Introduction to Thermodynamics

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Spring, 2021

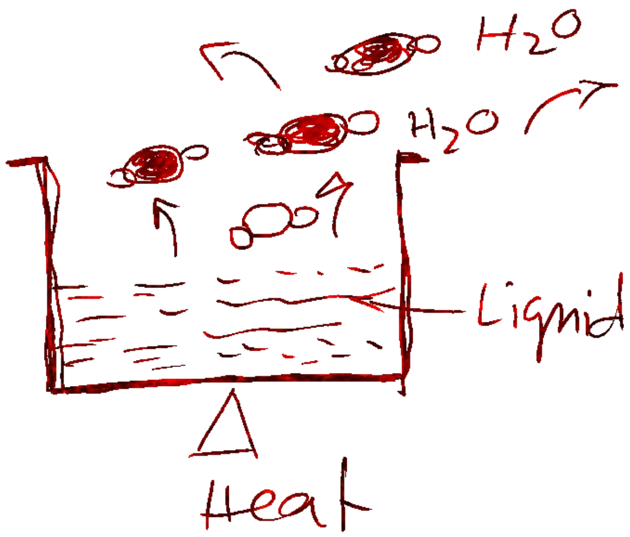
MECH 2430

Outline

- What is Thermodynamics?
- Thermodynamic system
- Control Volume
- Properties of Matters
- Process
- Cycle
- Units

What is Thermodynamics?

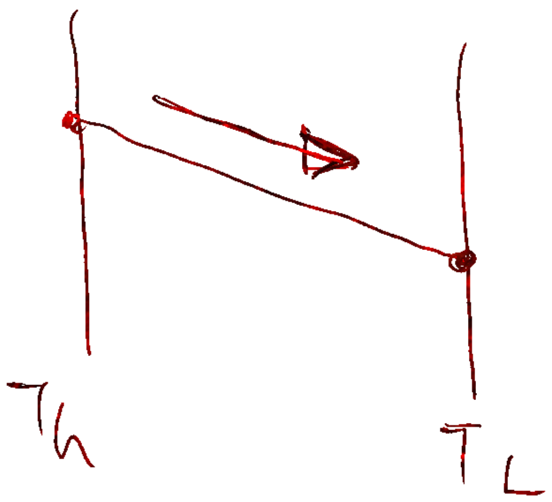
- It is a Science of Thermal Energy and Process about-
  - How the energy is conserved
  - How the energy is converted from one type to other.
- Example
  - A process how temperature is changed in the uni
  - Global warming
  - Refrigeration system
  - HAVC System
  - A combustion engine where chemical energy is converted into power.
  - Boiling water



What is Heat Transfer?

- A process of by which energy is transported in the form of heat between two places with a gradient in temperature.
- An intricate part of a thermodynamic system which deals with several mechanisms of energy transportation.
- Main reason behind the heat transfer
  - Thermal gradient
- Usually heat transfer occurs between

  two T.D. System.



