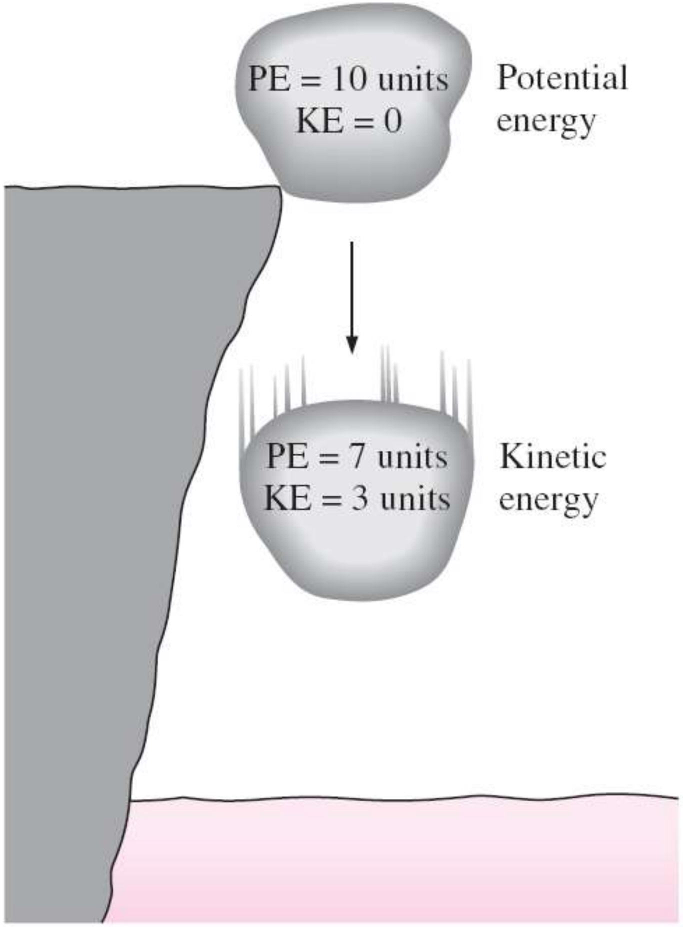
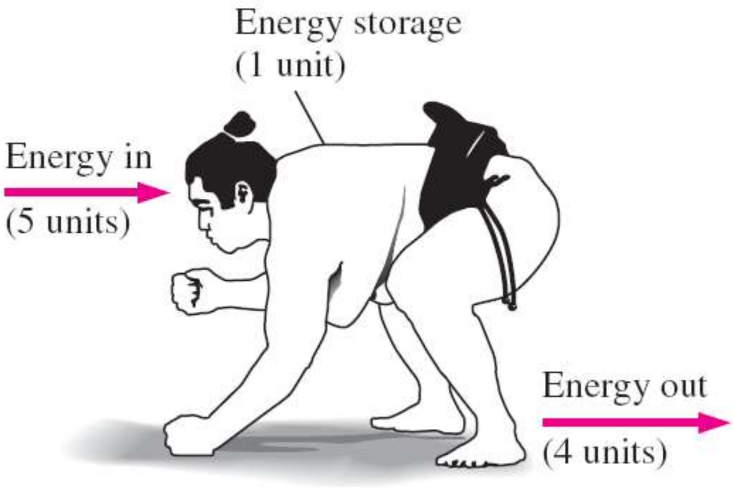
THERMODYNAMICS AND ENERGY

- **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.

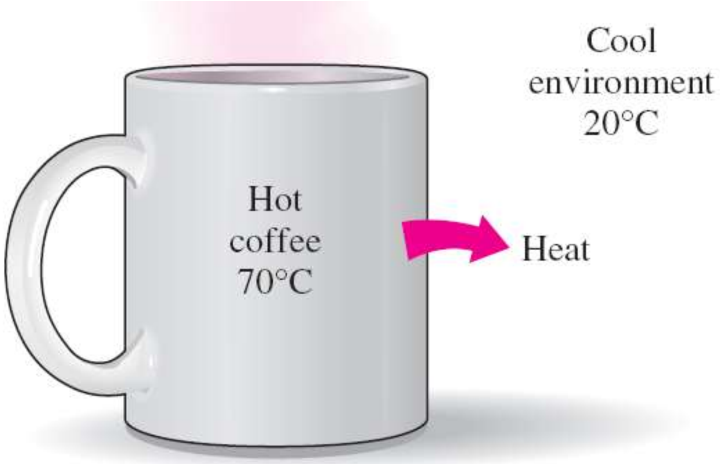


Energy cannot be created or destroyed; it can only change forms (the first law).

- **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.

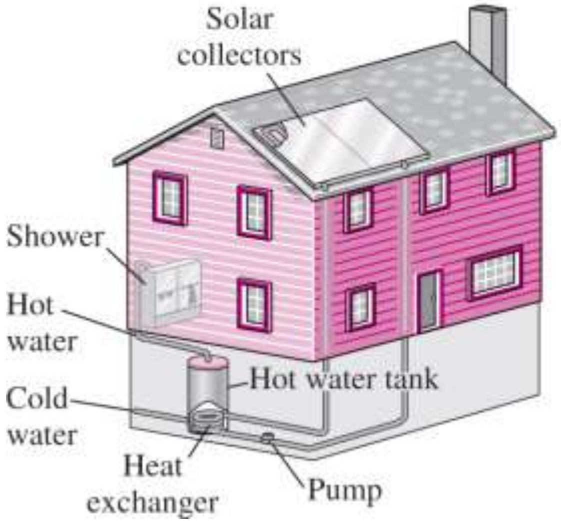


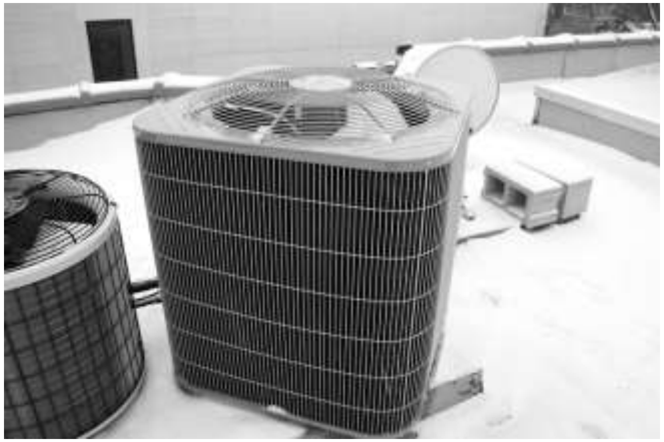
Conservation of energy principle for the human body.



Heat flows in the direction of decreasing temperature.

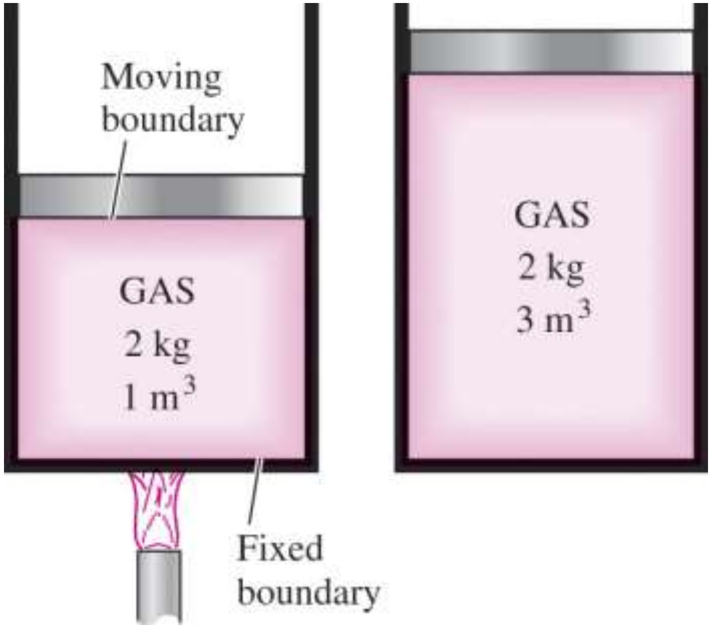
Application Areas of Thermodynamics



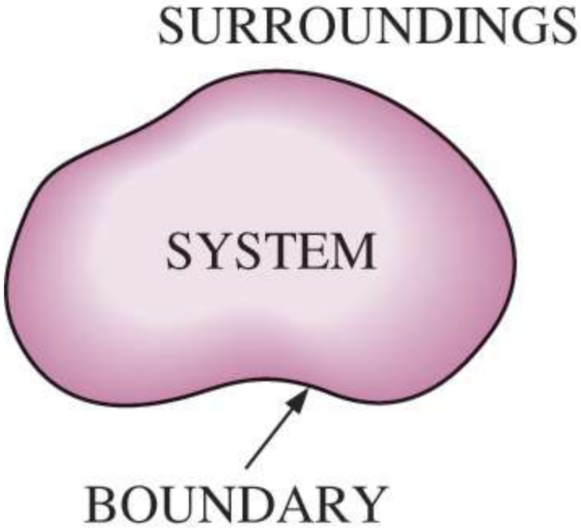


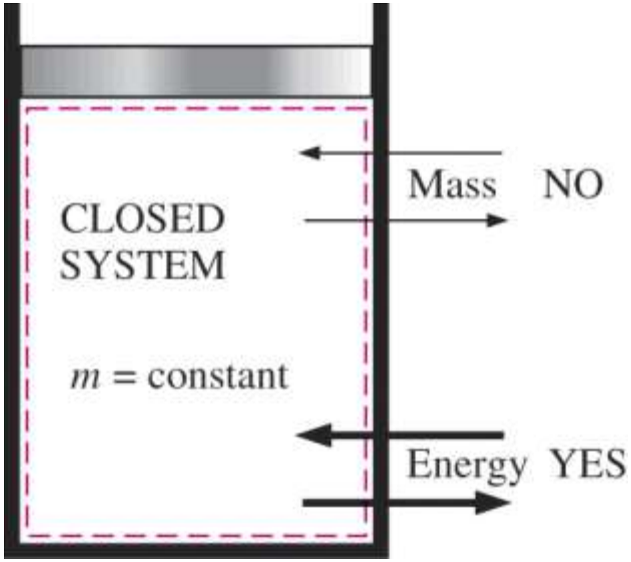
SYSTEMS AND CONTROL VOLUMES

- **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.*

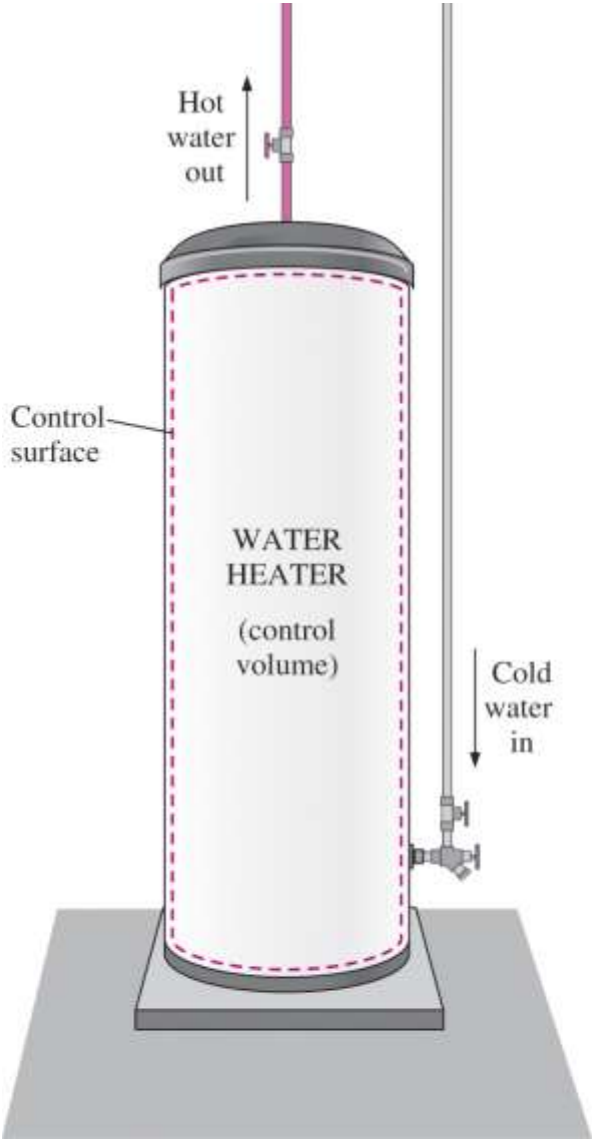


- **Closed system (Control mass):** A fixed amount of mass, and no mass can cross its boundary.

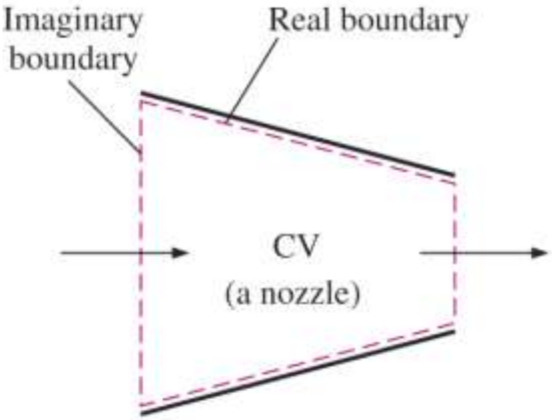




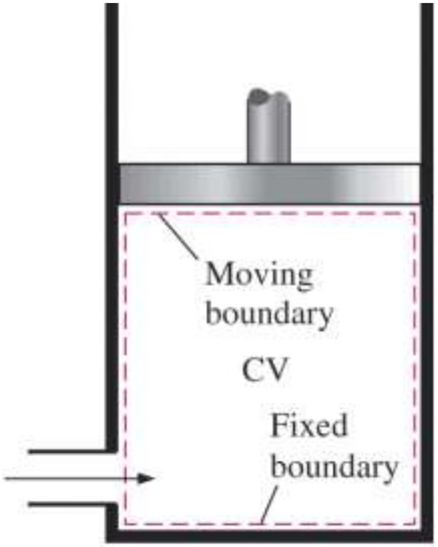
- **Open system (control volume)**: A properly selected region in space.
- It usually encloses a device that involves mass flow such as a compressor, turbine, or nozzle.
- Both mass and energy can cross the boundary of a control volume.
- **Control surface**: The boundaries of a control volume. It can be real or imaginary.



An open system (a control volume) with one inlet and one exit.



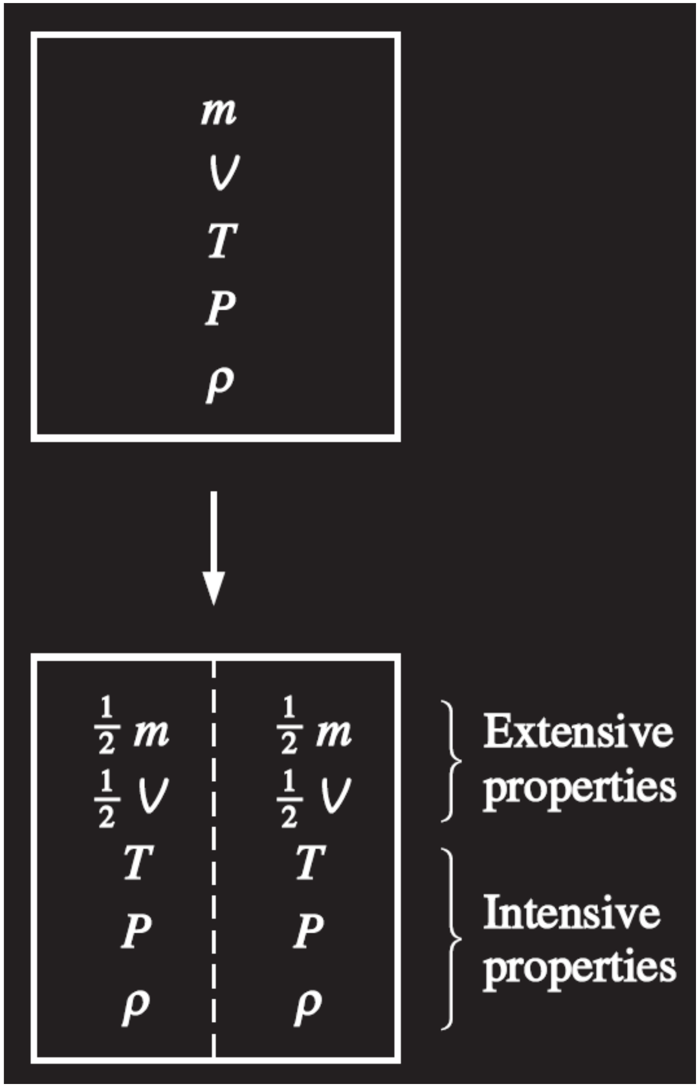
(*a*) A control volume with real and imaginary boundaries



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

PROPERTIES OF A SYSTEM

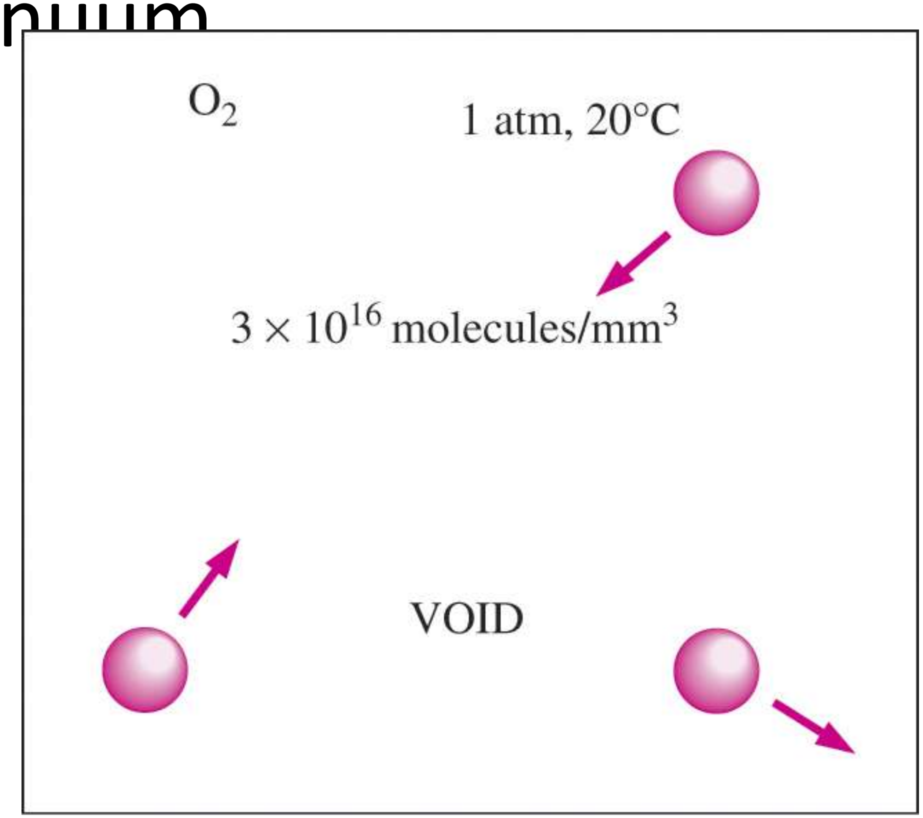
- **Property:** Any characteristic of a system.
- Some familiar properties are pressure *P*, temperature *T*, volume *V*, and mass *m*.
- Properties are considered to be either *intensive* or *extensive*.
- **Intensive properties:** Those that are independent of the mass of a system, such as temperature, pressure, and density.
- **Extensive properties:** Those whose values depend on the size—or extent—of the system.
- **Specific properties:** Extensive properties per unit mass.



Criterion to differentiate intensive and extensive properties.

Continuum

- Matter is made up of atoms that are widely spaced in the gas phase. Yet it is very convenient to disregard the atomic nature of a substance and view it as a continuous, homogeneous matter with no holes, that is, a **continuum**.
- The continuum idealization allows us to treat properties as point functions and to assume the properties vary continually in space with no jump discontinuities.
- This idealization is valid as long as the size of the system we deal with is large relative to the space between the molecules.
- This is the case in practically all problems.
- In this text we will limit our consideration to substances that can be modeled as a continuum.



Despite the large gaps between molecules, a substance can be treated as a continuum because of the very large number of molecules even in an extremely small volume.

DENSITY AND SPECIFIC GRAVITY

Density

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

Specific volume

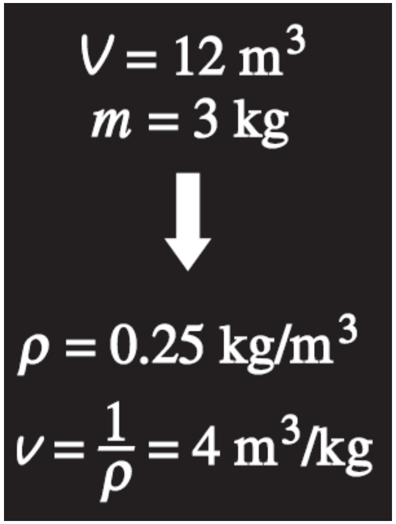
$$v = \frac{V}{m} = \frac{1}{\rho}$$

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.

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



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

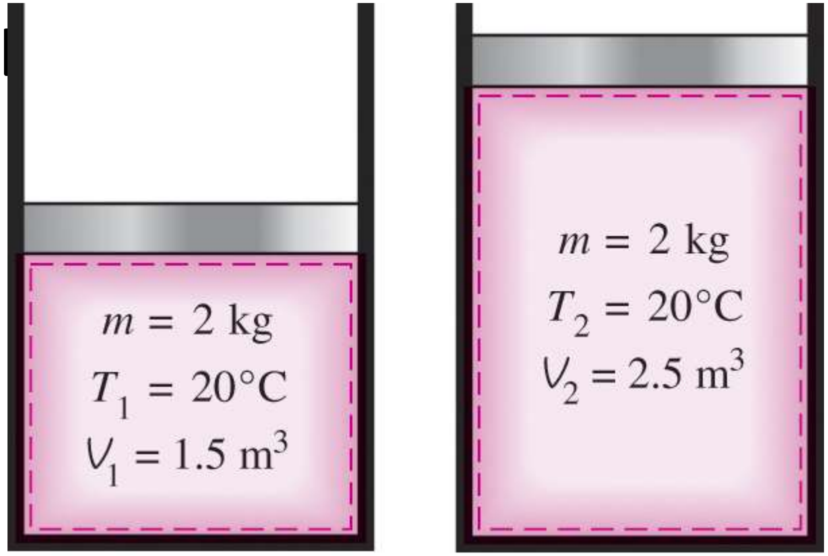
TABLE 1–3

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

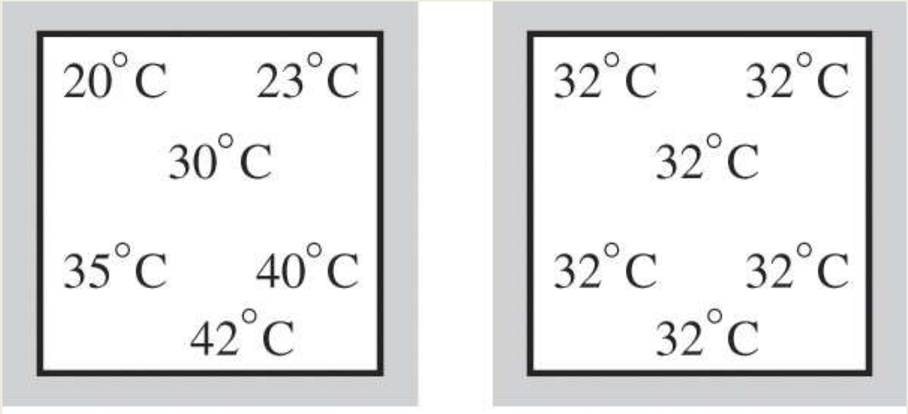
STATE AND EQUI

- Thermodynamics deals with *equilibrium* states.
- **Equilibrium**: A state of balance.
- In an equilibrium state there are no unbalanced potentials (or driving forces) within the system.
- **Thermal equilibrium**: If the temperature is the same throughout the entire system.
- **Mechanical equilibrium:** If there is no change in pressure at any point of the system with time.
- **Phase equilibrium:** If a system involves two phases and when the mass of each phase reaches an equilibrium level and stays there.
- **Chemical equilibrium:** If the chemical composition of a system does not change with time, that is, no chemical reactions occur.



(*a*) State 1 (*b*) State 2

A system at two different states.



(*a*) Before (*b*) After

A closed system reaching thermal equilibrium.

