 bar