Thermodynamic System

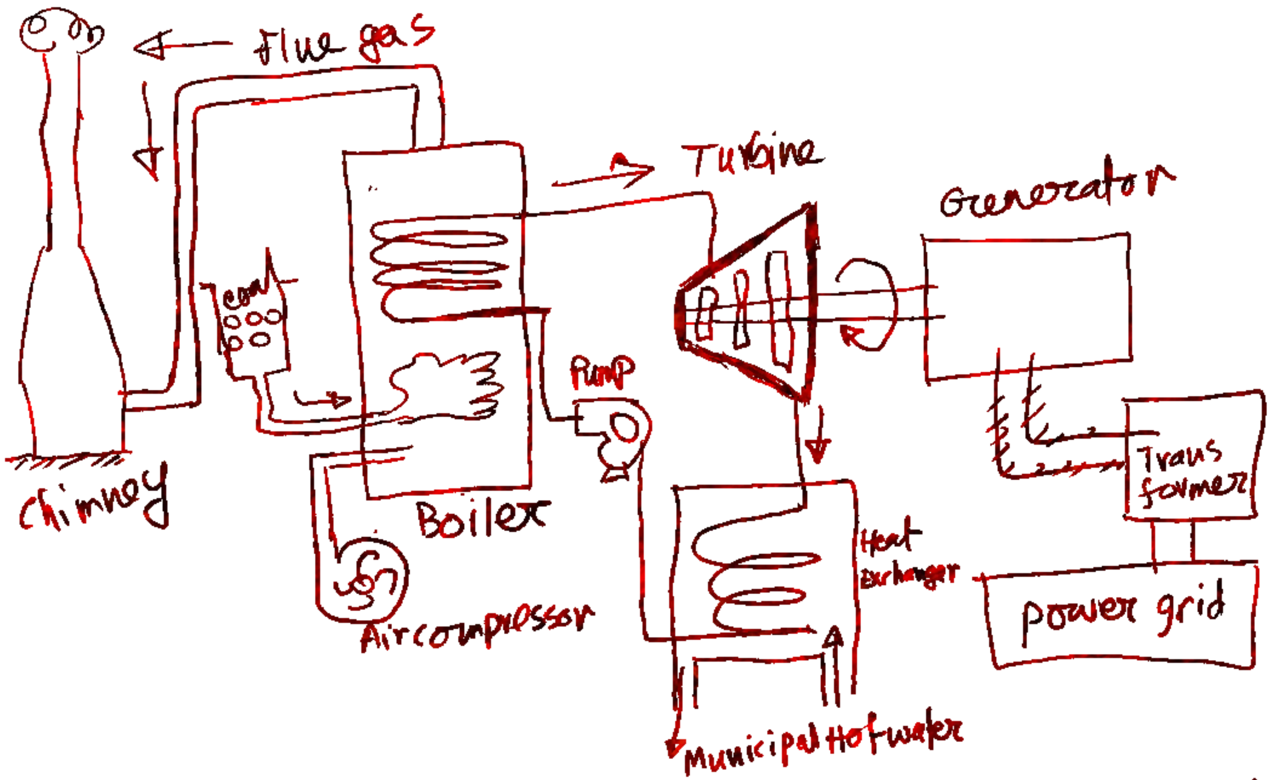
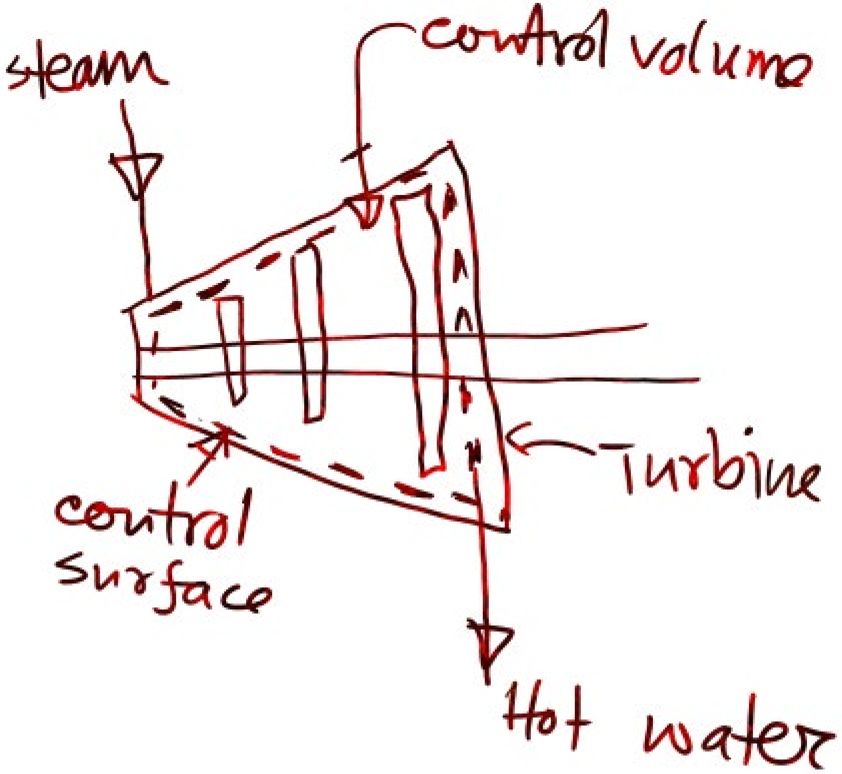