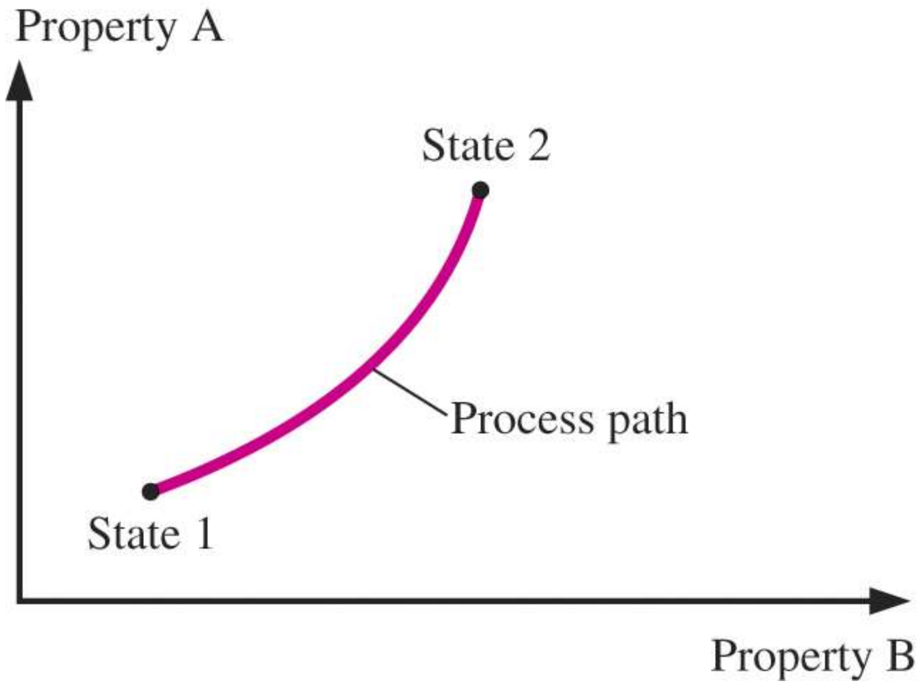
PROCESSES AND CYCLES

Process: Any change that a system undergoes from one equilibrium state to another.

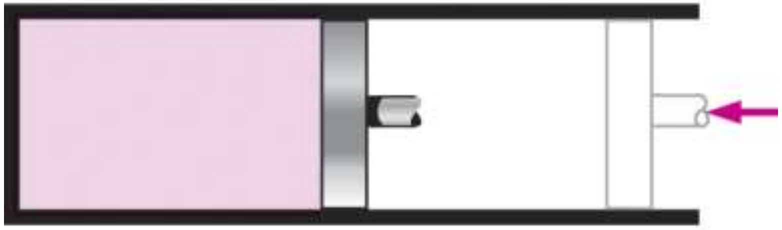
Path: The series of states through which a system passes during a process.

To describe a process completely, one should specify the initial and final states, as well as the path it follows, and the interactions with the surroundings.

Quasistatic or quasi-equilibrium process: When a process proceeds in such a manner that the system remains infinitesimally close to an equilibrium state at all times.

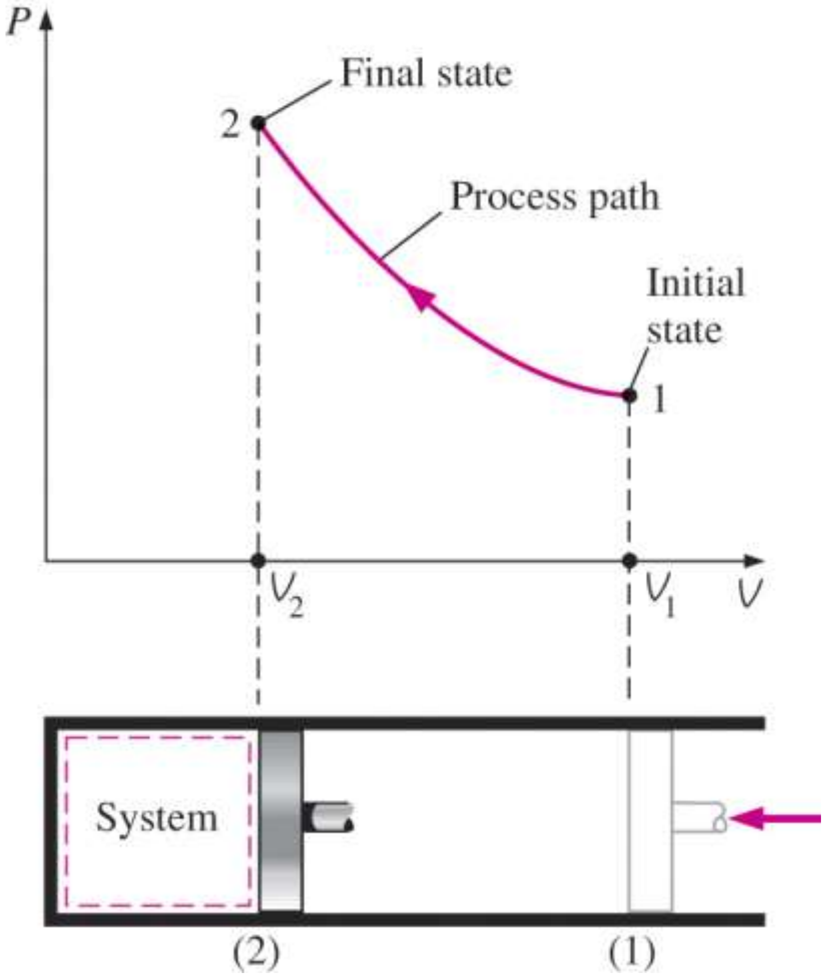


(*a*) Slow compression (quasi-equilibrium)



(*b*) Very fast compression (nonquasi-equilibrium)

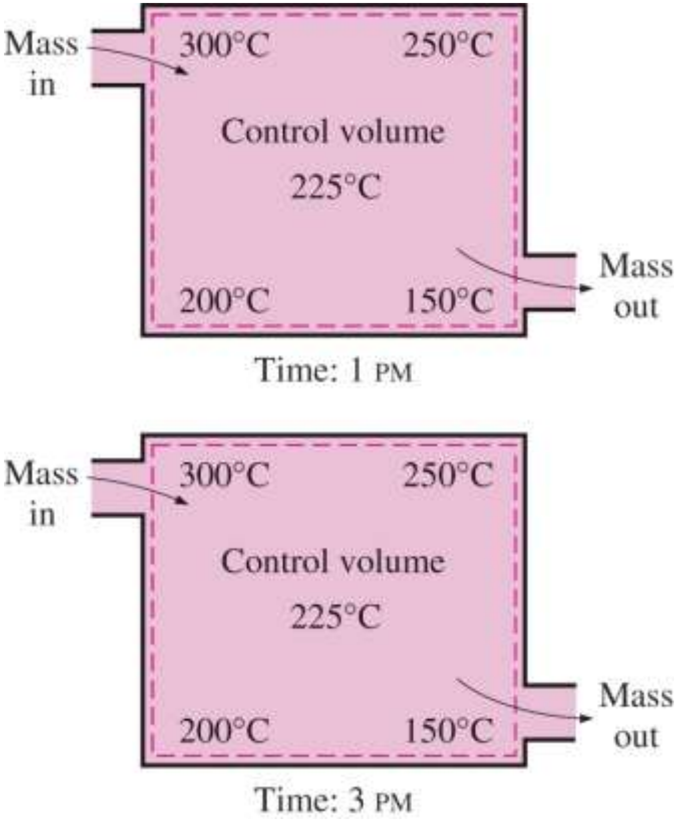
- Process diagrams plotted by employing thermodynamic properties as coordinates are very useful in visualizing the processes.
- Some common properties that are used as coordinates are temperature *T*, pressure *P*, and volume *V* (or specific volume *v*).
- The prefix *iso-* is often used to designate a process for which a particularproperty remains constant.
- **Isothermal process**: A process during which the temperature *T* remains constant.
- **Isobaric process**: A process during which the pressure *P* remains constant.
- **Isochoric (or isometric) process**: A process during which the specific volume *v* remains constant.
- **Cycle**: A process during which the initial and final states are identical.



The *P-V* diagram of a compression process.

The Steady-Flow Process

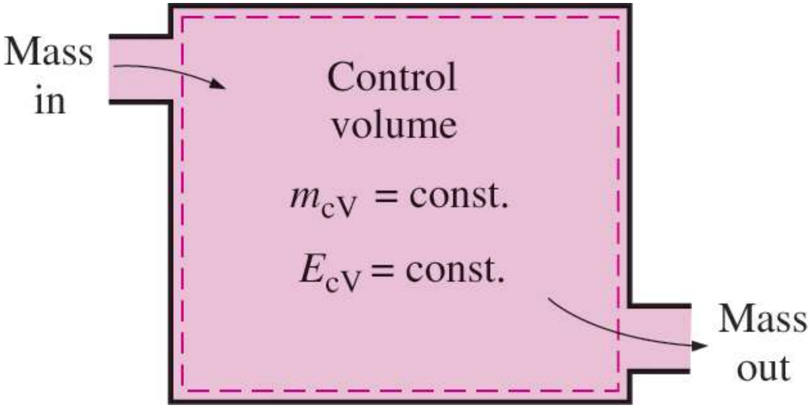
- The term *steady* implies *no change with time*. The opposite of steady is *unsteady*, or *transient*.
- A large number of engineering devices operate for long periods of time under the same conditions, and they are classified as *steady-flow devices*.
- **Steady-flow process**: A process during which a fluid flows through a control volume steadily.
- Steady-flow conditions can be closely approximated by devices that are intended for continuous operation such as turbines, pumps, boilers, condensers, and heat exchangers or power plants or refrigeration systems.



Time: 1 PM

Time: 3 PM

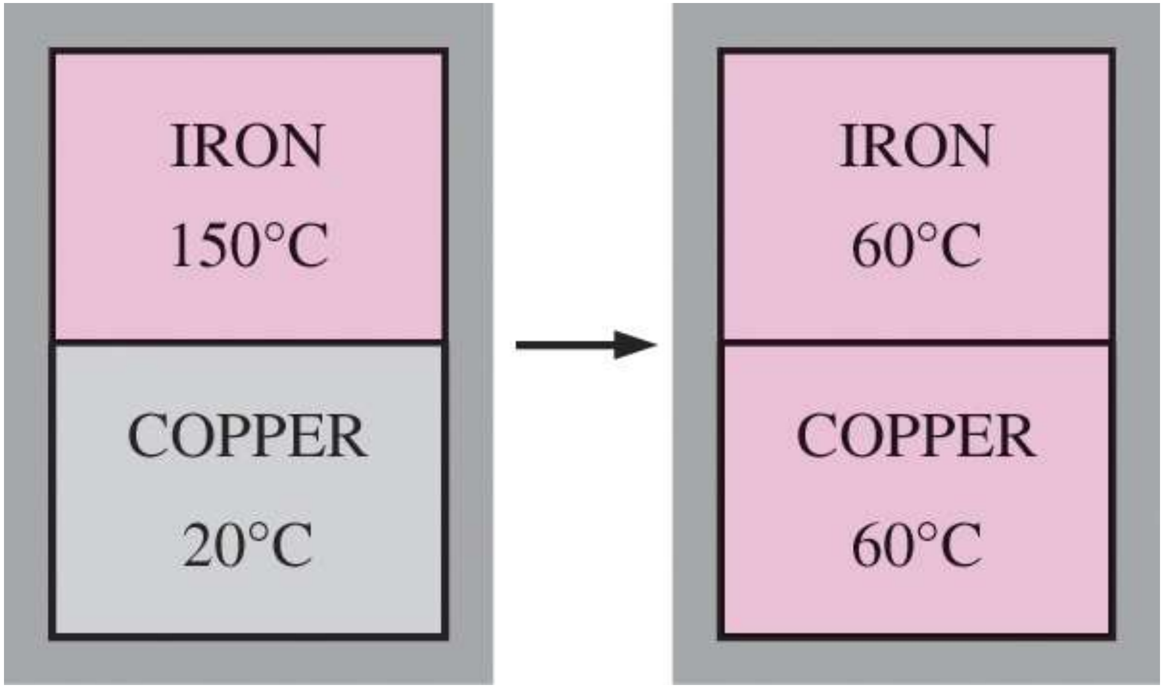
During a steady-flow process, fluid properties within the control volume may change with position but not with time.



Under steady-flow conditions, the mass and energy contents of a control volume remain constant.

TEMPERATURE AND THE ZEROTH LAW OF THERMODYNAMICS

- **The zeroth law of thermodynamics**: If two bodies are in thermal equilibrium with a third body, they are also in thermal equilibrium with each other.
- By replacing the third body with a thermometer, the zeroth law can be restated as *two bodies are in thermal equilibrium if both have the same temperature reading even if they are not in contact*.

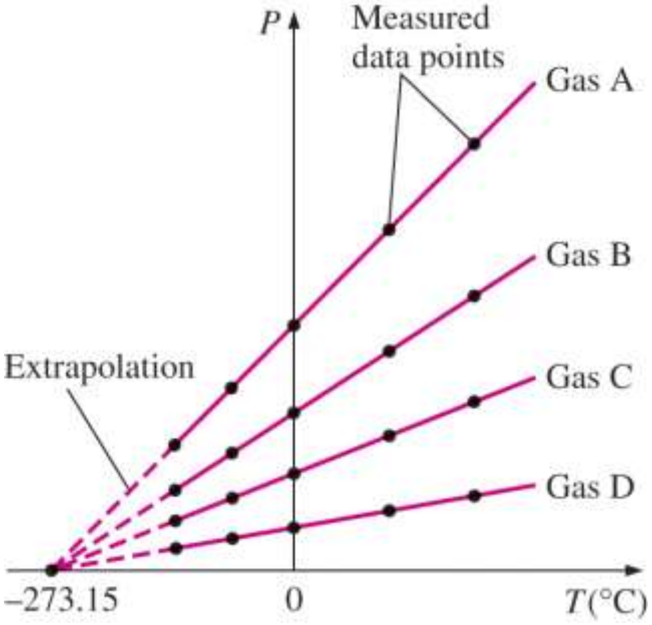


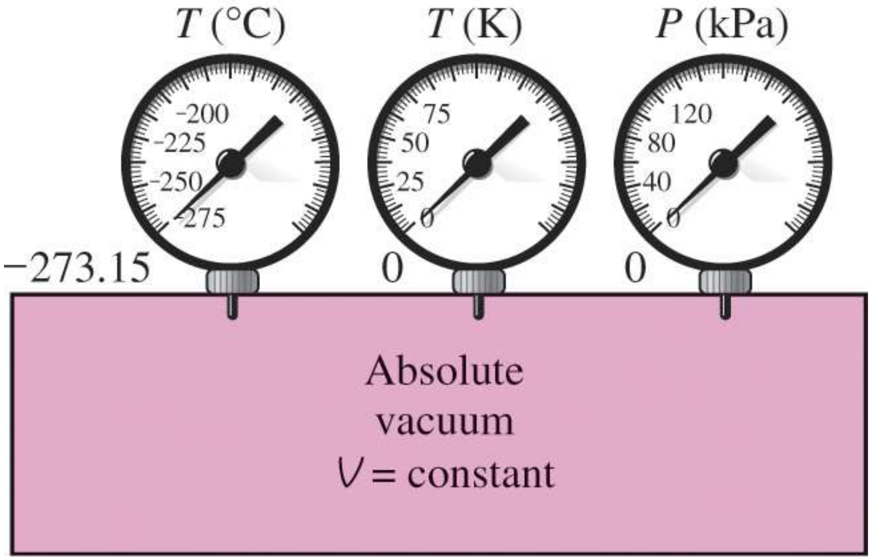
Two bodies reaching thermal equilibrium after being brought into contact in an isolated enclosure.

Temperature Scales

- All temperature scales are based on some easily reproducible states such as the freezing and boiling points of water: the *ice point* and the *steam point.*
- **Ice point**: A mixture of ice and water that is in equilibrium with air saturated with vapor at 1 atm pressure (0°C or 32°F).
- **Steam point**: A mixture of liquid water and water vapor (with no air) in equilibrium at 1 atm pressure (100°C or 212°F).
- **Celsius scale**: in SI unit system
- **Fahrenheit scale**: in English unit system
- **Thermodynamic temperature scale**: A temperature scale that is independent of the properties of any substance.
- **Kelvin scale** (SI) **Rankine scale** (E)
- A temperature scale nearly identical to the Kelvin scale is the **ideal-gas temperature scale**. The temperatures on this scale are measured using a constant-volume gas thermometer.

P versus *T* plots of the experimental data obtained from a constant-volume gas thermometer using four different gases at different (but low) pressures.





A constant-volume gas thermometer would read 273.15°C at absolute zero pressure.

$$T(\mathrm{K}) = T(^\circ\mathrm{C}) + 273.15$$

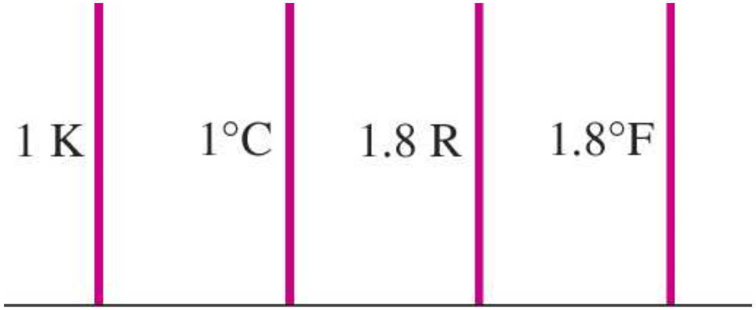
$$T(\mathrm{R}) = T(^\circ\mathrm{F}) + 459.67$$

$$T(\mathrm{R}) = 1.8T(\mathrm{K})$$

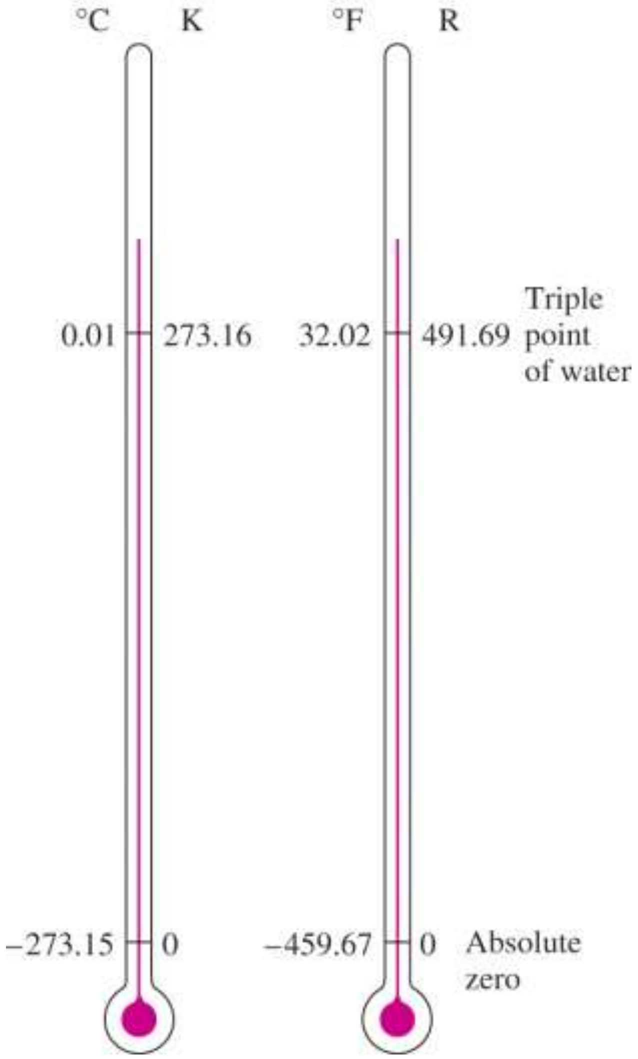
$$T(^\circ\mathrm{F}) = 1.8T(^\circ\mathrm{C}) + 32$$

$$\Delta T(\mathrm{K}) = \Delta T(^\circ\mathrm{C})$$

$$\Delta T(\mathrm{R}) = \Delta T(^\circ\mathrm{F})$$



Comparison of magnitudes of various temperature units.



Comparison of temperature scales.

- The reference temperature in the original Kelvin scale was the ***ice point***, 273.15 K, which is the temperature at which water freezes (or ice melts).
- The reference point was changed to a much more precisely reproducible point, the ***triple point*** of water (the state at which all three phases of water coexist in equilibrium), which is assigned the value 273.16 K.

PRESSURE

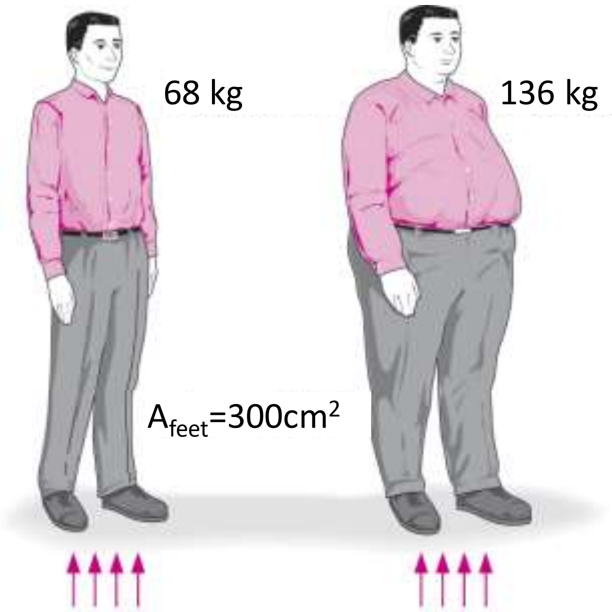
Pressure: A normal force exerted by a fluid per unit area

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

$$1\ \text{bar} = 10^5\ \text{Pa} = 0.1\ \text{MPa} = 100\ \text{kPa}$$

$$1\ \text{atm} = 101{,}325\ \text{Pa} = 101.325\ \text{kPa} = 1.01325\ \text{bars}$$

$$\begin{aligned} 1\ \text{kgf/cm}^2 &= 9.807\ \text{N/cm}^2 = 9.807 \times 10^4\ \text{N/m}^2 = 9.807 \times 10^4\ \text{Pa} \\ &= 0.9807\ \text{bar} \\ &= 0.9679\ \text{atm} \end{aligned}$$



P=68/300=0.23 kgf/cm^2

The normal stress (or "pressure") on the feet of a chubby person is much greater than on the feet of a slim person.

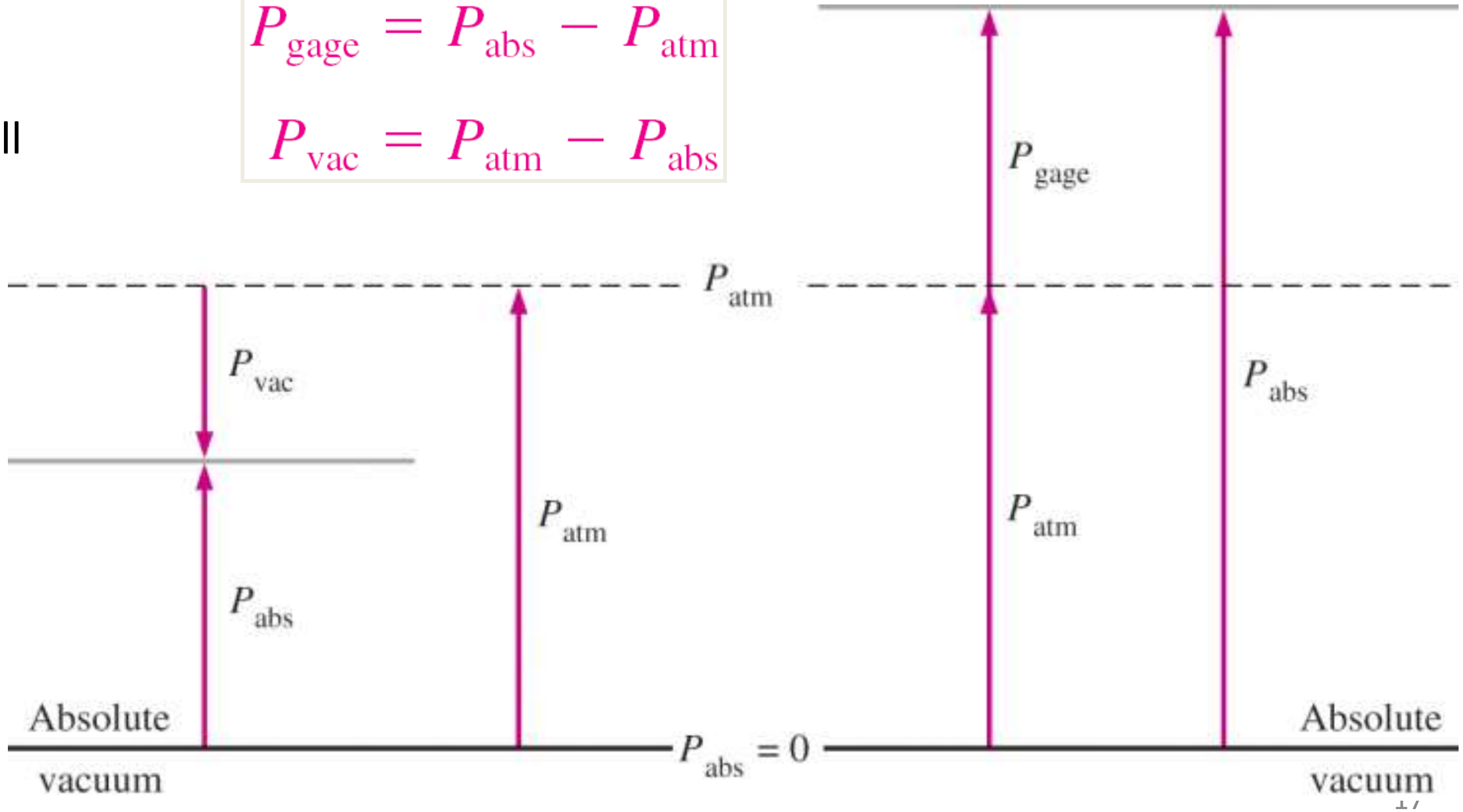
Some basic pressure gages.