Fig. Brief illustration of a coal based steam power plant

- A system that contains a device or devices, through which a matter is being studied.
- The study parameters are energy conversation, Conversion and transportation.
- Question for you-
- Name all the devices
- Name the thermodynamic systems, remember there is more than 1 system..
- Three major TD systems-
- 1. Coal combustion system
- 2. Steam generation system
- 3. Municipal hot water system

A Control Volume



- A volume enclosed by a surface to define the thermodynamic changes
- It is a confined space where thermodynamic process occurs

Properties of State and Substance

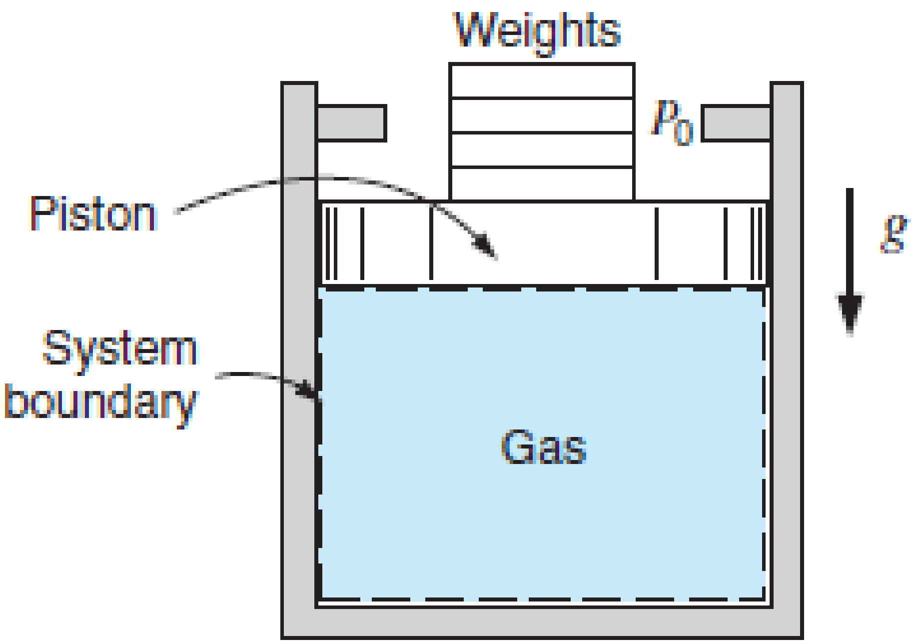
- Phase- it is a quantity of matter that is homogeneous throughout the volume considered.
  - Liquid
  - Solid
  - Vapor
- Macroscopic Properties
  - Observable- Pressure, Temperature, density
  - Is heat a property?

What is the difference between heat and temperature?

Intensive and Extensive Properties

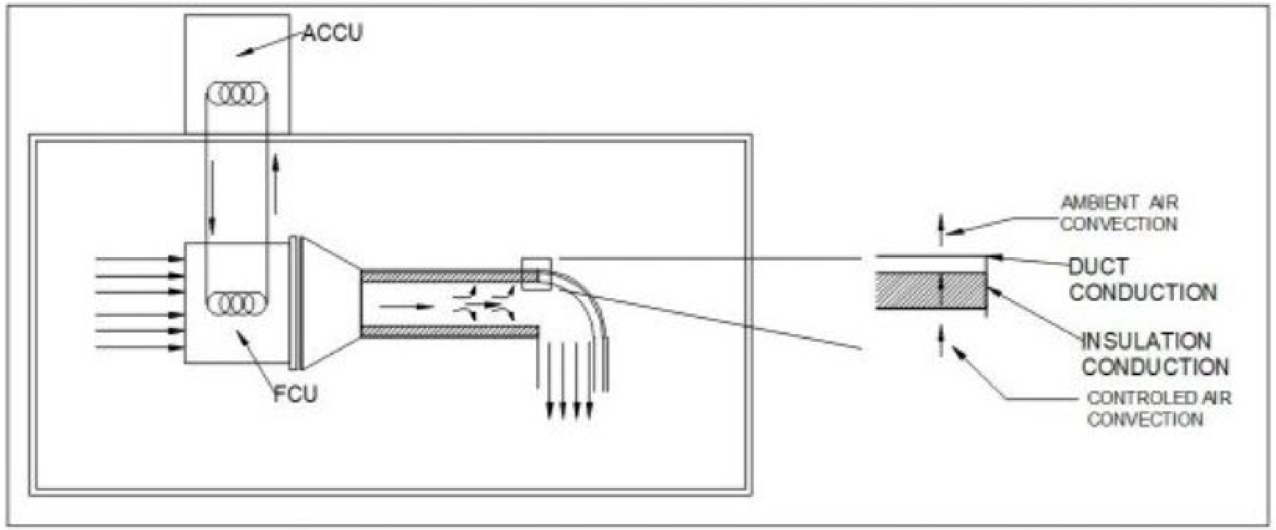
- Intensive Property
  - A property independent of mass
  - Pressure , temperature and density are intensive
    - Doesn’t change with mass
- Extensive Property
  - Mass
  - Total volume

Process



- Equilibrium condition
- A gravity driven process
- A process is a succession of states that passes through a path.
- E.g. This is a gas compression process
- Heating gas inside a piston is a process.

Cycle



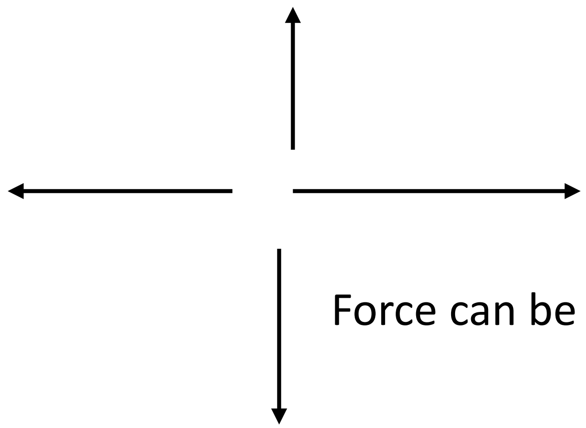
- It is a repetition of a process.
- Thermodynamic cycle-Where thermodynamic process is present.
- E.g- HAVC heating and cooling
- 4 stroke IC engine
- Steam boiler- Water circulates, converts into steam and returns to water

Units

- System of units- SI vs English or Metric vs US customary
- Sensitivity of units- Pico, nano, micro, milli, kilo, Mega, Giga
- Unit of mass- kg, Ton, lbm, Slug
- Unit of weight or Force- Newton, lbf
- What's the Difference between weight and force?

  Force=mass*acceleration

Weight depends on gravitational acceleration



Force can be applied to any direction

Gravitational Acceleration

g= 9.81 m/sec^2 or 32.2 ft/sec^2

SI System, 1 N=1 kg.m/s^2

Gravitational force, F=m*g

English system, 1lbf=32.2 lbm*ft/sec^2

What is the weight of a 1-kg mass at an altitude where the local acceleration of gravity is 9.75 m/s^2?

Ans- 9.75 N

What is the weight of a 1-lbm mass at an altitude where the local acceleration of gravity is 32.0 ft/s^2?