- **Absolute pressure**: The actual pressure at a given position. It is measured relative to absolute vacuum (i.e., absolute zero pressure).
- **Gage pressure**: The difference between the absolute pressure and the local atmospheric pressure. Most pressure-measuring devices are calibrated to read zero in the atmosphere, and so they indicate gage pressure.
- **Vacuum pressures**: Pressures below atmospheric pressure.

Throughout this text, the pressure ***P*** will denote ***absolute pressure*** unless specified otherwise.

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

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



Summary

- Thermodynamics and energy
  - Application areas of thermodynamics
- Importance of dimensions and units
  - Some SI and English units, Dimensional homogeneity, Unity conversion ratios
- Systems and control volumes
- Properties of a system
- Density and specific gravity
- State and equilibrium
  - The state postulate
- Processes and cycles
  - The steady-flow process
- Temperature and the zeroth law of thermodynamics
  - Temperature scales
- Pressure
  - Variation of pressure with depth
- The manometer and the atmospheric pressure
- Problem solving technique

QUESTION BANK

THERMODYNAMICS

1) a) Define a thermodynamic system. Differentiate between open system, closed system and an isolated system.

b) Determine the work done by the air which enters into an evacuated vessel from atmosphere when the valve is opened. The atmospheric pressure is 1.013 bar and 1.5 m^3 of air at atmospheric condition enters into the vessel. [6+8] **S**

2) a) Explain the following terms:

i) state ii) Process iii) Cycle

b) A fluid at a pressure of 3 bar, and with specific volume of 0.18 m^3/kg, contained in a cylinder behind a piston expands reversibly to a pressure of 0.6 bar according to a law $p = C/v^2$ where C is a constant. Calculate the work done by the fluid on the piston. [6+8] **S**

3) a) How does the homogeneous system differ from a heterogeneous system?

b) 1 kg of a fluid is compressed reversibly according to a law pv = 0.25 where p is in bar and v is in m^3/kg. The final volume is ¼ of the initial volume. Calculate the work done on the fluid also sketch the process on a p-v diagram. [6+8] **S**

4) a) What do you understand by path function and point function? What are the exact and inexact differentials?

b) A mass of 1.5 kg of air is compressed in a quasi-static process from 0.1 MPa to 0.7 MPa for which pv = constant. The initial density of air is 1.16 kg/m^3. Find the work done by the piston to compress the air. [7+7] **S**

5) a) Show that work is a path function and not a property.

b) A mass of gas compressed in a quasi-static process from 80 KPa, 0.1 m^3 to 0.4 MPa, 0.03 m^3. Assuming that the pressure and volume are related by pv^n = constant, find the work done by the gas system. [6+8] **S**

6) a) Define the term 'heat' in detail. Justify the statement that work and heat are not properties.

b) Calculate the non-flow work done for a gas which expands from initial pressure 5 bar and volume 4 m^3 to final volume 20 m^3 under the following reversible processes. Show the process on P-V diagram.

a) P= C b) V = C PV = C d) $PV^\gamma = C$ where $\gamma = 1.4$ e) $PV^n = C$ [6+8] **S**

7) A piston-cylinder arrangement is containing a fluid at 10 bar, the initial volume being 0.05 m^3. Find the work done by the fluid when it expands reversible for the following cases

a) at constant pressure to a final volume of 0.2 m^3

b) according to the linear law to a final volume of 0.2 m^3 and a final pressure of 2 bar.

c) according to law PV = constant to a final volume of 0.06 $m^{3.}$

d) according to law PV^3 = constant to a final volume of 0.06 m^3.

e) according to law = $(A/V^3) - (B/V)$ to final volume of 0.1 m^3 and a final pressure of 1 bar where A and B are constants. [14] **M**

8) Calculate the non-flow work done for a gas which expands from initial pressure 5 bar and volume 4 m^3 to final volume 20 m^3 under the following reversible processes. Show the process on P-V diagram.

a) P = c b) v = c c) pv = c d) $pv^\gamma = c$ where $\gamma = 1.4$ e) $pv^n = c$ Where n = 1.25. [14] **M**

9) a) Differentiate between the cyclic process and non-cyclic process.

b) Prove that heat and work are the path functions. [7+7] **S**

10) a) What is a quasi-static process? What is its characteristic feature?

b) An engine cylinder has a piston of area 0.12 m^3 and contains gas at a pressure of 1.5 MPa. The gas expands according to a process which is represented by a straight line on a pressure-volume diagram. The final pressure is 0.15 MPa. Calculate the work done by the gas on the piston if the stroke is 0.3 m. [6+8] **M**

11) A fluid is contained in a cylinder by a spring loaded, frictionless piston so that the pressure in the fluid is linear function of volume (p = a + bv). The internal energy of the fluid in KJ is given by the expression u = 32 + 3pv, where p is in KPa and V is in m^3. The initial and final pressures are 150 KPa and 350 KPa and the corresponding volumes are 0.02 m^3 and 0.05 m^3. Make calculations for the direction and magnitude of work and heat interactions. [14] **D**

12) a) Explain the terms state, path, process and cyclic process.

b) Discuss the macroscopic and microscopic point of view of thermodynamics. [7+7] **S**

13) a) Explain thermodynamic system, surroundings and universe, illustrate the same with examples.

b) Distinguish between closed system, open system and isolated system with suitable examples. [7+7] **S**

14) a) Explain the control volume and its significance

b) if a gas of volume 6000 cm^3 and at a pressure of 100 KPa, is compressed quasistatically to PV^2 = constant until the volume becomes 2000 cm^3. Calculate the final pressure and the work transfer. [4+10] **S**

15) a) What are different forms of work energy. Explain each of them briefly.

b) Why does free expansion have zero work transfer. [8+ 6] **S**

16) a) Explain the terms 'cyclic' and 'quasi static' process.

b) A piston-cylinder engine contains a fluid at 12 bar pressure. The cylinder volume is 0.03 m^3. Calculate the work done by the fluid when it expands reversibly as

a) according to a law PV = C to a final volume of 0.15 m^3.

b) according to law $P = A/V^3 - B/V$ to a final of 0.1 m^3 and a final pressure of 1.5

bar where A and B are constants. [6+8] **M**

17) a) Write the difference between system and control volume.

b) A gas undergoes a reversible non-flow process according to the relation P = (-3V + 15) where V is the volume in m^3 and P is the pressure in bar. Determine the work done when the volume changes from 3 to 6 m^3. [4+10] **S**

18) A gas expands according to the equation PV = 100, where P is the pressure in KPa and V is the specific volume in m^3/kg. The initial pressure of the gas is 1000 KPa and the final pressure is 500 KPa. The gas is then heated at constant volume back to its original pressure of 1000 KPa. Determine the work of combined process. Also sketch the process on P-V coordinates. [14] **D**

19) a) What is thermodynamic system? What is the difference between a closed system and an open system? Give few examples for closed and open systems.

b) An engine cylinder has a piston of area 0.12 m^2 and contains gas at a pressure of 1.5 MPa. The gas expands according to a process which is represented by a straight line of a pressure-volume diagram. The final pressure is 0.15 MPa. Calculate the work done by the gas on the piston if the stroke is 0.03 m. [7 + 7] **M**

20) A fluid is contained in a cylinder by a spring loaded, frictionless piston so that the pressure in the fluid is linear function of volume (p = a+bv). The internal energy of the fluid is KJ is given by the expression u = 32 + 3pv, where p is in KPa and V is in m^3. The initial and final pressures are 150 KPa and 350 KPa and the corresponding volumes are 0.02 m^3 and 0.05 m^3. Make calculations for the direction and magnitude of work and heat interaction. [14] **D**

21) A gas undergoes two processes that are in series. The first process is an expansion that is carried out according to the law PV = constant and the second process is a constant pressure process that returns the gas to the initial volume of the first process. The start of the first process is at 400 KPa and 0.025 m^3 with the expansion to 200 KPa. Sketch the process on a P-V diagram, and determine the work of the combined process. [14] **M**

22) A fluid contained in a horizontal cylinder fitted with frictionless leak proof piston, is continuously agitated by means of a stirrer passing through the cylinder cover. The cylinder diameter is 0.4 m. During the stirring process lasting 10 minutes, the piston slowly moves out a distance of 0.485 m against the atmosphere. The net work done by the fluid during the process is 2 KJ. The speed of the electric motor droving the stirrer is 840 rpm. Determine torque in the shaft and power output of the motor. [14] **D**

23) a) Show that work is a path function, and not a property.

b) A mass of gas is compressed in quasi-static process from 80 KPa, 0.1 m^3 to 0.4MPa, 0.03 m^3. Assuming that the pressure and volume are related by PV^n = constant, find the work done by the gas system. [4+10] **M**

24) a) Define the term ‘heat’ in detail. Justify the statement that work and heat are not properties.

b) A pressure gauge fixed in a boiler reads 1200 KN/m^2. The barometer reads atmospheric pressure as 735.5 mm of Hg. Determine the corresponding absolute pressure. [7+7] **M**

25) a) What are positive and negative work interactions.

b) A forced fan supplies air to the furnace of a boiler at a head of 40 mm of water column. Determine the absolute pressure of air supply if the barometric reading is 760 mm of Hg. [4+10] **M**

26) a) Distinguish clearly between the following, giving examples wherever necessary

i) Closed system and open system

ii) point function and path functions

b)A vacuum gauge fixed in steam condenser reads 71 cm of Hg. The barometric reading is 76 cm of Hg. Calculate the absolute pressure in the condenser. [7+7] **M**

27) a) Explain clearly what thermodynamic equilibrium is?

b) The pressure of steam generated in a boiler as recorded by the Bourdon pressure guage was 9.2 bar. Calculate the absolute pressure of steam if the barometer reads 774 mm of Hg. [6+8] **M**

28) a) Discuss the microscopic and macroscopic point of view of thermodynamics.

b) A non flow quasi-static (reversible) process occurs for which p = -3v + 16 bar, where V is in m$^{3.}$ What is the work done when V changes from 2 to 6 m^3? [6+8] **S**

29) a) Define property and classify it with proper examples.

b) A non-flow reversible process can be written down by and equation p = (V^2 + 8/V) bar. Determine the work done if volume changes from 1 to 3 m^3. [6+8] **S**

30) a) Justify the statement that work and heat are not properties.

b) Write short notes on

a) System b) properties c) path function and point function

d) work and heat [6+8] **S**

31) a) What do you understand by path function and point function.

b) State whether the following quantities are point functions or path functions? Explain briefly (i) $\int pdv$ (ii) $\int vdp$ (iii) $\int (pdv + vdp)$ (iv) $\int dv$. [6+8] **M**

32. a) Justify the statement that work and heat are not the properties.

b) A quantity of air having a volume of 0.03 m^3 at a temperature of 200^{0}C and pressure of 150 N/cm^2 is expanded at constant pressure to 0.06 m^3, it is then expanded adiabatically to 0.12 m^3. Find (i) Temperature and pressure at the end of the adiabatic process (ii) work done during each stage assuming $\gamma = 1.41$. [4+10] **M**

33. a) Define the term ‘heat’ in detail. Justify the statement that work and heat are not properties

b) The properties of a closed system change following the relation between pressure and volume as PV = 3 where P is in bar, V is in m^3. Calculate the work done when the pressure increases from1.5 bar to 7.5 bar. [7+7] **S**

34. a) Explain clearly what thermodynamic equilibrium is?

b) A fluid at a pressure of 3 bar, and with specific volume of 0.18 m^3/kg, contained in a cylinder behind a piston expands reversibly to a pressure of 0.6 bar according to a law $P = C/V^2$. Calculate the work done by the fluid on the piston. [6+8] **S**.

UNIT - 2

1. A new temperature scale in ^{0} N is to be defined. The boiling and freezing points on this scale are 400^{0}N and 100^{0}N respectively.

   a) Correlate this with Centigrade and Fahrenheit scale

   b) What will be the reading on the new scale corresponding to 60^{0}C [14] **M**

2. A fluid is confined in a cylinder by a spring loaded, frictionless piston so tha the pressure in the fluid is a linear function of the volume (P = a+bV). The internal energy in the fluid is given by the following equation.

$$U = 34 + 3.15 PV$$

Where U is in Kj, P in KPa and V in m^3. If the fluid changes from an initial state of 170 KPa, 0.03 m^3 to a final state of 400 KPa, 0.06 m^3 with no work other than that done on the piston, find the direction and magnitude of the work and heat transfer. [14] **D**

3. A piston and cylinder machine contains a fluid system which passes through a complete cycle of four processes. During a cycle, the sum of all heat transfers is -170 Kj. The system completes 100 cycles per minute. Complete the following table showing the method for each item, and compute the new rate of work output in KW. [14] **M**

Process	Q (KJ/min)	W (KJ/min)	ΔE (KJ/min)
a-b	0	2,170	--
b-c	21,000	0	--
c-d	-2,100	--	-36,600
d-a	--	--	--

4. A system receives 200 Kj of work at constant volume process and rejects 220 Kj of heat at constant pressure and 40 Kj of work is done on the system. The system is brought to its original state by an adiabatic process. Calculate the adiabatic work. If the initial internal energy is 240 Kj, then calculate the value of internal energy at all points. [14] **S**

5. In a vessel 10 kg of oxygen is heated in a reversible, now-flow, constant volume process so that the pressure of oxygen is increase two ties that of the initial vale. The initial temperature is 20 ^{0}C. Calculate

   a. The final temperature

b. The change in internal energy

c. The change in enthalpy and

d. The heat transfer.

Take R = 0.259 Kj/Kg K and C_v = 0.652 Kj/Kg K for oxygen. [14] **M**

6. Calculate the final temperature, pressure, work done and heat transfer if the fluid is compressed reversibly from volume 6 m^3 to 1 m^3 when the initial temperature and pressure of the fluid are 20^0 C and 1 bar. The index of compression may be assumed as 1, 1.3 and 1.4 respectively. Take C_p = 1.005 and C_v = 0.718 and R = 0.287 Kj/Kg K. [14] **M**

7. a) State the zeroth law of thermodynamics. Explain how it forms the basis for temperature measurement.

b) A closed system undergoes a thermodynamic cycle consisting of four separate and distinct processes. The heat and work transferred in each process are as tabulated below.

Process	Heat transfer in Kj/min	Work done in Kj/min
1-2	20,000	0
2-3	-10,000	30,000
3-4	0	20,000
4-1	15,000	-25,000

Show that the data is consistent with the first law of thermodynamics. Also evaluate the net work output in KW and the change in internal energy. [6+8] **S**

8. a) State the limitations of first law of thermodynamics.

b) A system undergoes a cycle composed of four processes. The heat transfers n each process are: 400Kj, -365 Kj, -200 Kj and 250 Kj. The respective work transfers are 140 Kj, 0, -55Kj and 0. Is the data consistent with first law of thermodynamics? [4+10] **M**

9. A system receives 200 kj of heat at constant volume process and rejects 220 kj of heat at constant pressure and 40 kj of work is done on the system. The system is brought to its original state by an adiabatic process. Calculate the adiabatic work. If the initial internal energy is 240 kj then calculate the volume of internal energy at all points. [14] **M**

10. A system containing 0.2 m^3 of air at a pressure of 4 bar and 160^0 C expands isentropically to pressure of 1.06 bar and after this the gas is heated at the constant pressure till the enthalpy increases by 65 kj. Calculate the work done. Now, imagine that these processes are replaced by

a single reversible polytropic process producing the same work between initial and final sate. Find the index of expansion in this case. C_p of air = 1.005 kj/kg K. [14] **D**

11. 2 m^3 of hydrogen at a pressure of 1 bar and 20^0 C is compressed isentropically to 4 bar. The same gas is expanded restored to original volume by constant volume heat rejection process. Determine a) pressure, volume and temperature at each end of operation, b) the heat added during the isothermal process. c) the heat rejected during constant volume process and d) change in internal energy during each process. Assume R = 4.206 kj/kg K, C_p = 14.25 kj/kg K. [14] **D**

12. a) Explain the limitations of first law and state the essence of second law.

b) Prove that the formula $T^bV^{a-b}e^{kt}$ = constant for the adiabatic expansion of the gas if $C_p = a + KT$ and $C_v = b + KT$, where a, b, and k are constants and T in K. [6+8] **M**

13. a) Explain in detail about constant volume gas thermometer.

b) In a certain cyclic process, the heat interactions are +44kj, -108 kj, -32j and 136 kj. Find the net work done during cyclic process. [6+8] **S**

14. A steam turbine operates under steady-flow conditions. It receives 7200 kg/h of steam from the boiler. The steam enters the turbine at enthalpy of 2800 kj/kg, a velocity of 4,000 m/min, and an elevation of 4m. The steam leaves the turbine at enthalpy of 2000 kj/kg a velocity of 8000 m/min and an elevation of 1m. Due to radiation, heat losses from the surrounding amount to 1580 kj/h. Calculate the output of the turbine. [14] **M**

15. Steam enters a nozzle at a pressure of 7 bar and 20^0 C (i.e. initially enthalpy 2850kJ/kg) and leaves at a pressure of 1.5 bar. The initial velocity of steam at the entrance is 40m/s and the exit velocity from the nozzle is 700nm/s. The mass flow rate through the nozzle is 1400 kg/h. The heat loss from the nozzle is 11705kJ/h. Determine the final enthalpy of steam. [14] **D**

16. In boiler, water enters with an enthalpy of 168 kj/kg and steam leaves with enthalpy of 2925 kj/kg. Find the heat transferred per kg of steam. The changes in kinetic and potential energies may be neglected. [14] **M**

17. A reciprocating water jacketed ammonia compressor installed in cold storage delivers 3 kg/min of ammonia with a enthalpy of 1670 kj/kg. At the suction line the enthalpy of ammonia is 1465 kj/kg. If the power input of the compressor is 16 kw, find the rate of heat transfer to the water jacket. Changes in kinetic and potential energies may be neglected. [14] **D**

18. A reciprocating air compressor installed in a fertilizer factory takes in air at 1 bar and 20^0 C and delivers at 6 bar. Calculate the work done, heat transfer and change in internal energy per kg of air compressed if the compression process follows a) isothermal, b) reversible adiabatic and c) polytropic $pv^{1.35}$ = constant. The change in potential and kinetic energies may be neglected.

[14] **M**

19. 1 kg of air at 3.5 bar and occupying 0.35 m^3 is heated at constant volume until its temperature has risen to 316^0 C. Find (a) initial temperature of air, (b) the final pressure of air, (c) heat added, (d) gain in internal energy per kg. $C_v = 0.715$ kj/kg k. [14] **M**

20. One kg of air having an initial volume of 0.3 m^3 is heated at constant pressure of 3.2 bar until the volume is doubled. Find (a) heat added, (b) work done, (c) the initial and final temperature of air. [14] **M**

21.a) Define first law of thermodynamics.

b) In a thermodynamic cycle 1-2-3-4-5-6, the following results were tabulated. Fill in the blanks.

	1-2	2-3	3-4	4-5	5-6	6-1
Q kj	6	--	3	5	-4	--
W kj	3	-3	-9	--	8	4
Δ U kj	--	4	--	7	--	--

[4+10] **M**

22. a) Explain in detail the constant pressure gas thermometer.

b) The readings t_A and t_B of two Celsius thermometers A and B agree well point (0^0 C) and steam point (100^0 C). At other points between these two, the temperatures are related by $t_A = p+qt_B+rt_B^2$, where p, q, and r are constants. When the two thermometers are immersed in a well stirred oil bath, while A reads 51, B reads 50. Determine what A reads when B reads 30.

[6+8] **M**

23. a) What are the advantages of gases over liquids as a thermometric substances.

b) During one cycle, the working fluid in an engine engages in two work interactions: 15 kj to the fluid and 44 kj from the fluid, and three heat interactions, two of which are 75 kj of the fluid, and 40 kj from the fluid. Evaluate the magnitude and direction of the third heat transfer.[6+8] **S**

24. a) Make a comprehensive energy analysis of the steam turbine

b) The gas leaving the turbine jet engine flows steadily into the jet pipe with enthalpy 960 kj/kg and velocity 250 m/s. The exit from the pipe is at enthalpy 860 kj/kg and exhaust is in line with intake. Neglecting heat loss from the system. Determine the velocity of gas leaving the pipe.

[6+8] **M**

25. A cylinder contains 0.115 m^3 of gas at 1 bar and 90^0C. The gas is compressed to a volume 0.0288 m^3 and the final pressure being 5.67 bar. Calculate (i) mass of the gas (ii) The value of index of compression (iii) Increase in internal energy and (iv) Heat transfer during the process.

[14] **M**

26. A system consists of 50 kg of copper block initially kept 5 m above the concrete floor and both are at the same temperature. The copper block is allowed to fall. Find Q, W, ΔU, ΔKE, ΔPE and ΔE for the following conditions.

a) at the instant the block if about to hit the floor

b) just after the block has come to rest on the floor.

c) after enough heat has been transferred so that the block and floor are essentially at the same temperature as they were initially. [14] **D**

27. In a piston-cylinder arrangement in which the system is air, calculate the quantity of heat added to the cycle, when the cycle is complete by two processes: compression and expansion as follows:

a) During compression process, piston does 20,0000 j of work on air while 80kj of heat is rejected to the surrounding

b) During expansion process, air does 3,00,000 j of work on the piston. [14] **D**

28. The following data refer to a closed system which undergoes a thermodynamics cycle consisting of four processes.

process	Heat transfer	Work transfer
1-2	Nil	-1000
2-3	40,000	Nil
3-4	-4,000	-26,000
4-1	12,000	-1000

Show that the data is consistent with thr first law of thermodynamics and calculate:

a) Net rate of work output in KW.

b) Efficiency of the cycle

c) Change in internal energy for each process. [14] **M**

29. In a vessel, 10 kg of O_2 is heated in a reversible, non-flow, constant volume process so that the pressure of O_2 is increased two times that of the initial value. The initial temperature is 20^0C. Calculate (a) the final temperature, (b) the change in internal energy, (c) the change in enthalpy and (d) the heat transfer. Take R = 0.259 Kj/kg K and C_v = 0.652 Kj/kg K for oxygen. [14] **M**

30. A system consists of stone having a mass of 10 kg and a bucket containing 200 kg of water. Initially the stone and water are at the same temperature and then stone falls into water at a height of 90 m. Calculate (i) the change in internal energy (ii) the change in kinetic energy (iii) the change in potential energy, (iv) the heat transferred and (v) the work transferred for the following cases:

a) At the instant the stone is about to enter the water

b) Just after the stone comes to rest in the bucket

c) Heat is transferred to the surroundings at such a rate that stone and water remain at a temperature at which they were initially [14] **D**

31. Air enters a compressor at 10^5 Pa and 25^0C having volume of 1.8 m^3/kg and is compressed to 5×10^5 Pa isothermally. Determine

(i) work done (ii) Change in internal energy (iii) Heat transfer. [14] **M**

32. A fluid system, contained in a piston and cylinder machine, passes through a complete cycle of four processes. The sum of all heat transferred during a cycle is -349 kj. The system completes 200 cycles per min.

Complete the following table showing the method for each item, and complete the net work output in KW. [14] **M**

33. a) Explain in detail about constant volume gas thermometer.

b) Define a new temperature scale, say ^{0}M. At ice and steam poi t the temperature are 80^0M and 300^0M respectively. Correlate this with the centigrade scale. [6+8] **S**

34. a) Define and explain zeroth law of thermodynamics.

b) Two thermometers, one Centigrade and other Fahrenhiet immersed in a fluid read the same numerical value. Find their temperature of the fluid expressed in ^{0}K and ^{0}R. [6+8] **S**

35. A certain thermometer using pressure as a thermometric property yields the values of pressure, p as 1.9 and 6.8 at the ice and steam point respectively. The temperature of the ice and steam point are assigned the number 32 and 212 respectively. Calculate the temperature

corresponding to p = 3, if the temperature T is expressed as T = a ln + b where a and b are constants. [14] **M**

36. a) Give the concept of temperature and differentiate between heat, temperature and internal energy.

b) A gas having the equation of state PV = RT + b(T)p is expanded isothermally and reversibly from an initial specific volume V_1 to a final specific volume V_2. Show that the work done per unit mass of gas is

$$RT \ln V_2 - b(T)/V_1 - b(T).$$ [6+8] **M**

37. The readings t_A and t_B of two centigrade thermometers A and B agree at ice point(0^0C) and the steam point (100^0C) but elsewhere are related by the equation $t_A = l + mt_B + nt_B^2$ where l, m and n are constants. When both thermometers are immersed in a well stirred oil bath A registers 51^0C while B registers 50^0C determine the reading on B when A reads 25^0C. [14] **M**

38. A new temperature scale in ^{0}N is to be defined. The boiling and freezing points on this scale are 400^0N and 100^0N respectively.

1. correlate this scale with the centigrade scale and Fahrenheit scale.
2. What will be the reading on new scale corresponding to 60^0C. [14] **M**

39. The temperature t on a thermometric scale is defined in terms of a property p by the relation t = alnp + b where a and b are constants. The temperatures of ice point and steam point are assigned the numbers 32 and 212 respectively. Experiment gives values of p of 1.86 and 6.81 at the ice point and steam point respectively. Estimate or evaluate the temperature corresponding to a reading of p = 2.5 on the thermometer. [14] **D**

40. What do you mean by “perpetual motion machine of first kind – PMM 1?”

b) Air at 1.02 bar, 22^0C, initially occupying a cylinder volume of 0.015 m^3, is compressed reversibly and adiabatically by a piston to a pressure of 6.8 bar. Calculate

(i) The final temperature (ii) The final volume (iii) The work done [4+10] **M**

UNIT – 3

1. a) Define Clausius inequality and prove it.

   b) An engine operating on a Carnot cycle works with in temperature limits of 600 K and 300 K. If the engine receives 2000 Kj of heat, evaluate the work done and thermal efficiency of the engine.

[6+8] **S**

2. In order to check the validity of second law of thermodynamics m_1 kg of water at temperature T_1 is isobarically and adiabatically mixed with m_2 kg of water at temperature T_2 ($T_1>T_2$). Determine the change in entropy of the universe and find an expression for the same for equal mass of water. Also prove that the change is necessarily positive. [14] **M**

3. The expansion of a perfect gas is so controlled that the pressure changes according to the law P = aV +b where a and b are constants and V is the volume. The mass of gas is 1.4 kg and the initial and final pressure are 6 bar and 2 bar respectively and the corresponding volumes of 0.2 and 0.6 m^3. Assume $\gamma = 1.39$ R = 0.28 kJ/kgK find (i) change in entropy /kg during the expansion (ii) Maximum value of internal energy/kg reckoned from 0^0C (iii) the net heat removed or added during the cycle. [14] **D**

4. Show that when a perfect gas changes from a state P_1, V_1, T_1 to another state P_2, V_2, T_2. The increase in entropy per unit mass if given by $S_2\text{-}S_1 = C_v \ln P_{2/}P_1 + C_p \ln V_{2/}V_1$. Find the value of index n so that the gain of entropy during heating of the gas at constant volume between temperatures t_1 and t_2 will be the same as that during an expansion according to the law $PV^n = K$ between the same temperatures. Show also that the heat supplied/unit mass of gas will be the same in each case. [14] **D**

5. 0.2 m^3 of air at 1 bar and 60^0C is compressed to 0.05 m^3 according to the law $PV^{1.3} = K$. Now the heat is added at constant volume until its pressure is 10 bar. Calculate the change in entropy in each process undergone. [14] **M**

6. a) Show that the approximate change of entropy during a polytropic process equals the quantity of heat transferred divided by the mean absolute temperature.

b) If 0.25 kg of air at pressure of 1 bar and temperature 20^0C is compressed to a pressure of 8 bar according to the law $PV^{1.25} = K$. Calculate the following 1) initial and final conditions of the gas 2) work interaction 3) heat interaction 4) change in entropy 5) approximate change in entropy 6) % error if the entropy calculated by the approximate method Assume $C_p = 1.045$ and $C_v = 0.727$ Kj/kg K. [6+8] **D**

7. One kg of air is compressed according to the law $PV^{1.25}$ = Constant from a pressure of 1.03 bar and a temperature of 15^0C to a pressure of 17 bar. Calculate (a) the temperature at the end of

compression, (b) the heat rejected or received by the air during the process and (c) the change in entropy. Sketch the operation on T-S diagram. Compare the results if the compression process is isothermal. [14] **M**

8. a) State and explain second law of thermodynamics.

b) 4 kg of air is compressed in a reversible steady flow polytropic process ($PV^{1.25}$= C) from 1 bar and 30^0C to 10 bar. Calculate the work input, heat transferred and the change in the entropy. [6+8] **S**

9. a) Define entropy and show that it is a property of the system.

b) A gas undergoes a non-flow process according to the law P = 0.15/V+2 bar, where V is volume in m^3. Calculate the change in enthalpy during the process if 20 kj of heat is rejected from the system. The initial volume is 0.8 m^3. [6+8] **M**

10. A certain process occurs in the following manner.

a) Addition of heat at constant volume so that the pressure rises from 6 bar to 15 bar.

b) Polytropic expansion $PV^{1.3}$ = C till the system reaches original temperature of 110^0C

c) Isothermal compression till the system reaches original state.

Find (i) temperature at the end of constant volume process (ii) pressure at the end of polytropic expansion (iii) change in entropy during each of the three stages per kg of air. [14] **D**

11. a) Show the equivalence of Clausius and Kelvin statement of second law.

b) A heat engine receives heat at the rate of 1500 kj/min and gives an output of 8.2 KW. Determine (i) the thermal efficiency (ii) the rate of hear rejection. [7+7] **S**

12. a) What is the difference between the heat engine and the reversed heat engine

b) A domestic food refrigerator maintains a temperature of -12^0C. The ambient air temperature is 35^0C. If heat leaks into the freezer at the continuous rate of 2 kj/s. Determine the least power necessary to pump this heat out continuously. [6+8] **M**

13.a) Enumerate the conditions which must be fulfilled by a reversible process. Give some examples of ideal reversible process.

b) Find the coefficient of performance and heat transfer rate in the condenser of a refrigerator in kj/h which has a refrigeration capacity of 12000 kj/h when power input is 0.75 KW. [6+8] **M**

14 a) Give the following statements of second law of thermodynamics

(i) Clausius statement (ii) Kelvin-Planck statement

b) A domestic food freezer maintains a temperature of -15^0C. The ambient air temperature is 30^0C. If heat leaks into the freezer at the continuous rate of 1.75 kj/s what is the least power necessary to pump this heat out continuously. [6+8] **M**

15. a) Define heat engine, refrigerator and heat pump.

b) A house require 2×10^3 kj/h for heating in winter. Heat pump is used to absorb heat from cold air outside in winter and send heat to the house. Work required to operate the heat pump is 3×10^4 kj/h. Determine

(i) Heat abstracted from outside

(ii) Co-efficient of performance. [6+8] **M**

16. a) What is perpetual motion machine of the second kind?

b) An inventor claims that his engine has the following specifications

Temperature limits ………..750^0C and 25^0C
Power developed ………. 75 KW
Fuel burned per hour………. 3.9 kg
Heating value of the fuel……74500 kj/kg

State whether his claims is valid or not. [4+10] **S**

17. a) Describe the working of a Carnot cycle.

b) A cyclic heat engine operates between a source temperature of 1000^0C and a sink temperature of 40^0C. Find the least rate of heat rejection per KW net output of the engine. [7+7] **S**

18. a) Derive an expression for the efficiency of the reversible heat engine.

b) 300 kj/s of heat is supplies at a constant fixed temperature of 290^0C to a heat engine. The heat rejection takes place at 8.5^0C. The following results were obtained

(i) 215 kj/s are rejected (ii) 150 kj/s are rejected (iii) 75 kj/s are rejected [6+8] **M**

Classify which of the result report a reversible cycle or irreversible or impossible results.

19) a) Define what do you mean by the term entropy.

b) Air at 20^0C and 1.05 bar occupies 0.025 m^3. The air is heated at constant volume until the pressure is 4.5 bar, and then cooled at constant pressure back to original temperature. Calculate

(i) The net heat flow from the air (ii) The net entropy change

Sketch the process on T-S diagram. [4+10] **M**

20) 0.04 m^3 of nitrogen contained in a cylinder behind a piston is initially at 1.05 bar and 15^0C. The gas is compressed isothermally and reversible until the pressure is 4.8 bar. Calculate

(i) The change of entropy (ii) The heat flow (iii) The work done. Sketch the act of P-V and T-S diagram. Assume nitrogen to act as a perfect gas. Molecular weight of nitrogen = 28. [14] **D**

21. a) Define entropy and show that it is a property of the system.

b) In Carnot cycle, heat is supplied at 350^0C and rejected at 27^0C. The working fluid is water which, while receiving heat, evaporates from liquid at 350^0C to steam at 350^0C. The associated entropy change is 1.44 Kj/kg K i) if the cycle operates on a stationary mass of 1 kg of water, find the work done per cycle, and the heat supplied (ii) if the cycle operates in steady flow with a power output of 20 KW, and determine the steam flow rate. [6+8] **D**

22) A reversible het engine operates between two reservoirs at temperature 700^0C and 500^0C. The engine drives a reversible refrigerator which operates between reservoirs at temperature of 50^0C and -25^0. The heat transfer to the engine is 2500kj and the network output of the combined engine refrigerator plant 400 kj. Determine the heat transfer to the refrigerant and the net heat transfer to the reservoir. [14] **M**

23) 90 Kj of heat is supplied to a system at a constant volume. The system rejects 95 Kj of heat at constant pressure and 18 Kj of work is done on it. The system is brought to original state by adiabatic process. Determine (i) adiabatic work (ii) the values of internal energy at all end states if initial value is 105 Kj. [14] **M**

24) a) What is a flow process and derive the steady flow energy equation.

b) The power developed by a turbine in a certain steam plant is 1200 KW. The heat supplied to the steam in the boiler is 3360 Kj/kg the heat rejected by the system to cooling water in the condenser is 2520 Kj/kg and the feed pump work required to pump the condensate back into the boiler is 6 KW. Calculate the steam flow round the cycle in kg/s. [6+8] **M**

25) a) Derive the expression for heat transfer in the polytropic process.

b) 0.44 kg of air at 180^0C expands adiabatically to three times its original volume and during the process, there is a fall in temperature to 15^0C. The work done during the process is 52.5 Kj/kg. Calculate C_p and C_v. [6+8] **S**

26) a) Define available energy and unavailable energy.

b) 1000 Kj of heat is supplied to a reversible cyclic engine at 327^0C. The surroundings are at 27^0C. Find the available energy and unavailable energy. [6+8] **S**

27) a) What do you mean by availability.

b) In a process where mercury is condensing at 327^0C, transfer heat to 10 kgs of saturated water evaporating at 227^0C. The resulting steam is used to run reversible cyclic heat engine which rejects heat at 27^0C What is the amount of energy available what is the amount lost due to its transfer from 327^0C to 227^0C. Take latent heat at 227^0C is 1941 kj/kg. [4+10] **M**

28) a) What is irreversibility

b) Hot gases at 5 kg/s in a furnace at 1027^0C are cooled at constant pressure to 327^0C by transferring the heat to a reversible cyclic heat engine. If the surroundings are maintained at 27^0C find the amount of energy available and unavailable. Take C_p of gases = 1.1 Kj/kg K. [2+12] **M**

29) A system at 500 K receives 7200 Kj/min from a source at 1000 K. The temperature of atmosphere is 300 K. Assuming that the temperatures of system and source remain constant during heat transfer find out (i) the entropy produced during heat transfer (ii) The decrease in available energy after heat transfer. [14] **D**

30) Calculate the decrease in available energy when 20 kg of water at 90^0C mix with 30 kg of water at 30^0C, the pressure being taken as constant and the temperature of the surrounding being 10^0C. Take C_p of water as 4.18 Kj/kg K. [14] **M**

31) a) Define the coefficient of volume expansion and isothermal compressibility.

b) Show that the equation of state of a substance may be written in the form

$$dv/v = -Kdp + \beta dT. \qquad [6+8]\ \mathbf{M}$$

32) Derive the Maxwell relations and explain their importance in thermodynamics. [14] **D**

33) For the following given differential equations

$$du = Tds - pdv \quad \text{and} \quad dh = Tds + vdp$$

Prove that for perfect gas equation

$$\left(\frac{\partial u}{\partial P}\right)_T = 0 \quad \text{and} \quad \left(\frac{\partial h}{\partial P}\right)_T = 0$$

[14] **D**

34) From the fundamentals of Maxwell's relations prove that $C_p - C_v = T\beta^2V/K$. [14] **M**

35) Write the various forms of Tds equations and hence prove Tds = $\frac{C_p}{\beta V}$ dv + $C_v \frac{k}{\beta}$ dp [14] **M**

36) a) State the limitations of first law of thermodynamics.

b) A cyclic heat engine operated between a source temperature of 900^0C and a sink temperature of 50^0C. What is the least rate of heat rejection per KW net output of engine. [6+8] **S**

37) a) State and prove clausius inequality

b) A thermal energy source at 800 K loses 2000 K of heat to a sink at (i) 500 K and (ii) 750 K. Determine which heat transfer process is more irreversible. [7+7] **S**

38) a) Show that the COP of heat pump is greater than the COP of a refrigerator by unity.

b) Prove that the efficiency of a reversible engine operating between two given constant temperatures is the maximum. [7+7] **S**

39) a) Explain the concept of heat pump

b) A heat engine performs many cycles during which it develops 21 kj work and receives 85 kj heat from the source. Evaluate the thermal efficiency and the heat rejected by the engine.

[6+8] **S**

40) a) State the Kelvin-Planck and Clausius statements of the second law of thermodynamics and establish equivalence between them.

b) Determine the power required to run the refrigerator that transfers 2000 Kj/min of heat from a cooled space at 0^0C to the surrounding atmosphere at 27^0C. The refrigerator operates on reversed Carnot cycle. [7+7] **S**

UNIT – 4

1. a) Describe the process of formation and give its graphical representation.
b) Steam enters an engine at a pressure 10 bar absolute and 250^0C. It is exhausted at 0.2 bar. The steam at exhaust is 0.9 dry. Find
(i) Drop in enthalpy (ii) Change in enthalpy. [6+8] **D**

2. a) Explain the difference between internal energy and enthalpy of wet and dry steam.
b) 2 kg of steam initially at a pressure of 12 bar and a temperature of 250^0C expands polytropically to 1.2 bar. Find
(i) Final condition (ii) Work done (iii) Change in entropy, assume the index of expansion as 1.25. [6+8] **D**

3. a) Explain with a neat diagram p-v-t surface
b) Find the enthalpy and entropy of steam when the pressure is 2 MPa and the specific volume is 0.09 m^3/kg [7+7] **M**

4. A vessel having a capacity of 0.05 m^3 contains a mixture of saturated water and saturated steam at a temperature of 245^0C. The mass of liquid present is 10 kg. Find the following
(i) The pressure (ii) The mass (iii) The specific volume (iv) The specific enthalpy (v) The specific entropy (vi) The specific internal energy. [14] **D**

5. a) Explain the following terms relating to the steam formation
(i) Sensible heat of water (ii) Latent heat of steam. (iii) Dryness fraction of steam. (iv) superheated steam
b) Determine entropy of 5 kg of steam at 2 MPa and 300^0C, take specific heat of super heated steam as 2.1 Kj/kg K. [8+6] **M**

6. a) Explain T-S diagram for a pure substance.
b) Find the dryness fraction, specific volume and internal energy of steam at 7 bar and enthalpy 2550 kj/kg. [7+7] **S**

7. a) Why cannot a throttling calorimeter measure the quality if the steam is very wet.
b) Find the enthalpy, entropy and volume of steam at 1.4 MPa, 380^0C using steam tables only.
[7+7] **M**

8. a) Explain the significance of triple point in case of pure substance.
b) Explain in detail the formation of steam with the help of T-H diagram indicating the salient points. [7+7] **M**

9. Find the internal energy and enthalpy of unit mass of steam of a pressure of 7 bar
a) When its quality is 0.8
b) When it is dry and saturated
c) Superheated, the degree of superheat being 65^0C. The specific heat of superheated steam at constant pressure is 2.1 Kj/kg K. [14] **M**

10. a) Write a short note on Mollier chart.
b) Find the internal energy of one kg of steam at 14 bar the following conditions:

a) When steam is 0.85 dry
b) When steam is dry and saturated
c) When the temperature of the steam is 300^0C. Take C_{ps} = 2.25 Kj/kg K [4+10] **M**

11. a) Draw a neat sketch of throttling calorimeter and explain how dryness fraction of steam is determined. Clearly explain its limitations.
b) Find the dryness fraction, specific volume and internal energy of steam at 7 bar and enthalpy 2600 Kj/kg. [7+7] **M**

12. a) Describe with a neat sketch a separating-throttling calorimeter for measuring the dryness fraction of steam.
b) Find the specific volume, enthalpy and internal energy of wet steam at 18 bar, dryness fraction 0.85. [7+7] **M**

13. a) Draw and explain P-T diagram for a pure substance.
b) Determine the amount of heat, which should be supplied to 2 kg of water at 25^0C to convert it into steam at 5 bar and 0.9 dry. [7+7] **S**

14. a) What is a triple point. Explain.
b) What amount of heat would be required to produce 4.4 kg of steam at a pressure of 6 bar and temperature of 250^0C from water at 30^0C. Take specific heat for super heated steam as 2.2 Kj/kg K. [6+8] **S**

15. a) Explain briefly the following processes as applied to steam.
(i) Isentropic process (ii) polytropic process (iii) throttling
b) Using steam tables, determine the mean specific heat for superheated steam:
(i) at 0.75 bar between 100^0C and 150^0C
(ii) at 0.5 bar, between 300^0C and 400^0C [6+8] **M**

16. a) Define dryness fraction and with a neat sketch explain any one method of measuring it .
b) Calculate the amount of heat supplied to a boiler to generate 10 kg/s of steam at a pressure of 10 bar and 0.95 dry if the water is supplied to if at 30^0C and at same pressure. [7+7] **S**

17. A closed vessel of 1.5 m^3 capacity contains steam at 3 bar and 0.8 dryness fraction. Steam at 10 bar and 0.9 dryness fraction is supplied until the pressure inside the vessel reaches 5 bar. Calculate the mass of steam supplied and the final condition of steam in the vessel. [14] **D**

18. a) Define critical point and triple point.
b) In a throttling calorimeter the pressure of the steam measure before and after throttling are 16 bar and 1 bar respectively. Find the dryness fraction of steam before passing through the calorimeter if the temperature after throttling is 150^0C. Assume C_p for superheated steam at 1 bar is 2.1 Kj/kg K. [6+8] **M**

19. Calculate the state of steam i.e. whether it is wet, dry or superheated for the following cases:
   (i) Steam has a pressure of 15 bar and specific volume of m^3/kg.
   (ii) Steam has a pressure of 10 bar and temperature 200^0C.
   (iii) Steam has pressure of 30 bar and if 2700 kj/kg of hat is required to generate steam.
[14] **M**

20. Two kg of steam at a pressure of 20 bar exists in the following conditions
   (i) wet steam with a dryness fraction of 0.9
   (ii) dry and sarurated steam
   (iii) super heated steam with temperature 250^0C.
   Calculate (a) enthalpy (b) volume (c) entropy and (d) internal energy
Assume C_p = 2.302 kj/kg K for superheated steam. [14] **M**

21. a) Draw and explain a P-T diagram for a pure substance.
b) Dry and saturated steam at 12 bar expands in cylinder to 2 bar having 0.8 dryness fraction according to the law $PV^n = c$. Calculate (a) The index of expansion and (b) work done. [7+7] **S**

22. Find the internal energy of 1 kg of steam at 20 bar when
   (i) it is superheated, its temperature being 400^0C
   (ii) it is wet, its dryness being 0.9
   Assume superheated steam to behave as a perfect gas from the commencement of superheating and thus obeys Charles's law. Specific heat for steam = 2.3 kj/kg K. [14] **D**

23. 1000 kg of steam at a pressure of 16 bar and 0.9 dry is generated by a boiler per hour. The steam passes through a super heater via boiler stop valve where its temperature is raised to 380^0C. If the temperature of feed water is 30^0C , determine:
   (i) The total heat supplied to feed water per hour to produce wet steam
   (ii) The total heat absorbed per hour in the super heater.
   Take specific heat for superheated steam as 2.2 kj/kg K. [14] **D**

24. A pressure cooker contains 1.5 kg of saturated steam at 5 bar. Find the quantity of heat which must be rejected so as to reduce the quality to 60% dry. Determine the pressure and temperature of the steam at the new state. [14] **D**

25. a) Steam at 150 bar has an enthalpy of 3309 kj/kg, find the temperature, the specific volume and the internal energy.
b) Steam at 19 bar is throttled to 1 bar and the temperature after throttling is found to be 150^0C. Calculate the initial dryness fraction of the steam. [7+7] **S**

26. Steam at 18 bar and 0.95 dry is throttled to 14 bar and passed to an engine which expands it isentropically to 0.3 bar and exhausts at this pressure. Determine (a) entropy per kg of steam entering the engine (b) the steam consumption of the engine in kg/kwh, (c) the thermal energy per kg of steam leaving the boiler. Use mollier chart. [14] **D**

Unit-I

Thermodynamic s:- - Thermodynamics is a science which deals with the relations among heat work and properties of system which are in equilibrium.

(or)

Thermodynamics deals with the behaviour of gases and weapours under variation temperature and pressure.

(or)

Thermodyamamics basically entails (explain) four laws known as zero th, 1st, 2nd and 3rd law of thermodyanamics.

Zeroth law:- concept of temperature

First law :- concept of internal energy

Second law :- concept of entrophy

Third law :- concept of absolute zero.

The application of thermodyanamics is extremely wide it's principles are used in desiging of energy converting devices such as steam engines, IC engines, steam tervine, gas tervine refrigirators air conditioners heat transfer etc.

Def:- The study of three E's is called thermodyanamics. The three E's are.

Macroscopic	Microscopic
1. classical thermodynamics In this approach a certian quanity of mater considerd without taking in to the even's accuring at molecular level. This approach is concern with over all behaviour it is known as classical thermodynamics.	1. statistical thermodynamics. 2. This approach is that the system of made up of a very large number of discript particles known as molecules. This approach is concerned directly with the structure of matter this is known as statistical thermodynamics
2. The values of the properties of system are their average values these properties like pressure and temperature canwe measure very easily the changes in properties can be test by all of senses the properties like velocity momentum.	2. The properties like velocity momentum impulse energy etc which describes the molecule can not be easily measure by instruments our senses cannot feel them.
3. The analaysis of macroscopic system requires simple mathematical formula	3. The behaviour of the system is found by using statistical methods. As the no.of molecules is very large. so advanced statistical and mathematical methods are need to explain the changes in the system.

4. Inorder to describe the system only few properties are needed.	4. large number of variables are needed to describe to a system so the approachis complicated.

Thermodynamic system the term system is defme
as a prescribied region of a spaced of
finate quantity of mater surraunding by an
envolpe is called boundary

Sourrounding :- the space and matter extern
al through the thermodynamic system and
out side the boundary is called the sourroun
ding.

Universe :- when system and sarrounding put
together is called universe.