Ans- F=m*g=1 lbm*32.0 ft/sec^2=32.0 lbm*ft/sec^2=1 lbf

If mass is 1 lbm, and gravity is 15 ft/sec^2→ weight= 15 lbm*ft/sec^2/(32.2 lbm*ft/sec^2)=0.465 lbf

Specific Volume and density

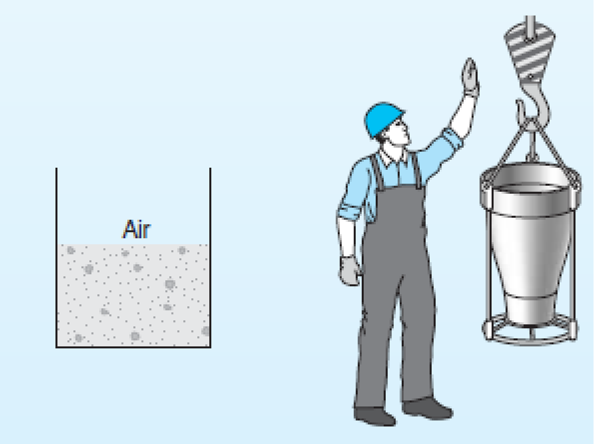
- Specific volume is Volume per unit mass, ν

Density= mass per unit volume, ρ

What is the relation between these two?

$$\nu = 1/\rho$$

A 1-m³ container, shown in Fig. 1.9, is filled with 0.12 m³ of granite, 0.15 m³ of sand, and 0.2 m³ of liquid 25°C water; the rest of the volume, 0.53 m³, is air with a density of 1.15 kg/m³. Find the overall (average) specific volume and density.



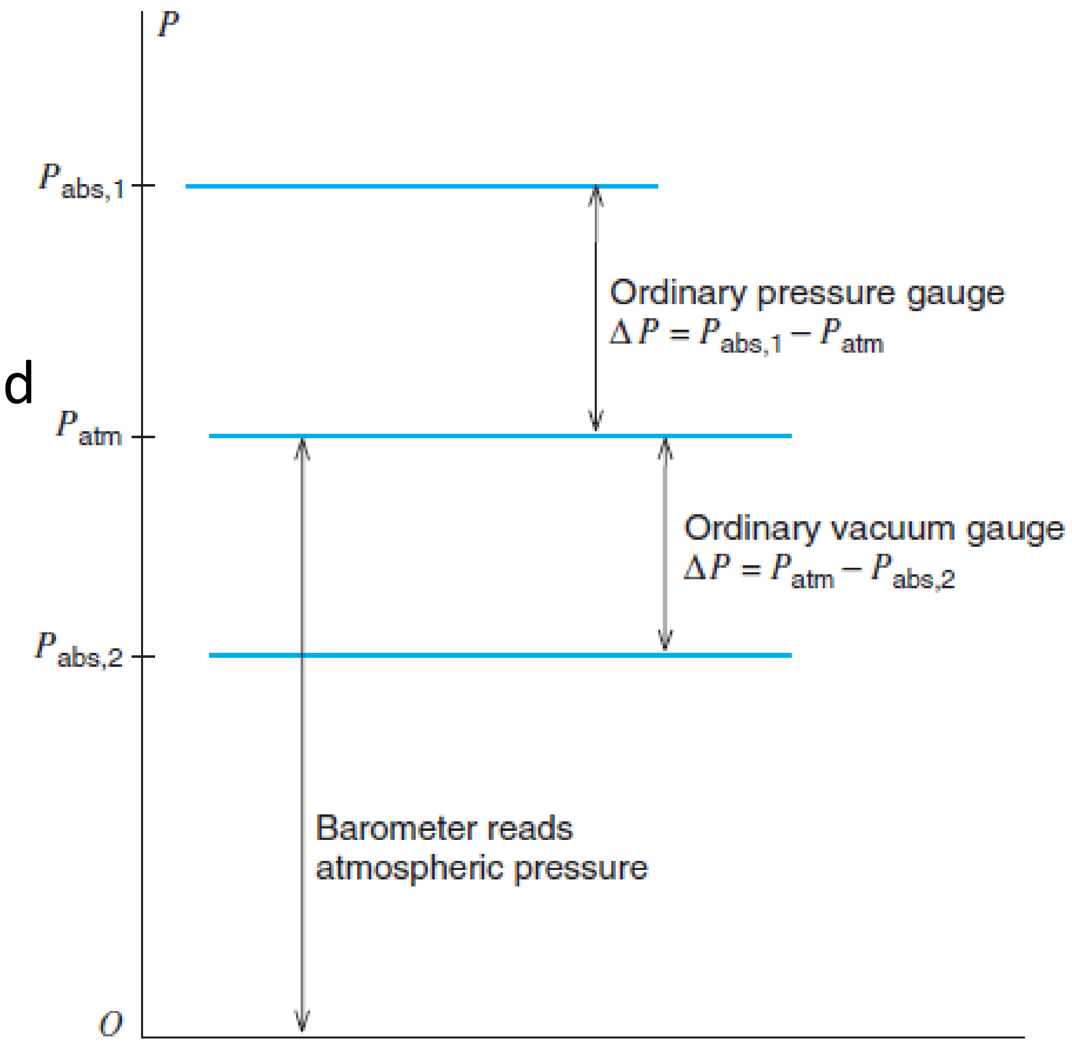
Given, Density of granite= 2750 kg/m^3
Density of Sand= 1500 kg/m^3
Density of water= 1000 kg/m^3