Types of system

1) closed system
2) open system
3) isolated system
4) Adiabatic system

closed system :- A system is called a closed system
if the mass exith in the boundary of the
system reamins constant and only energy
(Heat and work) may transfer across it's
boundary

EX:- Gas enclosed in a cyclinder

open system :- A system is called an open
system if the mass as well as the energy
transfer across it's boundary

EX:- air compreshon, terbied

isolated system :- A system is called an
isolated system if neigther mass nor enrgy
transfer across it's boundary

EX:- fluid in thermo flask

Adiabatic system :- An adiabatic system one
in which is thermaly insulated from it's sorraund
ing. It can however exchange work with it's
sourroundings

EX:- Air condition system or refigarator syste

State:- State is the condition of the system at an instant of time described by it's properties such as pressure, temperature etc.

path:- A Thermodyanmic system passing through Series of constitute path.

property:- A property of a system is it's measurable characterstics describing the system. The measurable characterstics are mass, Physical composition temperature, pressure volume etc.

Properties are classified into two catagerous

1) Intensive property
2) Extensive

Intensive:- If the value of the property of the system does not depend upon the mass of the system is called an intensive property

Ex: pressure, temperature, viscosity etc

Extensive:- If the value of the property of the system depends upon the mass of the system it is called an extensive property.

Ex:- volume, PE, KE, G.E etc

Derivation:- Assume an equation of state relating three properities of system such that x, y, z will be function of $f(x,y,z)=0 \rightarrow ①$

Assume that it is possible to solve the above equation for each of the variable that is

$$x = x(y,z) \quad y = y(x,z) \quad z = z(x,y) \text{ — } ②$$

if we suppose that the last equation z is the dependend variable then x and y are independent variables

$$dz = \left(\frac{dz}{dx}\right)_y dx - \left(\frac{dz}{dy}\right)_x dy$$

$m = \left(\frac{dz}{dx}\right)_y \cdot N = \left(\frac{dz}{dy}\right)_x$

$dz = M\,dx + N\,dy$

Solving the above equation with exact differential equation it can be written as. $\frac{\partial m}{\partial y} = \frac{\partial N}{\partial x}$

The function which satisify the above eq is called a point function a property of the system

problems

Disscus whether the following quantites as not can be used as the property

(i) $\int p\,dv + \int v\,dp$

$z = \int p\,dv + \int v\,dp$

$dz = m\,dx + N\,dy$

$\frac{\partial m}{\partial y} = \frac{\partial N}{\partial x}$

$\frac{\partial p}{\partial p} = \frac{\partial v}{\partial v}$

$1 = 1$

(ii) $z = \int p\,dv + 0\,0$

$dz = \int p\,dv + 0\,0$

$\frac{\partial p}{0} = \frac{0}{\partial v}$

$\neq 0$ it is not property

(iii) $z = v\,dP$

$dz = \int v\,dp + 0\,0$

$\frac{\partial v}{0} = \partial\frac{0}{\partial p}$

$1 \neq 0$ It is not property

(iv) $dp = f(T)dt + \frac{RT}{V} dv$

Mdx+Ndy

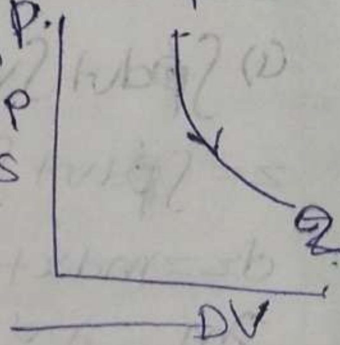
$$\frac{\partial m}{\partial y} = \frac{\partial N}{\partial x}$$

$$\frac{\partial f(t)}{\partial U} = \frac{\partial \left(\frac{RT}{V}\right)}{\partial T}$$

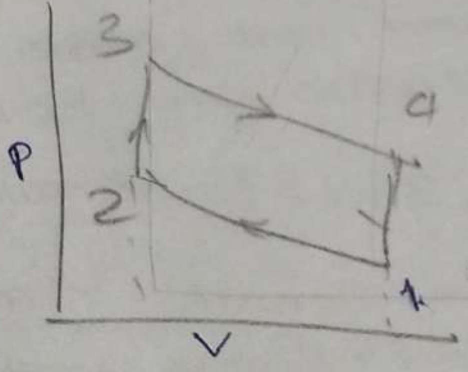
$$0 \neq \frac{R}{V}$$

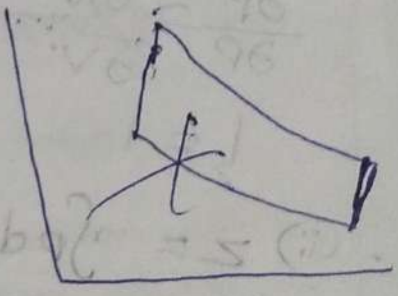
It is not a property

process:- A process is defined as a transianon in which a system changes from one intial state to a final state state one is the intial state of the system due to expenson of the system the final state is 2 the line p 1 to 2 is the process that has taken place



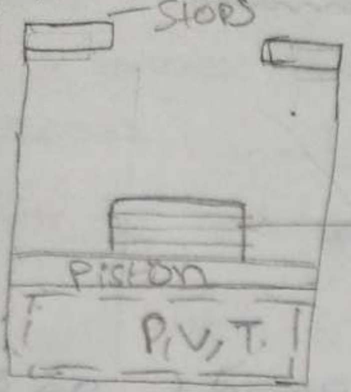
cyclic process:-

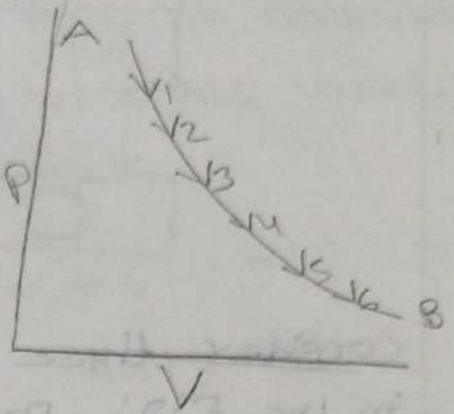




If any system under goes through a series of process from one state and hence with th same intial state by forming complete cycle, so that the property of the system are same as at at the end of the cycle the begaring. the system is said to unde go a cydic process

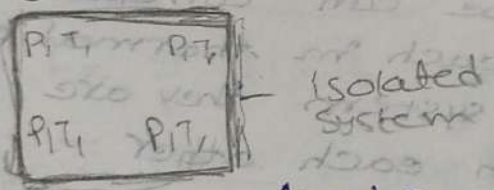
Quasi static process :-





A Quasistatic proces is one in which the syste[m] deviates from one equilibrium state by only infinatesimal amount through out the enter Process quasi mean's allmost infinate slow ness is the charaterstic feature of a quasi static process. A quasistatic process is also called reversiable process

Thermodynamic equilibrium

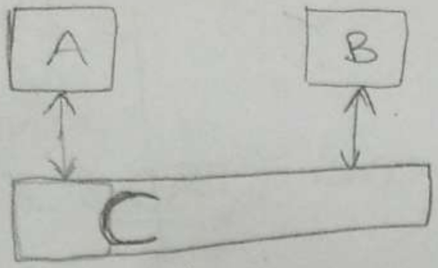


A system is said to be a state of thermodynamic equilibrium the value of the property is say at all points in the system

consider an isolated system, Gas enclosed in contain. The measured pressure and temperature made vary initialy with time but a final stage will come when they no variation of pressure and temperature. After equilibrium is reached it is invarient with time the equilibrium reached can not be departed spontenious

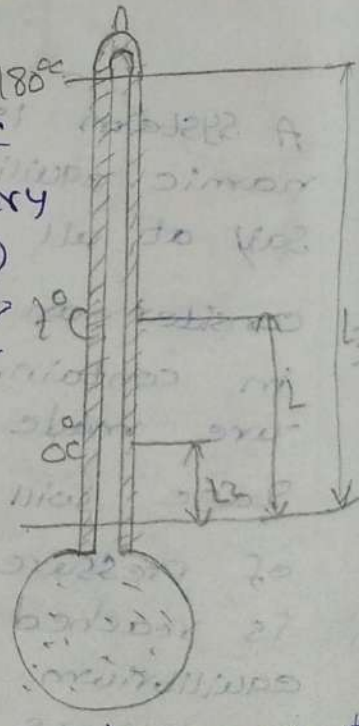
It can be noted that the thermodynamic equilibrium is a complete equilibrium and it include the mechanical, chemical, thermal and electrical equilibrium

Zeroth law of thermodyanmics



$t_1=t_2$

Consider three systems A, B and C as shown in the fig: perfectally insulated from sourroundings if A and C are brought in good contact energy in the form of heat will transfer from the body at a higher temperature to the body at lower temperature. After certian time they will be in thermal eauilibrium. If B and C are brought into good contact after some time this two will be in thermal eauilibrium. from this experiment we can concude that if two systems are each in thermal eauilibrium with a third system they are also in thermal eauilibrium with each other



Let us consider a thermametric property L (say Length of mercury colum of mercury thermometer) such that the temperature 't' is a linear function of this property

$$t = aL + b$$

where a and b are arbitary constants in order to determine this constant a and b are numirical values first as on numerical values room temperatur contion say both are fixed compenents

Let small I represent Ice point and S repres steam point then in centegrate scale $L_s - L_i = 100$ put in this values for t we get

at ice point $0 = aL_i + b \rightarrow ①$

at steam point $100 = aL_s + b \rightarrow ②$

$$\boxed{b = aL_i}$$

$$100 = aL_s - aL_i$$

$$= a(L_s - L_i)$$

$$\boxed{a = \frac{100}{L_s - L_i}}$$

$$\boxed{b = -\frac{100L_i}{L_s - L_i}}$$

$$t^\circ_c = aL + b$$

$$= \frac{100L}{L_s - L_i} - \frac{100L_i}{L_s - L_i}$$

$$t^\circ_c = \frac{100(L - L_i)}{L_s - L_i} \text{ in } {}^\circ CG \rightarrow ③$$

Similary in ferenHeat scale then are

$$\boxed{t^\circ_F = \frac{180 L - L_i}{L_s - L_i} + 32} \; {}^\circ FH \rightarrow ④$$

From eaquations ③ and ④ we can get the relation b/w CG and FH scale

from eq ③

$$\frac{L - L_i}{L_s - L_i} = \frac{t^\circ c}{100}$$

$$t^0_F = 180 \times \frac{t_C^0}{100} + 32$$

$$t^0_F = \frac{9}{5} t_C + 32$$

$$t^0_C = \frac{5}{9} \times (t^0_F - 32)$$

A thermometer is calibarated in such a maner that in ice it reads 32° and 212 when in boiling water what will it read when the measured temperature is 293 K

$$293K = 20 + 273$$

$$= 20^\circ C$$

$$t^0_C = \frac{5}{9}(t^0_F - 32)$$

$$20 = \frac{5}{9}(t^0_F - 32)$$

$$t^0_F = \frac{9}{5}(20 + 32)$$

$$\frac{9}{5}(52)$$

$$t^0_F = 68^0 F //$$

Rankine scale $= t^0_F + 460$

$$= 68 + 460$$

$$\boxed{= 528^0_R}$$

Define a new temperature scale say degre M at steam and Ice points the temperatures are 80° M and 300°M respectively corelate this with centegrade scale

$80 = aL_i + b$ --- ①

$300 = aL_S + b$ --- ②

~~$a = L_S - L_i$~~

$a = \frac{220}{L_S - L_i}$ $b = 80 - \frac{220L_i}{L_s - L_i}$

$t^\circ M = \frac{220L_i}{L_S - L_i} + 80 - \frac{220L_i}{L_s - L_i}$

$t^\circ M = \frac{220}{L_S - L_i}(L - L_i) + 80$

$t^\circ C = 100 \frac{L - L_i}{L_S - L_i}$

$\frac{L - L_i}{L_S - L_i} = \frac{t^\circ C}{100}$

$t^\circ M = 200 \times \frac{t^\circ c}{100} + 80$

$t^\circ M = 22t^\circ c + 80$

from eq ①

$b = -aL_i + 80$ → ③

From ③ in eq ②

$300 = aL_S + b$

$= aL_S - aL_i - 80$

$a(L_S - L_i) + 80$

$300 - 80 \cdot a(L_S - L_i)$

$a = \frac{220}{L_S + L_i}$

$b = \frac{80 - 220L_i}{L_S - L_i}$

What will be the temperature of fluid expressed in ~~degree~~ °R and °K when two thermameters one ferhart heat and another centregrade are imprsed in a same fluid the readings of ferhon heat is just thrise that of C° scale

$t^\circ F = 3t^\circ C$

$t^\circ C = \frac{5}{9}(t^\circ F - 32)$

$= \frac{5}{9}(3^\circ c - 32)$

$9t^\circ c = 5(3t^\circ c - 32)$

$9t^\circ c = 15t^\circ c - 160$

$15t^\circ c - 9t^\circ c = 160$

$6t^\circ c = 160$

$t^oC = \frac{160}{6}$

$t^oC = 26.6$

$t^oK = 26.6$

$t^oK = 26.6 + 273$

$t^o_k = 299.6^oK$

$t^oR = t^oF + 460$

$t^oF = \cdot 3(266)$

$t^oF = 79.8$

$t^oR = 79.8 + 460$

$t^o \cdot\cdot\ \overset{3}{[illegible]}\ ^oR$

1258

A certian thermometer using calculated ice and stream point as fixed point at temperature of 0° and 100° respectively the function of therometric substance is taken as:

$t = a\log_e x + b$ insted of usual linear function $t = ax + b$ show that the new scale is given by $t = \frac{100 \log_e x/x_i}{\log_e x/x_i}$

$0 = a\log_e x_i + b$ (ice point)

$100 = a\log_e x_s + b$ (steam point)

$100 = a\log_e x_s - a\log_e x_i$

$= a\log x_s/x_i$

$a = \frac{100}{\log_e x_s/x_i}$

$b = -a \log_e x_i$

$b = \dfrac{-100 \log_e x_i}{\log_e x_3/x_i}$

$t = \dfrac{100}{\log x_3/x_i} * \log_e x - \dfrac{100 \log_e x_i}{\log x_3/x_i}$

$= 100 \left\{ \dfrac{\log_e x/x_i}{\log_e x_3/x_i} \right\}$

The readings t_A and t_B of two centergade thermometers A and B agree at ice point 0°C and steam point at 100°C But it sacare $t_A = L + mt_B + nt^2_B$ where L and m and are constants when both therometers merst in well A registers 51°C and B registers 50°C Determine the reading on B when A is 25°C

$t_A = l + mt_B + nt^2_B$

at ice point

$0 = l + 0 + 0$

$l = 0$

Steam point

$100 = l + m(100) + n(100)^2$

$100 = m(100) + n(100)^2$ — ②

$t_A = 51°C \quad t_B = 50°C$

$51 = 0 + m(50) + n(50)^2$ — ③

Solving ② and ③

$m = \frac{104}{100}$ $n = -\frac{1}{2500}$

new scale:-

$t_A = 0 + \frac{104}{100} t_B - \frac{1}{2500} t_B^2$

$t_A = 25°C$

$0 \; t_B = 0. + \frac{104}{100} \cdot t_B - \frac{1}{2500} t_B^2$

$t_B = 24.27°C$

The temperature t as the thermometeric scale is defined in terms of property p by the relation $t = a \log_e p + b$ where A and B are constant. the temperature of ice point and steam point asined the numbers 32 and 212 experiment gives values of p as 1.86 and 6.81 at the ice point and steam point respectively. Evaluate the temperature corresponding to the reading of p = 2.50 on the thermometer

$t = a \log_e p + b$

$32 = a \log_e 1.86 + b$

$212 = a \log_e 6.81 + b$

$a = 1387$

$b = -54.07$

$t = 1387 \log p - 54.07$

$p = 25$

$t = 138.7 \log_e 2.5 - 54.07$

$t = 72.93$ (or) ≈ 73° FA]

chapter - 2

Work :- work is said to be done when a force move through a distance work is a trangiate quantity which only appears of the boundary while a change of state is taking place with in a system. work is something which appears at the boundary when a system changes it's state due to the moment of a part of the boundary under the action of force work done by a system $= +W$ workdone by a system $= -W$ It is denoted by 'W'

Heat :-

Heat is denoted by a symbol Q it may be defined as something which appears at the boundary when a system changes it's state due to a differents in temperature b/w the system and it's sourroundings heat like a work is a trange ante quantity which only appears boundary while change the place with in sentence.

Im Neisther δW or δQ are exact differen are therfore it is a path function

Heat received by the system $= +Q$

Heat rejected by the system $= -Q$

Comparison of work and Heat

Similarities

* Both are path function intact differential

* Both are boundary phenomena that is both are recognized at the boundaries of the system as they cross them

* Both are associated with a process not with a state

* systems pocess energy but not work on heat ~~dis~~

Dis similarities

* In heat transfer temperature difference is reaquired

* In a stable system there can't be work transfer however there is no restriction for transfer of heat.

* The sole effect external to the system could be reduced to raise of a weight but in case of heat transfer other effects of also observe

point function:- when two properties locate a point on the graph then those two properties is called as point function

Ex:- Temperature, volume, pressure etc.

path function:- There are certian quantites which can't be located on a graph by a point but are given by the area on that graph. The area parparing to the particular process to the function of path are process such quantites are called as path function

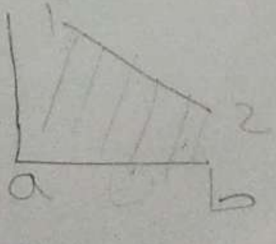
Ex:- Heat, work etc

W_{1-2}

Q_{1-2}

$\int^{2} \delta Q = Q_2 - Q_1$

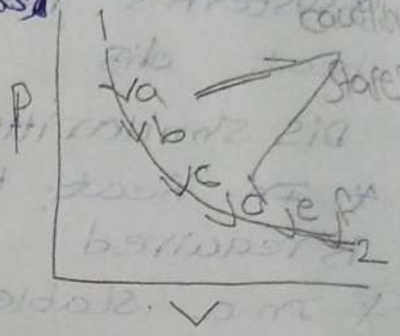
$\delta W = W_2 - W_1$



Control volume :- A fixed region in a phase called a control volume through which mass momentum and energy my flow the surface of the control volume of is called the control surface

Reversible and irreversible process:-

A Reversible process (also called as quasi static process) is one which can be stoped at any state and reverst so that the system and surroundings are exactly restored to their initial state



Ex:-1) Firction less relative motion

2) Expension and compherssion of spring

Irreversible process:-

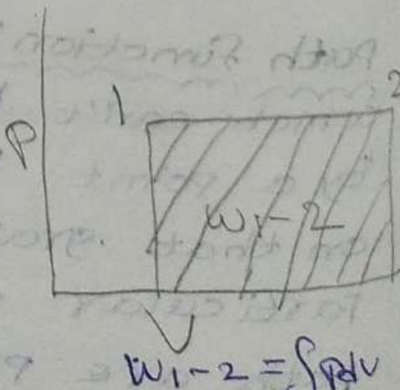
An Irreversible process is one in which heat is transfer through a finite temperature

Ex:- combusion, Expension

work done during reversible process $w_{1-2} = \int pdv$

P dv-work in various quasi static proces

(i) constant pressure process (isobaric process)



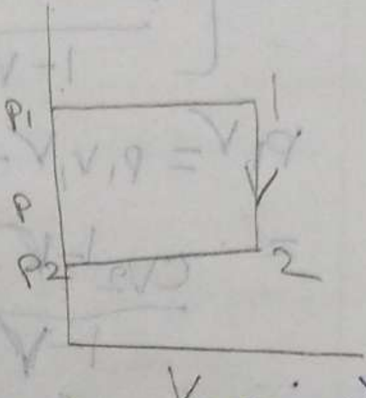
$w_{1-2} = \int pdv$

$w_{1-2} = p(v_2 - v_1$

(ii) constant volume process (isochoric process)

$$w_{1-2} = \int p\,dv$$

$$w_{1-2} = 0$$



constant temperature process (isothermal process)

$$w_{1-2} = \int p\,dv$$

$$pv = c$$

$$p = \frac{c}{v}$$

$$w_{1-2} = \int \frac{c}{v}\,dv$$

$$= c \int_1^2 \frac{dv}{v}$$

$$= c\ln v\Big]_1^2$$

$$= c\ln \frac{v_2}{v_1}$$

$$w_{1-2} = pv_1 \ln \frac{v_2}{v_1}$$

reversible adiabatic process

$$w_{1-2} = \int p\,dv$$

$$pv^{\gamma} = c \quad (\gamma = 1.4) \text{ for air}$$

$$p = \frac{c}{v^{\gamma}} = cv^{-\gamma}$$

$$w_{1-2} = \int cv^{-\gamma}\,dv$$

$$= c\left[\frac{v^{-\gamma+1}}{-\gamma+1}\right]_1^2$$

$$= c\left[\frac{v_2^{-\gamma+1} - v_1^{-\gamma+1}}{-\gamma+1}\right]$$

$$= c\left[\frac{V_2^{1-\gamma} - V_1^{1-\gamma}}{1-\gamma}\right]$$

$$P_1V^\gamma = P_1V_1^\gamma = P_2V_2^\gamma = C$$

$$= \frac{CV_2^{1-\gamma} - CV_1^{1-\gamma}}{1-\gamma}$$

$$= \frac{P_2V_2^\gamma V_2^\gamma - P_1V_1^\gamma V_1^{1-\gamma}}{1-\gamma}$$

e

$$P_2\cancel{V_2^\gamma} \quad \frac{V_2}{\cancel{V_2^\gamma}}$$

$$= \frac{P_2V_2 - P_1V_1}{1-\gamma}$$

$$W_{1-2} = \frac{P_1V_1 - P_2V_2}{1-\gamma}$$

Polytropic process:-

$PV^n = C$

$(n = 1.1 - 1.3$ for air$)$

$w_{1-2} = \int P\,dV$

$PV^n = C$ $(n = 1.1 - 1.3$ for air$)$

$P = \frac{C}{V^n} = CV^{-n}$

$w_{1-2} = \int CV^{-n}\,dV$

$$= C\left[\frac{V^{-n+1}}{-n+1}\right]_1^2$$

$$= C\left[\frac{V_2^{-n+1} - V_1^{-n+1}}{-n+1}\right]$$

$$= c\left[\frac{v_2^{1-n} - v_1^{1-n}}{1-n}\right]$$

$$p_1^n = p_1 v_1^n = p_2 v_2^n = c$$

$$= \frac{c v_2^{1-n} - c v_1^{1-n}}{1-n}$$

$$= \frac{p_2 v_2^n v_2^n - p_1 v_1^n v_1^{1-n}}{1-n}$$

$$\cancel{p_2 v_2^n} \quad \frac{v_2}{\cancel{v_2^n}}$$

$$= \frac{p_2 v_2 - p_1 v_1}{1-n}$$

$$w_{1-2} = \frac{p_1 v_1 - p_2 v_2}{n-1}$$

$$w_{1-2} = \frac{p_1 v_1 - p_2 v_2}{n-1}$$

What is the work done ~~what do you~~ volume change from 4 m^3 metere cubed for 8 m^3 metery cubed through a non flow Quasis static process in which the pressure p is given by $p = (4v - 5)$ bar

$$p = (4v-5)\text{ bar}$$

$$w_{1-2} = \int_1^2 p\,dv$$

$$= \int_1^2 (4v-5) \times 10^5 \cdot dv$$

$$= \left[4\frac{v^2}{2} - 5v\right]_4^8 \times 10^5$$

$$= 4\left[\frac{(8^2-4^2)}{2} - 5(8-4)\right] \times 10^5$$

$$= 4\left[\frac{(64-16)}{2} - 5(4)\right]$$

$$= 4\left[\left(\frac{48}{2}\right) - 20\right]$$

$$= 4\left[(24) - 20\right]$$

$w_{1-2} = 6 \times 10^5$ Joule

In a piston system arrangement the non flow process is given by $v = \frac{200}{p}$ m³ where 'P' is 'in ba find work done where the pressure increa from one bar to 10 bar

$v = \frac{200}{p}$. $p = \frac{200}{v}$

$V_1 = \frac{200}{1} = 200 m^3$

$V_2 = \frac{200}{10} = 20 m^3$

$w_{1-2} = \int_1^2 p dv$

$= \int_{200}^{20} \frac{200}{v} dv$

$= 200 \times \int_{200}^{20} \frac{dv}{v}$

ln V

$= 200 \times [\ln v]_{200}^{20} \times 10^5$

$= 200 \times \ln(20-200) \times 10^5$

$= 200 [\ln 20 - \ln 200] \times 10^5$

= ~~200 ([illegible]87961) × 10^5~~ $= 200 (-2.30258) \times 10^5$

= ~~200 (268196. 1052~~ $= -460.5 \times 10^5$

$= -4.605 \times 10^7$ J

A non flow reversible process across for which $p = 3v^2 + \frac{1}{v}$ where p in the bar and v is m³ what will be the work done when change from 0.5 m³ to 1.5 m³

$p = 3v^2 + \frac{1}{v}$

~~$\frac{3 \cdot v^3}{3}$~~

$w_{1-2} = \int p\,dv$

$= \int_{0.5}^{1.5} (3v^2 + \frac{1}{v})\,dv$

$= \int 3\frac{v^3}{3} + \log v$

$= \left[3 \cdot \frac{v^3}{3} + \log v\right]_{0.5}^{1.5} \times 10^5$

$= \left[3 \cdot \frac{(1.5)^3}{3} + \log(1.5)\right] - \left[3 \cdot \frac{(0.5)^3}{3} + \log(0.5)\right]$

$= [3.36 + 0.405] - [0.125 + (-0.693)]$

$= [3.765] - [-0.568] \times 10^5$

$= [3.765 + 0.568] \times 10^5$

$= 4.333 = 4.333 \times 10^5$ Joules

* The gas having eacation of the state $pv = RT + b(T)p$ is expanded isothermal 'm' and reversibly from an initial specific volume 'v_1' to a final specific volume v_2 show that the work done per unit mass of gas is

$RT \ln \frac{v_2 - b(T)}{v_1 - b(T)}$

Sol/

$pv = RT + b(T)p$

$pv - b(T)p = RT$

$p[v - b(T)] = RT$

$p = \frac{RT}{v - b(T)}$

$$w_{1-2} = \int_{v_1}^{v_2} p\,dv$$

$$= \int_{v_1}^{v_2} \frac{RT}{v-b(T)}\,dv$$

$$= RT \int_{v_1}^{v_2} \frac{1}{v-b(T)}\,dv$$

$$= RT\left(\ln v - b(T)\right]_{v_1}^{v_2}$$

$$= RT\left(\ln v_2 - b(T)) - \ln v_1 - b(T)\right]$$

$$w_{1-2} = RT \ln \frac{v_2 - b(T)}{v_1 - b(T)}$$

Hence proved

* A piston cylinder arrangment contiaing a fluid at a 10 bar, the inital volume beaing 0.05 m³ find the workdone by the fluid when it's expensons reversbily for the following cases

(1) At constant pressure to a final volume of 0.2 m³

2. A/c to linear law to a final value of 0.2 m³ and final pressure of 2 bar

3. A/c to law pv = constant to a final volume of 0.1 m³

4. A/c to law pv^3 = constant to a final volume of 0.06 m³

5. A/c to law $p = \frac{A}{v^3} - \frac{B}{v}$ to a final volume of 0.01 m³ and a final pressure of 1 bar where A and B are constants

1) Given that

Intial volume $= 0.05\ m^3$

final volume $= 0.2$

$w_1 - w_2$ ~~$\int pdV$~~

$= P(0.2m^3 - 0.05m^3)$

$= 10(0.15)$

$10 = A(0.05) + B$

$2 = A(0.2) + B$

$A + B = \frac{10}{0.05}$

$A + B = \frac{20}{A}$

$2 = A(0.2) + \frac{20}{A}$

$2 =$

2. $y = mx + c$

$p = AV + B$

$P_1 = AV_1 + B \Rightarrow ①$

$P_2 = AV_2 + B \Rightarrow ②$

$10 = A\,0.5 + B =$

$2 = 0.2 + B =$

~~$10 = 0.05 + B$~~

~~$2 = 0.2 + B$~~

~~$8 = 0.15$~~

$$\begin{aligned} 10 &= A(0.05) + \cancel{B} \\ -\,2 &= -A(0.2) + \cancel{B} \\ \hline -8 &= 0.15A \end{aligned}$$

$A = \frac{-8}{0.15}$

$A = -53.3$

$10 = -2.665 + B$

$B = 12.260$

$A = -53.33$

$B = 12.66$

$P = -53.33 + 12.66$

$$w_{1-2} = \int_{V_1}^{V_2} p\,dV$$

$$= \int_{V_1}^{V_2} (-53.33 + 12.60)\,dV$$

$$= \left[-53.33\,\frac{V^2}{2}\right]_{0.05}^{0.2} + \left(12.66V\right]_{0.05}^{0.2}$$

~~$(12.66\,(0.2) - 12.66\,(0.05))$~~

$= \cancel{[-53.33} = \left[-53.33\,\frac{(0.05)^2}{2}\right] + \left[12.66\,(0.2) - 12.66(0.\right.$

$= -\cancel{1.06}66 = \left[-53.33\,\frac{(0.05)^2}{2} + 53.33\,\left(\frac{0.2}{2}\right)^2\right]$

$+ \left[12.66\,(0.2) - 12.66\,(0.05)\right]$

$= \left[-53.33\,\frac{(0.2)^2}{2} - (53.33\,\frac{(0.05)^2}{2}\right] + \left[12.66(0.2) + 12.66(0.05)\right]$

$= -1.0666 - (-53.33\,(1.25 \times 10^{-3})$

$-1.066 - 0.666$

$-1.732 + [2.532 + 0.633]$

$-1.732 + 4.897$

iii) $= 1.433 \times 10^5$

$pv = c$

$= \int_{0.05}^{0.1} \frac{c}{v}\,dv$

$= c\,[\ln v]_{0.05}^{0.1}$

$= c\,[\ln 0.1 - \ln 0.05]$

$= p_1 v_1\,[\ln 0.1 - \ln 0.05]$

$= 10 \times 10^5 \times 0.05\,[\ln 0.1 - \ln 0.05]$

$= 10 \times 105 \times 0.05\,[\cancel{0.05}]$

$50000\,[\ln 0.1 - \ln 0.05)$

$= \cancel{34.657} \; 50000\,(0.69314718 06)$

$= 34657.$

34.657

$pv^3 = c$

$w_{1-2} = \int p\,dv$

$= \int_{v_1}^{v_2} \frac{c}{v^3}\,dV$

$= c\int_{0.05}^{0.06} \frac{1}{v^3}\,dV$

$= c\left[\frac{-3+1}{-3+1}\right]_{0.05}^{0.06}$

$= P_1V_1^3\left[\frac{V^{-2}}{-2}\right]_{0.05}^{0.06}$

$= \frac{-10\times10^5\times(0.05)^3}{2}\left[\frac{1}{V^2}\right]_{0.05}^{0.06}$

$= \frac{-10\times10^5\times(0.05)^3}{2}\left[\frac{1}{(0.06)^2} - \frac{1}{(0.05)^2}\right]$

$\cancel{\left[\frac{1}{2500} - \frac{1}{400}\right]}$

$\cancel{\left[\frac{1}{10000}\right]}$

$-62.5\,[277.77 - 400]$

$[2$

$= 7.639\times10^{-3}\,kg$ ✓

$= 0.01 m^3$

$p_2 = 1$ bar

$\therefore p = \frac{A}{V^3} - \frac{B}{V}$

$10 = \frac{A}{(0.05)^3} - \frac{B}{(0.01)}$ ①

$1 = \frac{A}{(0.01)^3} - \frac{B}{0.01}$ — ②

1) A fluid at pressure of 3 bar with specific volume 0.18 m3 per kg contained in a cylinder behind a piston expends reversbily to a pressure of 0.6 bar A/C to law $\boxed{P = \frac{C}{V^2}}$ where c is constant calculated the workdone by the fluid on the friction

$$P_1 v_1^2 = P_2 v_2^2$$

$$v_2^2 = \frac{P_1 V_1^2}{P_2}$$

$$= \frac{3 \times (0.18)^2}{0.6}$$

$$= \frac{3 \times 0.0324}{0.6}$$

$$= \frac{0.0972}{0.6}$$

$$V_2^2 = 0.162$$

$$V_2 = \sqrt{0.162}$$

$$V_2 = 0.402$$

$$= c \int_{0.18}^{0.40} \frac{1}{V^2} dv$$

$$= c \int_{0.18}^{0.40} V^{-2} dV$$

$$= c \int_{0.18}^{0.40} \left[\frac{V^{-2+1}}{-2+1} \right]^{0.40}_{0.18}$$

$$= -c \left[\frac{1}{V} \right]^{0.40}_{0.18}$$

$$= -P_1 V_1^2 \left[\frac{1}{0.40} - \frac{1}{0.18} \right]$$

$$= -\left[3 \times (0.18)^2\right] \left[2.5 - 5.55\right]$$

$$= -(0.0972) \times 105 \left[[illegible] -3.05 \right]$$

$$= -(0.0972) \times 105 \left[-3.05 \right]$$

$$= 0.0972 \times 3.05 \times 10^5$$

$$= 0.29646 \times 10^5$$

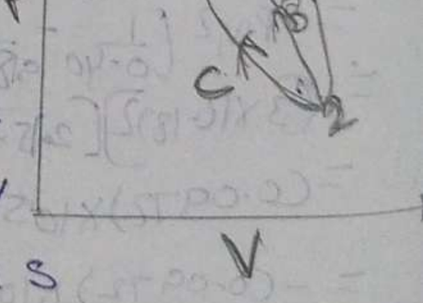
$$= 29.646 \text{ kj}$$

First law of Thermodynamics

This law isthe conservation of energy i.e energy can eisther be created or destroyed but only converted from one from to anothe Thermodyanamicaly the first law may be stated as the algebraic sum of the cw delivered through the sowrrounding is propotion to the algebric sumof is taken by the surroundings

$$\oint \delta q - \oint \delta w$$

No machime is capabile producing the energy without corresponding expendature of the energy are it's imposible to constr a porvachuel motion machine - I (PMM-I) A machime are device which contniuasly produced work without any other in ction with the envoirnment is called PMM-I



one very important conceptence of first law of thermodyamamics is that the energy of a system is a property in order to prove this consider a closed system which conders a change of it's state 1 to 2 as show in the figure. The system may produced from 1-2 along the path A and then back to varignal state 1 along the path B and C. If. the system operate 1-A-2-B-1 then $\oint \delta Q = \oint \delta w$

$\oint \delta q - \oint \delta w = 0$ $\oint (\delta q - \delta w) = 0$

$\int_1^2 (\delta q - \delta w)$ path A + $\int_2^1 (\delta q - \delta w)$ path B = 0

1-A-2-C-1

$\int_1^2 (\delta q - \delta w)$ path c + $\int_2^1 (\delta q - \delta w)$ path c = 0

Comparing the above two equations

$\int_2^1 (\delta q - \delta w)$ path B = $\int_2^1 (\delta q - \delta w)$ path c $\rightarrow$ ①

equation ① suggest that when a system operators b/w state 1 and state 2 the quantity $\int_2^1 (\delta Q - \delta w)$ is constant A respective path B or path C does the value of $\int_1^2 \delta q - \delta w$ is solely fixed by the end states and is independent of the path therfore $(\delta q - \delta w)$ it is exact differential equation and it's integral is a property this called the total energy E of the system

$$\int_1^2 \delta Q - \delta w = \int_1^2 dE$$

$$\delta q - \delta w = dE \rightarrow ②$$

Equation ② is the differential from of first law of thermodyanamic applied to a closed system (non flow process)

For an isolated system $\delta Q = 0, \delta W = 0$

[illegible] $= dE$

Therfore the differential form of first law of thermodyanamics is $\boxed{Q_{1-2} - W_{2-1} = U_2 - U_1}$

or $\boxed{\delta Q - \delta W = du}$

Application of first law to a closed system (non - flow process)

Constant volume (or) isochoric process:-

$$Q_{1-2} = du + \cancel{W_{1-2}} \rightarrow 0$$

$$Q_{1-2} = \overset{\rightarrow \text{Internal engergy}}{U_2 - U_1}$$

Heat $Q_{1-2} = mVc_v (T_2 - T_1)$

Constant pressure (or) isobaric process:-

$$dq = dw + du$$

$$= dPV + du$$

$$= d(u + PV)$$

$$dq = dH = mc_p (T_2 - T_1)$$

H = enthalpy

dH = change in enthalpy

constant tempratuce (or) isothermal process

$$\delta Q = \overset{0}{\cancel{du}} + \delta W$$

$$= \int p\,dv$$

$$= pv = c$$

$$p = \frac{c}{v}$$

$$= \int \frac{c}{v}\,dv$$

$$\delta Q = p_1 v_1 \ln \frac{v_2}{v_1}$$

Reversible adiabatic process

$\delta Q = 0$

Polytropic process :-

$$Q_{1-2} = U_2 - U_1 + W_{1-2}$$

$$= m c_v (T_2 - T_1) + mR \frac{(T_2 - T_1)}{1-n}$$

$$= m (T_2 - T_1) \left[c_v + \frac{R}{1-n} \right]$$

$\boxed{R = c_p - c_v}$ $$= m (T_2 - T_1) \left[c_v + \frac{c_p - c_v}{1-n} \right]$$

$$= m (T_2 - T_1) \left[\frac{\cancel{c_v} - n c_v + c_p - \cancel{c_v}}{1-n} \right]$$

$$= m (T_2 - T_1) \left[\frac{c_p - n c_v}{1-n} \right]$$

$$c_n = \frac{c_p - n c_v}{1-n}$$

$$Q_{1-2} = m (T_2 - T_1) c_n$$

$$n = \frac{c_p - n c_v}{1-n}$$

$$\frac{c_v \left(\frac{c_p}{c_v} - n \right)}{1-n}$$

$$= \frac{c_v (\gamma - n)}{1-n}$$

$$c_n = \frac{c_v (\gamma - n)}{1-n}$$

$$c_p - c_v = R$$

$$c_v \left(\frac{c_p}{c_v} - 1 \right) = R$$

$$c_v (\gamma - 1) = R$$

$$\therefore c_v = \frac{R}{\gamma - 1}$$

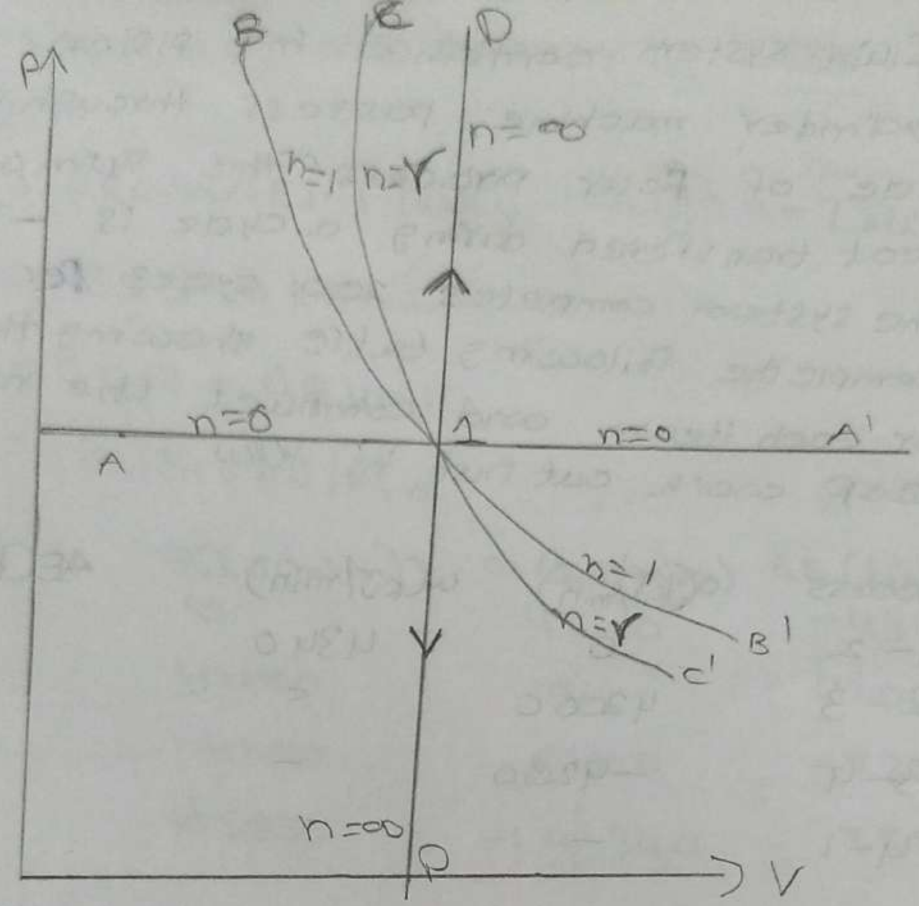
$$Q_{1-2} = m \frac{c_v (\gamma - n)}{1-n} (T_2 - T_1)$$

$$= m \times \frac{R}{\gamma - 1} \times \frac{\gamma - n}{1-n} (T_2 - T_1)$$

$$Q_{1-2} = \frac{\gamma - n}{\gamma - 1} \times \frac{mR (T_2 - T_1)}{1 \cancel{n} - n}$$

$Q_{1-2} = \frac{\gamma-n}{\gamma-1} \times$ w.D during polytropic process

Process	Index (n)	Heat added	$\int_1^2 P\,dv$	P, V, T relations	Specific heat, C
Constant pressure	$n=0$	$C_p(T_2-T_1)$	$P(V_2-V_1)$	$\frac{T_2}{T_1} = \frac{V_2}{V_1}$	C_p
Constant volume	$n=\infty$	$C_v(T_2-T_1)$	$\boxed{0}$	$\frac{T_1}{T_2} = \frac{P_1}{P_2}$	C_v
Constant temperature	$n=1$	$P_1V_1\log_e\frac{V_2}{V_1}$	$P_1V_1\log_e\frac{V_2}{V_1}$	$P_1V_1 = P_2V_2$	∞
Reversible adiabatic	$n=\gamma$	0	$\frac{P_1V_1-P_2V_2}{\gamma-1}$	$P_1V_1^\gamma = P_2V_2^\gamma$ $\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{\gamma-1}$ $= \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}}$	0
Polytropic	$n=n$	$mC_n(T_2-T_1)$ $= C_v\left(\frac{\gamma-n}{1-n}\right)$ $\times (T_2-T_1)$ $= \frac{\gamma-n}{\gamma-1} \times$ work done (non-flow)	$\frac{P_1V_1-P_2V_2}{n-1}$	$P_1V_1^n = P_2V_2^n$ $\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{n-1}$ $= \left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}}$	$C_n = C_v\left(\frac{\gamma-n}{1-n}\right)$



Explanation of graph

In a PV diagram drawn

State 1 to state A is constant pressure cooling

State 1 to state B is the isothermal compression

State 1 to state C is the Reversable adiabatic process (n=γ)

State 1 to state D is the

Similarly state 1 to A' is constant pressure heat (n=0)

State 1 to state B' is the isothermal expension (n=1)

State 1 to state C' is the Reversable adiabatic expansion (n=γ)

State 1 to state D' is the constant volume cooling process

Afluid system cortianed ina piston and cyclinder machine passess through a complet cycle of four porocess the sum of all heat transfered during a cycle is -340 kJ the system completes 200 cycles per minute comple the following table showing the method for each iteam and compuct the net rate ~~of~~ work out put in kW

process	Q(kJ/min)	W(kJ/min)	ΔE(kJ/min)
1-2	0	4340	—
2-3	42000	0	—
3-4	-4200	—	-73200
4-1	—	—	—

sum of all heat transfored cycle $= -340$

number of cycle completed 200 per minute

$\delta Q = \Delta E + \delta W$

$Q = \Delta E + W$

$0 = \Delta E + 4340$

$\Delta E = -4340$ kJ/min

$\delta Q = \Delta E + \delta W$

$Q = \Delta E + W$

$= \Delta E + 4340$

$\Delta E = -4340$ kW

proof 2-3 ; $Q = \Delta E + W$

$42000 = \Delta E + 0$

$\Delta E = 42000$ kJ/min

$\frac{73}{42}$

proof 3-4 $Q = \Delta E + W$

$-4200 = -73200 + W$

$W = 69000$ kJ/min

$106660 = 68000$

prooff 4-1 $Q_{1-2} + Q_{2-3} + Q_{3-4} + Q_{4-1} = -340 \times 200$

$Q_{4-1} = -105800$ kJ/min

cyclic integral of any property is zero

$\oint \delta E = 0$

$\Delta E_{1-2} + \Delta E_{2-3} + \Delta E_{3-4} + \Delta E_{4-1} - 4200 = -73200 + w$

$\Delta E_{1-1} = 35540$ kJ/min

$w_{4-1} = Q_{4-1} - \Delta E_{4-1}$

$w_{4-1} = -141340$ kJ/min.

process	q(kJ/min)	w (kJ/min)	ΔE (kJ/min)
1-2	0	4340	-4340
2-3	42000	0	42000
3-4	-4200	69000	-73200
4-1	105800	-141340	35540

$$\sum_{cycle} q = \sum_{cycle} w$$

Work O/P = -68000 kJ/min = $-\frac{68000}{60} \frac{kJ}{s}$

In a wegam 10 kg of oxygen is heated in a Reversible non flow constant volume Process so that pressure of oxygen is increased 20 time that of intial volume the intial temperature is 20°c calculate

1) Final temperature
2) change in internal energy
3) The change in Enthpipy
4) Heat transform

Take R = 0.259 and cv = 0.652 kJ/kg k for oxygen

1) $\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$

$T_2 = \frac{P_2}{P_1} \times T_1$

$= \frac{2}{1} \times (20+273)$

$T_2 = 586\,K$

2) $\Delta U = m\,c_v\,(T_2 - T_1)$

$= 10 \times 0.652\,(586 - 293)$

$\Delta U = 191036\,kJ$

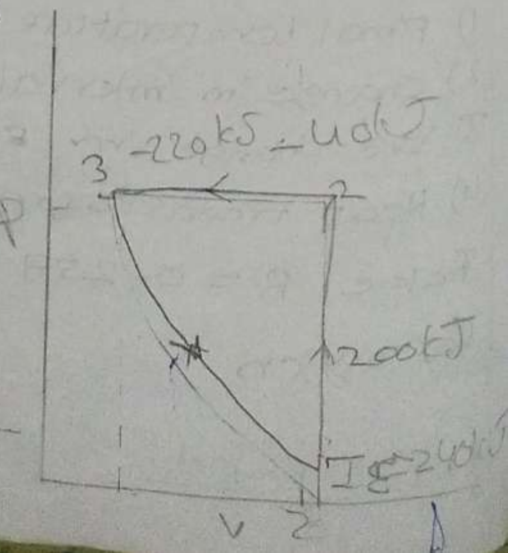
3) $\Delta H = m\,c_p\,(T_2 - T_1)$

$= 10 \times 0.911 \cdot (586 - 293)$

4) $Q_{1-2} = \overset{0}{\cancel{W_{1-2}}} + \Delta U$

$Q_{1-2} = 191036\,kJ$

A system recives 200 kJ of heat at constan volume process and rejects 220 kJ of heat at constant pressure and 40 kJ of work done a system the system is brough to it's origin state by a adiabatic process calcalate the adiabatic work if the internal energy is 240 kJ then calcuate the value of interna energy at all the points



process 1-2

$Q_{1-2} = u_2 - u_1 + W_{1-2}$

$200 = u_2 - 240$

$u_2 = 440\,kJ$

process 2-3

$Q_{2-3} = u_3 - u_2 + W_{2-3}$

$-220 = u_3 - 440 - 40$

$u_3 = 260\,kJ$

process 3-1

$\overset{\to 0}{Q_{3-1}} = u_3 - u_1 + W_{1-3}$

$= 260 - 240 + W_{1-3}$

$W = -20\,kJ$

Calculate the final temperature pressure work done and heat transformer if the fluid is compreshed Reversibility from volume 6 m3 to 1 m3 when the initial temperature and pressure of fluid or 20°C and 1 bar the index of comprhesion may be assumed as 1, 1.3 and 1.4 respectively take $C_p = 1.005$ and $C_v = 0.718$ kJ per kg kelvin