Find total mass= density*volume= $m_{granite}+m_{sand}+m_{water}+m_{air}$
=2750*0.12+1500*0.15+1000*0.2+1.15*0.53
=755 kg

Sp. Volume= Volume/unit mass=1 m^3/755 kg=0.001325 m^3/kg
Average density=1/ sp. Volume=1/0.001325= 755 kg/m^3

Pressure

- Force per unit volume
- Atmospheric pressure, $p = p_{atm} = 14.7$ psi at sea level
- Two ways to measure pressure, Gauge and absolute.



If absolute pressure is 4 psi, then gauge pressure
Is -10.7 psi, 10.7 psi (vacuum gauge)

Question

A 1-m^3 container is filled with 400 kg of granite stone, 200 kg of dry sand, and 0.2 m^3 of liquid 25°C water. Using properties from Tables A.3 and A.4, find the average specific volume and density of the masses when you exclude air mass and volume.

Given, Density of granite= 2750 kg/m^3
Density of Sand= 1500 kg/m^3
Density of water= 1000 kg/m^3

Find a handwritten solution. Show me in the next class

Example Problem on Pressure

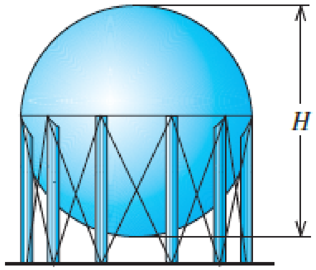


FIGURE 1.15 Sketch for Example 1.6.

What is the pressure at the bottom of the 7.5-m-tall storage tank of fluid at 25°C shown in Fig. 1.15? Assume that the fluid is gasoline with atmospheric pressure 101 kPa on the top surface. Repeat the question for the liquid refrigerant R-134a when the top surface pressure is 1 MPa.

Solution

The densities of the liquids are listed in Table A.4:

$$\rho_{\text{gasoline}} = 750\ \text{kg/m}^3; \quad \rho_{\text{R-134a}} = 1206\ \text{kg/m}^3$$

The pressure difference due to gravity is, from Eq. 1.2,

$$\Delta P = \rho g H$$

The total pressure is

$$P = P_{\text{top}} + \Delta P$$

For the gasoline we get

$$\Delta P = \rho g H = 750\ \text{kg/m}^3 \times 9.807\ \text{m/s}^2 \times 7.5\ \text{m} = 55\,164\ \text{Pa}$$

Now convert all pressures to kPa:

$$P = 101 + 55.164 = 156.2\ \text{kPa}$$

For the R-134a we get

$$\Delta P = \rho g H = 1206\ \text{kg/m}^3 \times 9.807\ \text{m/s}^2 \times 7.5\ \text{m} = 88\,704\ \text{Pa}$$

Now convert all pressures to kPa:

$$P = 1000 + 88.704 = 1089\ \text{kPa}$$