R = 0.287 kJ per kg kelvin

1) $P_1V_1 = P_2V_2$

$1\times 6 = P_2 \times 1$

$P_2 = 6$ bar

2) $T_1 = 20 + 273$

$T_2 = 293$

3) $W.D = P_1V_1 \ln\frac{V_2}{V_1}$

$= 1\times 10^5 \times 6 \ln\frac{1}{6}$

$= -1075055.68 J$

$W_n = -1075 kJ$

$Q_{1-2} = \overset{\nearrow 0}{u_2 - u_1} + W_{1-2}$

$Q_{1-2} = -1075 kJ$

$n = 1.3$

$P_1 V_1^n = P_2 V_2^n$

$P_1 V_1^{1.3} = P_2 (V_2)^{1.3}$

$\therefore \frac{P_2}{P_1} = \left(\frac{V_1}{V_2}\right)^{1.3}$

$P_2 = P_1 \times \left(\frac{V_1}{V_2}\right)^{1.3}$

$= 1 \times \left(\frac{6}{1}\right)^{1.3}$

$P_2 = 10.27 bar$

$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{n-1}$

~~$\frac{T_2}{(20+273)} = \left(\frac{6}{1}\right)^{1.3-1}$~~

$\frac{T_2}{293} = \left(\frac{6}{1}\right)^{1.3-1}$

$T_2 = 293 \left(\frac{6}{1}\right)^{0.3}$

$T_2 = 501.54$

$W.D = \frac{P_1 V_1 - P_2 V_2}{n-1}$

$= \frac{1 \times 10^5 (6) - 10.27 [illegible] \times 10^5 (1)}{1.3 - 1}$

$W.D = -1423 kJ$

$Q_{1\cdot2} = m\,C_n\,(T_2 - T_1)$

$= m\left(\frac{c_p - n\,c_v}{1-n}\right)(T_2 - T_1)$

$p_1 v_1 = m R T_1$

$m = \frac{p_1 v_1}{R T_1}$

$Q_{1\cdot2} = \frac{1\times10^5\times6}{287\times293} = \frac{\frac{N}{m^2}\times m^3}{\frac{J}{kg\cdot K}\times K} = \frac{N\text{-}m}{\frac{J}{kg}} = \frac{J}{\frac{J}{kg}} = kg$

$m = 7.135\ kg$

~~$Q = 7.135\left(\frac{1.005 - 1.3\times0.718}{1-1.3}\right)(501.54 - 293)$~~

~~208.54~~

$7.135(-1.2884)(208.54)$

$Q_{1\cdot2} = -355\ kJ$

$7.135\left(\frac{1.005 - 1.3\times0.7184}{1-1.3}\right)(501.54 - 293)$

$7.135\left(\frac{1.005 - 0.9334}{-0.3}\right)(208.54)$

$7.135\left(\frac{0.0716}{-0.3}\right)(208.54)$

$7.135(-0.23866)(208.54)$

$Q_{1\cdot2} = -355$

$p_1 v_1^n = p_2 v_2^n$

$p_1 v_1^{1.4} = p_2 (v_2)^{1.4}$

$\frac{p_2}{p_1} = \left(\frac{v_1}{v_2}\right)^{1.4}$

$p_2 = p_1\times\left(\frac{v_1}{v_2}\right)^{1.4}$

$p_2 = 1\times\left(\frac{6}{1}\right)^{1.4}$

$= (6)^{1.4} = 12.28$

$= 12.286$

$\frac{T_2}{T_1} = \left(\frac{p_2}{p_1}\right)^{\frac{\gamma-1}{\gamma}}$

$\frac{T_2}{T_1} = \left(\frac{v_1}{v_2}\right)^{n-1}$

~~$\frac{501.54}{293} = \left(\frac{6}{1}\right)^{1.4-1}$~~

$= 599k$

~~$1.7140664 = \left(\frac{6}{1}\right)^{0.4}$~~

$T_2 = \left(\frac{6}{1}\right)^{1.4-1}\times293 = 599\,kJ$

$$w.D = \frac{P_1V_1 - P_2V_2}{\gamma - 1} \qquad w.D = \frac{P_1V_1 - P_2V_2}{\gamma - 1}$$

$$= \frac{1 \times 10^5 (6) - 12.286 (1)}{1.4 - 1} \qquad = \frac{1\times10^5\times6 - 12.286\times10^5}{1.4-1} \quad 0.4$$

$$= -1570 \text{ kJ}$$

~~= 600000 − 12.286~~

prove that the formula $T^b V^{a-b} e^{kT} = \text{constant}$ for adiabatic expension of gas if $c_p = a + kT$, $c_v = b + kT$ where a, b and k are constant and T in kelvin

$$\delta Q = du + \delta w$$

$$0 = du + \delta w$$

$$= m c_v \, dT + P dV$$

$$0 = C_v dT + P dV \qquad PV = RT \qquad P = \frac{RT}{V}$$

$$0 = (b + kT)\, dT + RT \times \frac{dV}{V}$$

$$R = C_p - C_v.$$

$$= a + \cancel{kT} - b - \cancel{kT}$$

$$R = a - b$$

$$0 = (b+kT)\,dT + (a-b)\,T\,\frac{dv}{v}$$

$$0 = (b+kT)\,\frac{dT}{T} + (a-b)\,\frac{dv}{v}$$

$$b\ln T + kT + (a-b)\ln v = C$$

$$b\ln T + kT\ln e + (a-b)\ln v = \ln k$$

$$\ln T^{b} + \ln e^{kT} + \ln v^{a-b} = \ln k$$

$$\ln T^{b} e^{kT} \cdot v^{a-b} \cdot = \ln k$$

$$\boxed{T^{b}\, e^{kT}\, v^{a-b} \cdot = k}$$

Chapter-2

Flow process! - various forms of energy assosiated in flow process for unit mass

$$e_f = u + pv + \frac{c^2}{2} + gz$$

$$e_f = h + \frac{c^2}{2} + gz$$

The general studied flow energy eq (SFE)

$$e_{f_1} + q = e_{f_2} + w$$

$$h_1 + \frac{c_1^2}{2} + gz_1 + q = h_2 + \frac{c_2^2}{2} + gz_2 + w$$

workdone during study flow process

$$w_{sf} = -\int v\,dp - d(KE) - d(PE)$$

$$w_{sf} = -\int v\,dp$$

Study flow process for an ideal gas

we assume that an ideal gas undergoes a studied flow process from state 1 to state 2 The equation for studied flow return as

$$q - w = (h_2 - h_1) + \frac{c_2^2 - c_1^2}{2} + g(z_2 - z_1$$

$$\delta q - \delta w = dh + d(KE) + d(PE)$$

Adiabatic process

$$\delta w_{sf} = -dh - d(KE) - d(PI)$$

$$\delta w_{sf} = (h_1 - h_2) + \frac{c_1^2 - c_2^2}{2} + g(z_1 - z_2)$$

for an ideal gas

$dh = C_p \Delta T$

$\therefore \Delta h = \int_1^2 c_p \, dT = h_2 - h_1$

$\delta w_{sf} = -\int_1^2 C_p \Delta T + \frac{c_1^2 - c_2^2}{2} + g(z_1 - z_2)$

$w_{sf} = -\Delta h = (h_1 - h_2) = -\int_1^2 c_p \Delta T$

~~Work~~ Do

For any flow process in (study flow the work done by the expressed equation)

$\delta w_{sf} = -v\,dp - d(KE) - d(PE)$

Reversible isothermal process

$P\forall = C$

$v = \frac{c}{P}$

$W_{sf} = -\int v \, dP$

$= -\int \frac{c}{P} dP$

$= -c \ln P \Big]_1^2$

$= -P_1V_1 \ln \frac{P_2}{P_1}$

$w_{sf} = P_1V_1 \ln \frac{P_1}{P_2}$

$w_{sf} = mRT_1 \ln \frac{V_2}{V_1}$

polytropic process

$Pv^n = c$

$v^n = \frac{c}{P}$

$$v = \frac{c^{1/n}}{p^{1/n}}$$

$$v = c^{1/n} p^{-1/n}$$

$$w_{sf} = -\int_1^2 v\,dp$$

$$= -c^{1/n} \cdot \int_1^2 p^{-1/n}\,dp$$

$$= -c^{1/n} \left[\frac{p^{-\frac{1}{n}+1}}{-\frac{1}{n}+1}\right]_1^2$$

$$= -c^{1/n} \left(\frac{p_2^{1-\frac{1}{n}} - p_1^{1-\frac{1}{n}}}{1-\frac{1}{n}}\right)$$

$$= \frac{-c^{1/n} p_2^{1-\frac{1}{n}} - c^{1/n} p_1^{1-\frac{1}{n}}}{\frac{n-1}{n}}$$

$$p_1 v_1^n = p_2 v_2^n = C$$

$$= \frac{-(p_2 v_2^n)^{1/n} p_2^{1-\frac{1}{n}} - (p_1 v_1^n)^{1/n} p_1^{1-\frac{1}{n}}}{\frac{n-1}{n}}$$

$$= \frac{p_2 v_2 - p_1 v_1}{\frac{n-1}{n}}$$

Heat transform er

$$\delta Q - \delta W = d(h + \frac{c^2}{2} + gz)$$

$$\delta Q - \delta W = dh$$

$$\delta Q = dh + \delta W$$

$= (h_2 - h_1) + \frac{n}{n-1}(P_2V_2 - P_1V_1)$

For reversable adiabatic process

$W_{sf} = \frac{\gamma}{\gamma-1}(P_2V_2 - P_1V_1)$

Constant volume process

$W_{sf} = -\int_1^2 V\,dP$

$= -V \int_1^2 dP$

$= -V(P_2 - P_1)$

$W_{sf} = V(P_1 - P_2)$

$W_{sf} = -\int_1^2 V\,dP$

$W_{sf} = 0$

process	Studyflow	nonflow
constant volume	$V(P_1 - P_2)$	0
constant temperature	$P_1V_1 \ln\left(\frac{V_2}{V_1}\right)$	$P_1V_1 \ln\left(\frac{V_2}{V_1}\right)$
constant pressure	[illegible]	~~$P(V_2 - V_1)$~~ $P(V_2 - V_1)$
reversible	0	$\frac{P_1V_1 - P_2V_1}{\gamma - 1}$
Polytropic	[illegible]	
~~Heat trans~~form	$\frac{n}{n-1}(P_2V_2 - P_1V_1)$	$\frac{P_1V_1 - P_2V_2}{n-1}$

Process	Studyflow	nonflow
constant volume		
constant temperature		
constant pressure		
reversible adiabatic		
Polytropic		

A steam turbine operates under study flow conditi[…] it receives 7200 kg/hr steam from the boiled. The steam end of the turbine at entholphy of 2800 kJ/kg a velocity of 4000 m/min under an avelation of 4m due to radition heat loses from the turbine to the surroundings amounts to -1580 kJ/hr the steam leaves the turbine at the enthlopy of 2000 kJ/kg at velocity of 8000 m/min under elvation of 1m calculate out put of the turbine

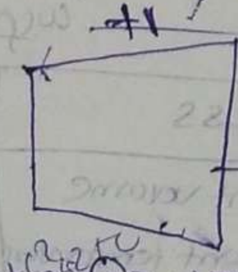
$$ef_1 + q = ef_2 + w$$

$$h_1 + \frac{c_1^2}{2} + gz_1 + q = h_2 + \frac{c_2^2}{2} + gz_2 + w$$

~~$2800 + \frac{16000000}{2} + 9.81 \times 4 (-15800) = 2000 + \frac{64000000}{2} + 9.81$~~

$$\frac{kJ}{kg} + \frac{m}{s} + \frac{m}{s^2} + m + \frac{kg}{hr}$$

$$\frac{-1580}{3600 \times 2}$$



$h_1 = 2800 kJ$

$V_1 = 4000 m/min$

$Z_1 = 4m$

$W = ?$

$Q = -1580 kJ/hr$

$h_2 = 2000 kJ/kg$

$V_2 = 8000 m/min$

$Z_2 = 1m$

$$\dot{m} = \frac{7200}{3600} \frac{kg}{h} \times \frac{kg}{s}$$

$$\dot{m} = 2 kg/s$$

$$h_1 + \frac{c_1^2}{2} + gz_1 + q = h_2 + \frac{c_2^2}{2} + g$$

$$= \frac{-1580}{3600 \times 2} \frac{kJ}{s} \times \frac{s}{kg}$$

$$q = -0.219 kJ/kg$$

$$\frac{-1580}{3600 \times 2}$$

$$h_1 + \frac{c_1^2}{2g_c} + \frac{gz_1}{g_c} + q$$

$$\frac{1}{g_c} = 1 \quad (SI units)$$

$$g_c = kg\text{-}m/N\text{-}sec^2$$

$$\frac{c_1^2}{2g_c} = \frac{m^2}{sec^2} \times \frac{N\text{-}sec^2}{kg\text{-}m}$$

$= \frac{N-m}{kg} = \frac{J}{kg} = \frac{kJ}{kg \times 1000}$

$\frac{gz}{gc} = \frac{m}{sec^2} \times m \times \frac{N-sec^2}{kg-m} = \frac{N-m}{kg} = \frac{J}{kg} = \frac{kJ}{kg \times 1000}$

$2800 + \frac{(4000)^2}{(60)^2 \times 2 \times 1000} + \frac{9.81 \times 4}{1000} - 0.219$

$(60)^2 \times 2 \times 1000 \qquad = 2000 + \frac{(8000)^2}{(60)^2 \times 2 \times 1000} + \frac{9.81 \times 1}{1000} + \omega$

2800 + ~~8888888.889~~ + 0.~~03924 - 0.219~~

889168.709 = ~~355566668~~ 35557555.57

$2800 + 2.22 + 0.039 - 0.219 = 2000 + 8.88 + 9.81 \times 10^{-3}$

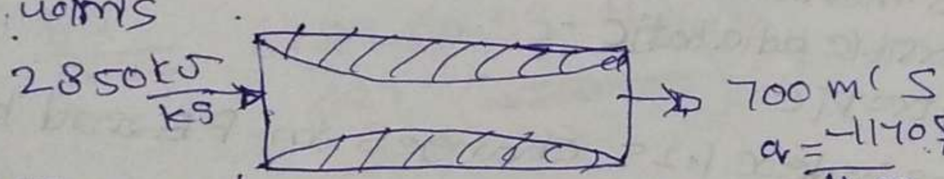
$2802.04 = 2008.88$

$\omega = 793.143 \frac{kJ}{kg}$.

$= 793.143 \times 2 \frac{kJ}{kg} \times \frac{kg}{s}$ $\quad h_1 + \frac{c^2}{2} + gz_1 + q$

$\omega = 1586.28$ kJ/s (or) kW

Steam enters a nozzle at a pressure of 7 bar and 205°c intial velocity of steam at enters is 40 m per sec and at exist is 700 m/s with an intial entholpy 2850 kJ/kg the mass flored = 1400 kg/hr heat rosed from the nozel is -1105 kJ/hr mass flored through nozzle is determine the final enthlopy of steam.



$m = 1400$ kg/hr $\quad q = -11705 \frac{kJ}{hr}$

$q = \frac{-11705}{1400} \frac{kJ}{hr} \times \frac{hr}{kg}$

$q = -8.36$ kJ/kg

$h_1 + \frac{c_1^2}{2g} + z_1 g + q = h_2 + \frac{c_2^2}{2g} + z_2 g + \omega$

$h_1 + \frac{c_1^2}{2} + q = h_2 + \frac{c_2^2}{2}$

$h_2 = h_1 + \frac{c_1^2 - c_2^2}{2} + q$

$= 2850 + \frac{(40)^2 - (700)^2}{2 \times 1000} - 8.36$

$h_2 = 2597.4$ kJ/kg

In a boilear water enters with a enthlpy of 168 kJ/kg and, steam leaves with a enthlphy of 2925 kJ/kg find the heat transfer per kg of steam the changes in KE and PE may be neglate

$$h_1 + \cancel{\frac{c_1^2}{2000}} + \cancel{\frac{gz_1}{1000}} + q = h_2 + \cancel{\frac{c_2^2}{2000}} + \cancel{\frac{gz_2}{1000}} + \cancel{w}$$

$$h_1 + q = h_2$$

$$q = h_2 - h_1$$

$$q = 2925 - 168$$

$$q = 2757 \text{ kJ/kg}$$

A reciprocating air compressre installed in a fertillizer factory takes in air at 1 bar 20°C and deliverse at 6 bar calculate work done heat transfer and change in internal energy per kg of air compresed if the compreshon process follows

a) Iso thermal

b) Reversible adiabatic

c) polytropic having index 1.25 changes in PE and KE may be neglated

Isothermal process

$$w_{sf} = P_1 V_1 \ln \frac{V_2}{V_1}$$

$$= RT_1 \cdot \ln \frac{P_1}{P_2}$$

$$= 0.287 \times (293) \ln \frac{1}{6}$$

$$w_{sf} = -150.67 \text{ kJ/kg}$$

Heat

$$\delta Q - \delta W = d\cancel{U}$$

$$\delta Q - \delta W = mC_p\cancel{T} \rightarrow 0$$

$$\delta Q = \delta W$$

$$\delta Q = -150\ 67 \text{ kJ/kg}$$

$$\Delta u = 0$$

reversible adiabatic

$$W_{sf} = \frac{\gamma}{\gamma-1}(P_1V_1 - P_2V_2)$$

$$= \frac{\gamma}{\gamma-1}R(T_1 - T_2)$$

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}}$$

$$T_2 = T_1\left(\frac{P_2}{P_1}\right)^{\frac{1.4-1}{1.4}}$$

$$T_2 = 293\left(\frac{6}{1}\right)^{\frac{\cancel{0.4}}{1.4}} \quad 0.285$$

$$T_2 = 293\left(\frac{6}{1}\right)^{\cancel{0.685}} \qquad 501.03$$

~~W_{sf}~~ $T_2 = 486.38\text{ K}$

$$= \frac{1.4}{1.4-1}\ 0.287\ (293 - 486.38)$$

$$3.5 \quad 0.287\ (\cancel{-208.03})$$

$$W_{sf} = -\underline{1942}5 \text{ kJ/kg}$$

$$\delta Q = 0$$

$$\Delta u = C_v\,\Delta T$$

$$= 0.717(489.1 - 293)$$

$$\Delta u = 140.6 \text{ kJ/kg}$$

Gowri

Gangaraju

Gangaraju

Gangaraju

Poly tropic process

workdone

$\frac{n}{n-1}(P_1V_1 - P_2V_2)$

$-\frac{n-1}{n} R\left(\frac{T_1 - T_2}{n-1}\right)$

$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}}$

$T_2 = T_1\left(\frac{P_2}{P_1}\right)^{\frac{1.025-1}{1.25}}$

$= 293\left(\frac{6}{1}\right)$

$= 293\left(\frac{6}{1}\right)^{0.2}$

$= 419.27$

$W_{fs} = \frac{n}{n-1} R(T_1 - T_2)$

$= \frac{1.25}{1.25-1}(298 - 419.27)$ ~~-384~~ -121.27

$= -181097$ kJ/kg

$\delta q = \delta w + dh$

$= -181.09 + C_p(T_2 - T_1)$

$= -181.09 + 1.005(419.2 - 293)$

$= -54.259$ kJ/kg

$\Delta u = C_v\, dT$

$= 0.712(T_2 - T_1)$

$= 0.717(4192.2 - 293)$

$\Delta u = 2795.726$

$\Delta u = 2795.872$

Unit-3

Second law of Thermodynamics

~~what is discription~~

Limitations of first law and essence of second law

1) A/c to first law in every cyclic process work is completely converted into heat or heat is completely converted into work. In natural process work is not completly converted into heat.

2) Potiential energy is transformed into K.E are K.E can be transformed into P.E.
PE can be converted into KE But reverse is not true.

3) Heat flows from hot to cold are from cold to hot. Heat flows from hot to cold but reverse is not true

4) Gas expense from higher pressure to lower pressure are form low pressure to high pressure. High pressure gas will expend to low pressure pressure but revers is not true

5) The spatentauis process can be reverse but they will be not reverse automatically they reauire some external source for reverse process.. All this examples saust that they are some limitation on the aplication of first law of thermodynamics

1) The law does not specifi the direction of process under consideration

2) There is limitation on the converstion of one form of energy in to another.

part of heat supied to a heat engine may be converted in to work but part of heat must be rejected to the sink. This limitations form the basis of second law of thermodynamics.

* kelvin planck statement:-

kelvin planck statemant it is imposible to construc an engine working on cyclic process whose sole purpose is to convert all the heat suplie in two equalent of work.
such an engine will afcouse not willdly the first law of thermodynamics but it is not possible to have hundred present apiest engine in view of the limitations expressed by second law of thermodyanamics A/C to ch path of heat drawn from heat source must be rejected to the lower temperature reservioux.

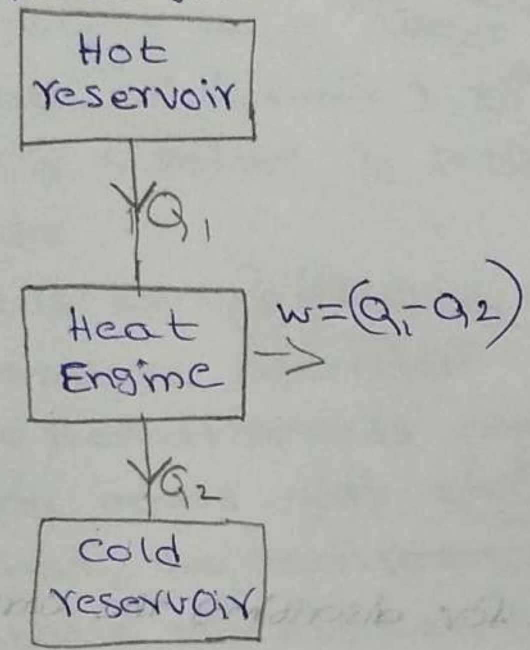
* clausius statement:- It is imposible to construct a heat pump which is operating a cycle will produce no effect other than the transfer of heat from low temperatu body to a hish temperature body.

(or)

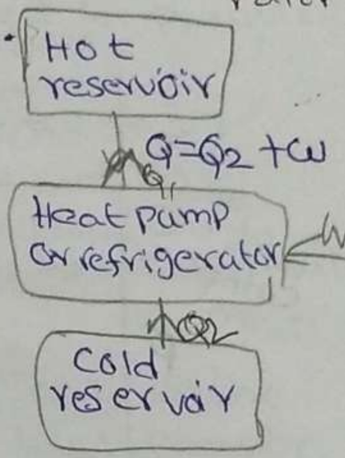
Heat can't it self flow from a colder body to hoter body

performanse of heat engine and reverse heat engine.

Heat engine



Heat pump (or) refri rator



Heat Engine: Heat engine is used to produce the maximum work transform from a given positive heat transform

$$\text{Effesinency} = \frac{w.D}{\text{heat suplied}} = \frac{Q_1-Q_2}{Q_1} = \frac{T_1-T_2}{T_1}$$

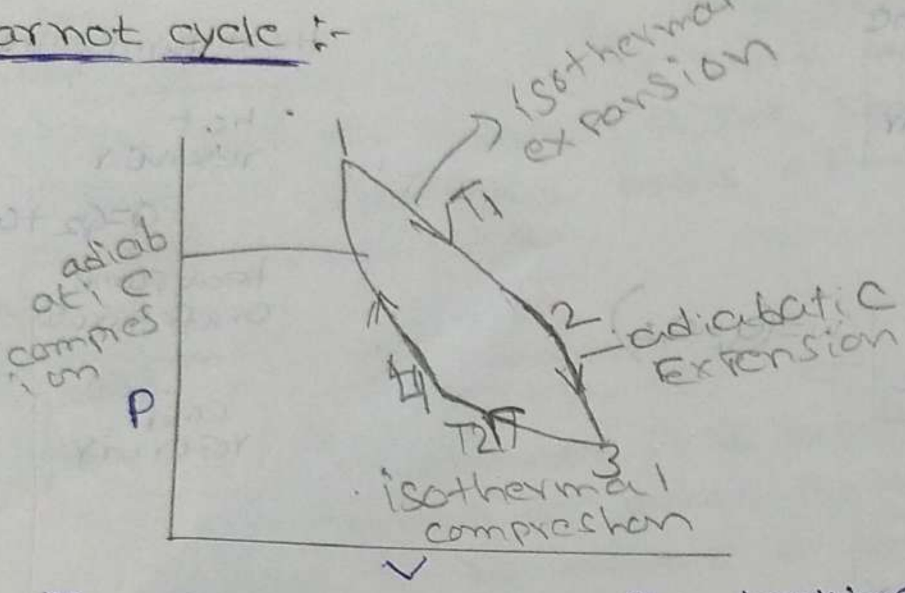
Refrigerator :- when the purpose is used to achive maximum from the cold reservoir the measure of success is called the coefficent of performance

$$(cop)_{ref} = \frac{\text{refrigerator effect}}{\text{work Done}} = \frac{Q_2}{Q_1-Q_2} = \frac{T_2}{T_1-T_2}$$

Heat pump :- It is defined as the ratio of heat transform to hot reservoir to work transform to the heat pump

$$(cop)_{\text{Heat pump}} = \frac{\text{Heat effect}}{w.D} = \frac{Q_1}{Q_1-Q_2} = \frac{T_1}{T_1-T_2}$$

Carnot cycle :-



The asumptions made for discribing the carnot engine are as follows

1) The pistion moving in a cyclinder does not deal any friction during motion.

2) The wall of piston and cyclinder are consideras perfect insulatores of heat

3) The transform of heat does not effect the temperature of source are sink

4) working medium is a perfect gas

5) compHreson and extenseon are reversible

Process 1-2: Hot energ is suplied . ~~Hea~~ Heat ~~Qq~~r is taken fluid expense iso thermaliy at temperature t_1

Process 2-3 :- the ~~fluid~~ fluid expense adiabaticaly. temperature falls from t_1 to t_2

Process 3-4 :- Heat Q_2 flows from fluid and compreset isothermaly

Process 4-1 :- compreshon is continued adidbatical temperature is raised from t_2 to t_1

$$\text{Thermal efficency} = \frac{\text{work Done}}{\text{heat suplied}} = \frac{Q_1 - Q_2}{Q_1}$$

$$= 1 - \frac{Q_2}{Q_1}$$

$$\eta_{Th} = 1 - \frac{T_2}{T_1}$$

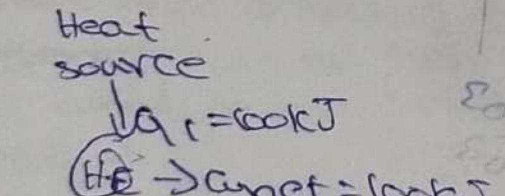
The carnot cycle can't be performed in practice because of following of reasons

1. It is imposible to perfom a friction less process

2. It is an imposible to transfor the heat without temperature potential

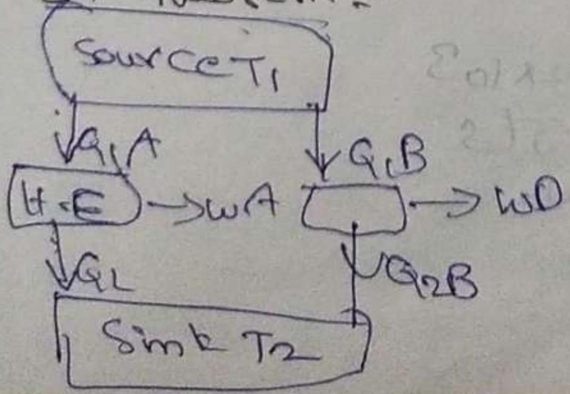
3. Iso thermal process can be acheive only if the piston moves very slowly to allow heat transfer so that the temperature reamins constant. Adiabatic process can be achieve only if the piston moves as fast as possible so that the heat transform is neglible due to very short time avaiable. The isothermal adiabatic process takes place or during the same stroke thefore the piston as to move very slowly for path of the stroke and it has to move very fast during the reaming stroke. The variation of position of the piston during the same stroke is not possible

PMM II = perpectual motion machine - 2

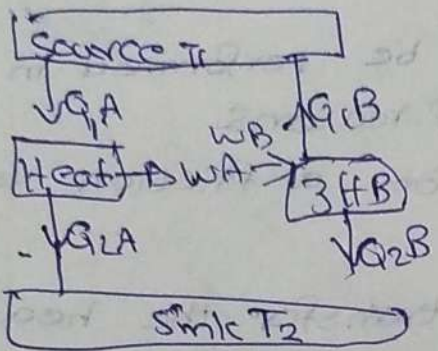


Viocation of II law

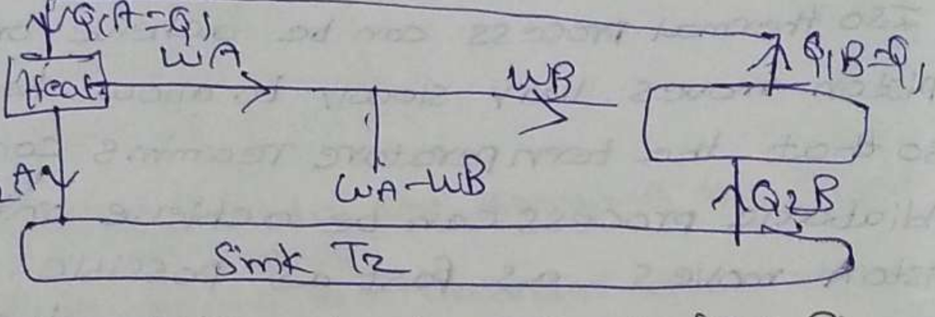
Carnot theorem:-



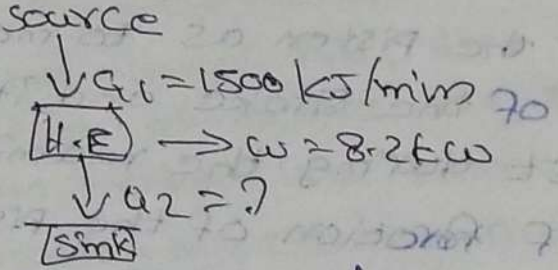
II Stage:-



Stage :- III



① A heat engine recaues heat at the rate of 1500 kJ/min and gives an output of 8.2 kW. Determine (i) Thermal efficiency, (ii) The rate of heat rejection.



Given data

$Q_1 = 1500$ kJ/min

$= \frac{1500 \times 1000}{60}$

$Q_1 = 25 \times 10^3$ J/S

$W = 8.2$ kW

$W = 8.2 \times 10^3$ J/S

$\eta_{Th} = \frac{W.D}{H.S} = \frac{8.2 \times 10^3}{25 \times 10^3}$

$\eta_{Th} = 32.87\%$

② $Q_1 - Q_2 = W$

$Q_2 = Q_1 - W$

$= 25 \times 10^3 - 8.2 \times 10^3$

$= 16.8 \times 10^3$ J/S

$Q_2 = 16.8$ kN

what is the highest possible therotical efficiency of a heat engine operating with the hot reservoir gases at 2100°c whe the cooling rate available is 15°C

$$\eta = 1 - \frac{T_2}{T_1} = \frac{T_1 - T_2}{T_1}$$

$$= 1 - \frac{15+273}{2100+273}$$

$$\eta = 87.8\%$$

A carnot cycle refrigerator 250k and 300k.

$$(COP)_R = \frac{T_2}{T_1 - T_2} = \frac{250}{300-250} = 5$$

A cycle heat engine does 50 kJ or work of cycle of the efficiency of the heat engine 75%.

a) $16\frac{2}{3}$ kJ (B) $33\frac{1}{3}$ kJ (c) $37\frac{1}{2}$ kJ (D) $66\frac{2}{3}$ kJ.

$$\text{Efficiency} = \frac{\text{work done}}{\text{heat supplied}} = \frac{W}{Q_1}$$

$$0.75 = \frac{50}{Q_1}$$

$$\Rightarrow Q_1 = \frac{50}{0.75} = \frac{200}{3}$$

$$W.D = Q_1 - Q_2 \Rightarrow 50 = \frac{200}{3} - Q_2$$

$$Q_2 = \frac{50}{3} = 16.66\,kJ = 16\tfrac{2}{3}\,kJ$$

A carnot cycle is having an efficiency of 0.75. If the ~~temperature~~ temperature of high temperature reservior is 727t. what is the temperature of ~~low~~ low temperature reservoir

(A) 23°c (B) -23°c ✓ (C) 0°c (D) 250°C

$$\text{Efficiency}\,(\eta) = 1 - \frac{T_2}{T_1}$$

$$0.75 = 1 - \frac{T_2}{1000}$$

$$0.75 = \frac{1000 - T_2}{1000} \quad -250k$$

$$\Rightarrow 1000 \times 0.75 = 1000 - T_2$$

$$750 = 1000 - 750$$

$$250k = 200 + 273$$

$$= 473$$

$= 273 - 250$

$= -23°C$ //

Find the cop and heat transfer rate in the condens of a refrigerator in kJ/hr which has a refrigerato capacity of 12000kJ/hr when power input in 0.75k

$Q_2 = 12000 kJ/hr$

$Power = 0.75 kJ/s$

$Power = 0.75 \times 3600 \frac{kJ}{hr}$

$cop = \frac{R.E}{W.D} = \frac{12000}{0.75 \times 60 \times 60}$

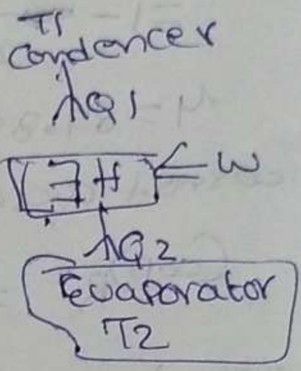
$= 4.44$

$Q_1 - Q_2 = w$

$Q_1 = Q_2 + w$

$= 12000 + 0.75 \times 60 \times 60$

$Q_1 = 14700 kJ/hr$



A domestic food refrigerator maintaince a temperature of -12°c the ambient temperature 35°c If heat leaks into the freezer at a continu rate of 2kJ/s. determine the least power necessa pump this heat out continuously

$\frac{q_2}{T_2} = \frac{q_1}{T_1}$

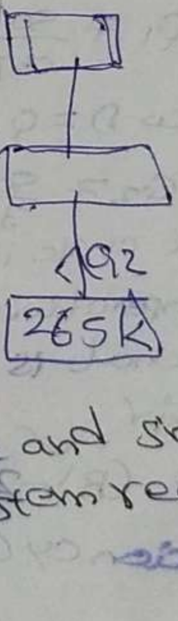
$Q_1 = \frac{T_1}{T_2} \times Q_2$

$= \frac{308}{261} \times 2$

$= 2.036 kJ/s$

$w = Q_1 - Q_2$

$= 2.036 - 2 = 0.36 kW$



A carnot cycle operates b/w source and sink temperature of 250°C and 15°C of the system receives 90kJ from the source. Find

(i) Efficiency of the system

(ii) the network transfer

(iii) Heat rejected to sink

$T_1 = 250 + 273 = 523°K$

$T_2 = -15 + 273 = 258K$

$q_1 = 90kJ$

$= 1 - \frac{T_2}{} = 1 - \frac{258}{523} = 0.506$

$= 50.6$

$$\eta = \frac{\omega.D}{H.S} = \frac{\omega.D}{Q_1}$$

$$\omega = \eta \times Q_1 = 0.506 \times 90 = 45.5$$

$$\omega = Q_1 - Q_2$$

$$Q_2 = Q_1 - \omega = 90 - 45.5 - 44.46$$

Unit - III Introduction

Second law of thermodynamics :-

Entropy :-

$$\frac{fq}{T} = ds$$

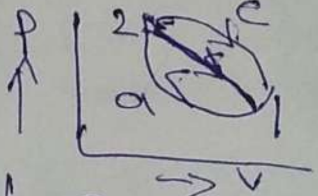
The cyclic integral of the quantity $\frac{fq}{T}$ for reversible cycle = 0. ~~suggest~~ that the quantity $\frac{fq}{T}$ is a point function.

$$\int_1^2 \left(\frac{fq}{T}\right) = \int_1^2 ds$$

where 'S' is entrophy

$$\left(\frac{fq}{T}\right)_{rev} = S_2 - S_1$$
$$= dS$$

Defiuition of entropy :- The amount of heat contian in substance and the degree to which it is ordered (or) described by the property of state known as entropy



$$\oint \frac{fq}{S} = 0$$

1-A-2-B-1

$$\oint \left(\frac{fq}{T}\right]_1 = \int_2^2 \left(\frac{fq}{T}\right]_{\text{path A rev}} + \int_2^1 \left(\frac{fq}{T}\right)_{\text{rev path B}}$$

similarly

$$\oint \left[\frac{fq}{T}\right]_R = \int_1^2 \left[\frac{fq}{T}\right]_{\text{rev path A}} + \int_2^1 \left(\frac{fq}{T}\right]_{\text{rev}}$$

2 path C

comparing

$$\int_2^1 \left(\frac{\delta q}{T}\right]_{\text{rev path B}} = \int_2^1 \left(\frac{\delta q}{T}\right)_{\text{rev path C}}$$

$\int \frac{fq}{T}$ is independent of the path

— A property

— A point function (Exact differential)

$$S_2 - S_1 = \int_1^2 \left(\frac{fq}{T}\right)_{rev}$$

Reversible adiabatic process

- $\delta q = 0$

$S_2 - S_1 = 0$

$S_2 = S_1$

V.V Imp.:

Entropy changes for an ideal gas during process:-

$\delta q - \delta w = du$

$(\delta q)_{rev} \; \delta w = du$

Dividing the above expression by 'T'

$\left[\frac{\delta q}{T}\right]_{rev} - \left[\frac{Pv}{T}\right] = \frac{du}{T}$

$ds = \frac{\delta w}{T} + \frac{du}{T}$

$ds = \frac{Pdv}{T} + \frac{du}{T} \to ①$

$Tds = Pdv + du \to ②$

$H = U + PV$
$U = H - PV$

$Tds = Pdv + d(H - PV)$

$= \cancel{Pdv} + dH - \cancel{Pdv} - Vdp$

$TdS = dH - Vdp$

$ds = \frac{dH}{T} - \frac{Vdp}{T} \to ③$

Integrating eq ① and ③

$S_2 - S_1 = \int_1^2 \frac{P}{T} dv + \int_1^2 \frac{du}{T} \to ④$

$S_2 - S_1 = \int_1^2 \frac{dH}{T} - \int_1^2 \frac{v}{T} dp \to ⑤$

For a perfect gas

$du = mc_v dT$

$dH = mc_p dT$

$PV = mRT$

$\frac{P}{T} = \frac{mR}{V}$

$\frac{V}{T} = \frac{mR}{P}$

From eq ①

$ds = \frac{mR}{V} dv + \frac{mc_v dT}{T}$

$S_2 - S_1 = mR \int_1^2 \frac{dv}{V} + mcv \int_1^2 \frac{dT}{T}$

$S_2 - S_1 = mR \ln \frac{V_2}{V_1} + mcv \ln \frac{T_2}{T_1}$ → ⑥

From eq ③

$ds = \frac{mcpdT}{T} - \frac{mR}{P} dP$

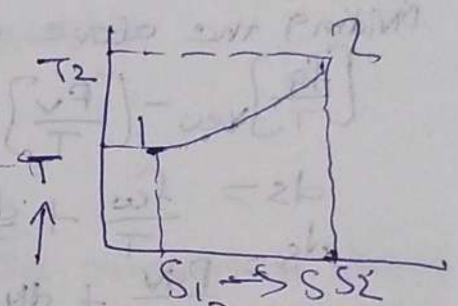
$S_2 - S_1 = mcp \int_1^2 \frac{dT}{T} \; mR \int_1^2 \frac{dP}{P}$

$S_2 - S_1 = mcp \ln \frac{T_2}{T_1} - mR \ln \frac{T_2}{T_1}$ → ⑦

① constant volume process:-

From eq ⑥

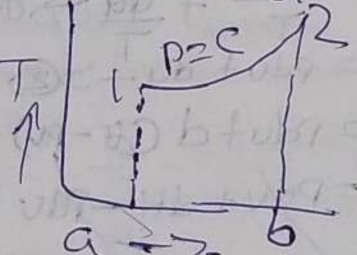
$S_2 - S_1 = mcv \ln \frac{T_2}{T_1}$



② constant pressure process

From eq ⑦

$S_2 - S_1 = mcp \ln \frac{T_2}{T_1}$



③ Isothermal process:-

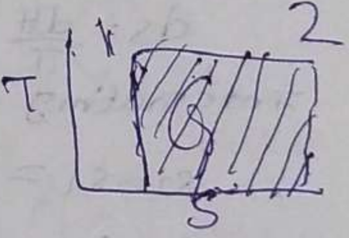
From eq ⑥

$S_2 - S_1 = -mR \ln \frac{P_2}{P_1}$

$S_2 - S_1 = mR \ln \frac{P_1}{P_2}$

From eq ⑥

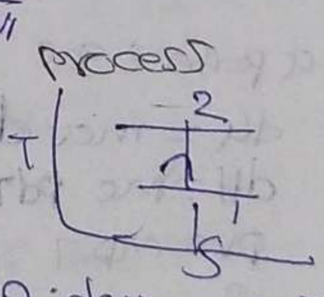
$S_2 - S_1 = mR \ln \frac{V_2}{V_1}$



④ Reversible adiabatic process

$S_2 - S_1 = 0$

$S_2 = S_1$



⑤ polytropic proces

$Q_{1-2} = \frac{\gamma - n}{\gamma - 1} \times$ W.D during polytropic

$Q_{1-2} = \frac{\gamma - n}{\gamma - 1} \times pdv$

But $ds = \frac{\delta Q}{T}$

$ds = \frac{\gamma - n}{\gamma - 1} \times \frac{P}{T} dv$

$ds = \frac{\gamma-n}{\gamma-1} mR \frac{dv}{v}$

Integrating above expression

polytropic $\begin{cases} s_2-s_1 = \frac{\gamma-n}{\gamma-1} mR \ln \frac{V_2}{V_1} \\ s_2-s_1 = \frac{\gamma-n}{1-n} c_v \ln \frac{T_2}{T_1} \end{cases}$

Formulas:-

constant volume :- $s_2-s_1 = mc_v \ln \frac{T_2}{T_1}$

constant pressure :- $s_2-s_1 = mc_p \ln \frac{T_2}{T_1}$

Constant temperature :- $S_2-S_1 = mR \ln \frac{V_2}{V_1}$ (or) $mR \ln \frac{P_1}{P_2}$

Reversible adiabatic :- $S_1 = S_2$

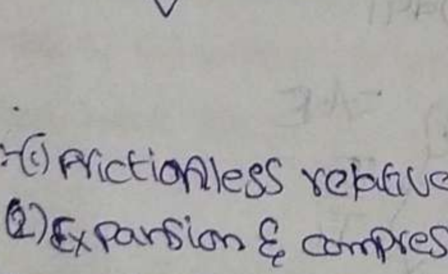
polytropic process :- $S_1 = S_2 = \frac{\gamma-n}{\gamma-1} mR \ln \frac{V_2}{V_1}$

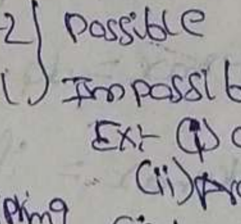
(or)

$S_1 - S_2 = \frac{\gamma-n}{1-n} c_v \ln \frac{T_2}{T_1}$

*Irreversible → It is nature

*Reversible → It is ideal





Irreversible

1-2 } possible

2-1 } Impossible

Ex:- (1) frictionless relative motion

(2) Expansion & compression of spring

(3) polytropic & isothermal expansion and compression

Ex:- (i) combustion

(ii) free expansion

(3) Throttling

(4) plastic deformatio

Reasons for irreversibility:-

1. Lack of thermodynamic equilibrium during the process

2. Involvement of dissipative effect during the process

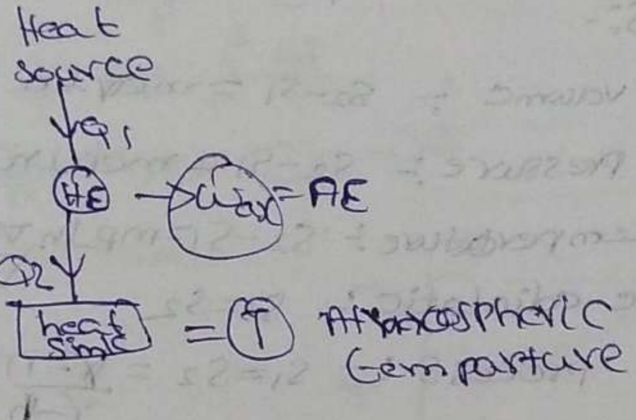
(a) Heat transfer through a finite temperature difference.

b) Free expansion

(a) Braking of rotating fly wheel

(b) paddle wheel work.

Available energy :- AE



$$Q_1 = A.E + U.E$$

$$\eta_{cycle} = 1 - \frac{T_2}{T_1}$$

$$\eta_{max} = 1 - \frac{T_0}{T_1}$$

$$W_{max} = \left(1 - \frac{T_0}{T_1}\right) Q_1$$

$$\eta_{th} = \frac{W.D}{H.S}$$

$$W.D = \left(1 - \frac{T_0}{T_1}\right) Q_1$$

$$dW_{max} = \left(\frac{T_1 - T_0}{T}\right) dQ_1$$

$$dW_{max} = dQ_1 - \frac{T_0 dQ_1}{T_1} = A.E$$

$$\int_x^y dW_{max} = \int_x^y dQ_1 - \int_x^y \frac{T_0}{T_1}$$

$$\underbrace{W_{max}}_{A.E} = \underbrace{Q_{xy}}_{H.S} - \underbrace{T_0 (S_y - S_x)}_{U.E}$$

$$U.E = T_0 (S_y - S_x)$$

Availability :-

Total work – pdv work

maximum useful work that in obtainable in a process which the system comes to equilibriu surroundings.

Availability - for Study flow process

$$w = H_1 - T_0 S_1 + \left(\frac{mV_1}{2} + mgZ_1\right) - (H_0 - T_0 S_0 + mgZ_0)$$

Availabity in a non flow System:-

$$A = W_{max} = E - E_0 + P_0(V - V_0) - T_0(S - S_1)$$

$$\delta q - \delta w = dE(du)$$

$$= \left(u + \frac{mv^2}{2} + mgz\right) - (u_0 - mgz_0)$$

neglecting K.E & P.E

$$A = (u - u_0) + P_0(v - v_0) - T_0(s - s_0)$$

$$= (u + P_0 v - T_0 s) - (u_0 + P_0 v_0 - T_0 s_0)$$

$$= \phi - \phi_0$$

$$A = \phi - \phi_0$$

problem s on entropy:-

① During summer to cool water for drinking purpose of ice at 0°C is mixed with 5kg of water at 27°C. The system is opened to atmosphere which has a pressure of 1 bar. calculate the temperature of mixture and change in entropy for the spontaneous process.

Take Cp water = 4.18 kJ/kgk.

Lated heat LH Ice = 335 kJ/kg

$$0_{min} = 27_{max}$$

Heat gained by ice = heat losed by water

Energy balanced equation

$$m_i L_i + C_{pw}(T - 0) = m_w \cdot C_{pw}(27 - T)$$

mass of ice = 1kg

L.H ice = 335

mass of ice = 1×4.18

$$1 \times 335 + 1 \times 4.18(T - 0) = 5 \times 4.18(27 - T)$$

$$T = 9.142\ ^\circ C$$

change in entropy of ice

$(\Delta S)_{ice}$ = Entropy change due to melting of ice at constant temperature + Entropy charge due to heating of melting of icefrom $0°C - 9.14°C$.

$$S = \frac{d\theta}{T} = \frac{Q_1}{T_1} + mc_p \ln \frac{T_2}{T_1}$$

$$Q = mL = \frac{1 \times 335}{0+273} + 1 \times 4.18 \ln \frac{273+9.147}{273+0}$$

$(\Delta S)_{Ice} = 1.36\ kJ/k$

* change in entropy of water

ΔS = change due to cooling of water from $27°$ to $9.142°C$

$$\Delta S = mc_p \ln \frac{T_2}{T_1}$$

$$= 5 \times 4.18 \times \ln \frac{273+9.142}{273+0}$$

$\Delta S = -1.282\ kJ/kg$

change in entropy $= (\Delta S)_{ice} + (\Delta S)_{water}$

$= 1.364 - 1.282$

$= 0.082\ kJ/k$

$\boxed{\text{Ice + water}} \leftrightarrow$ Intermediate temperature

In order to check the validity of second law of thermodynamics of m_1 kg of water at temperature in mixed with m_2 kg of water at tem T_2 Determine the change in entropy of the universe and find an expression for the same also prove that the change in necessary $\boxed{\text{Positive}}$

Heat closed by M_1 kg of at $T_1°C$ = heat gained by m_2 of water at $T_2°C$

$$M_1 C_{pw}(T_1 - T_f) = m_2 C_{pw}(T_f - T_2)$$

$$T_f = \frac{m_1 T_1 + m_2 T_2}{M_1 + m_2}$$

change in entropy

$m_1 kg - T_1 \Delta T_f$

$(\Delta S_1) = m_1 c_p \ln \frac{T_f}{T_1} = m_1 c_p \ln \frac{m_1 T_1 + m_2 T_2}{T_1(m_1+m_2)}$

$(\Delta S_2) = m_2 c_p \ln \frac{T_f}{T_2} = m_2 c_p \ln \frac{m_1 T_1 + m_2 T_2}{T_2(m_1+m_2)}$

(ΔS) universe $= \Delta S_1 + \Delta S_2$

$= m_1 c_p \ln \frac{m_1 T_1 + m_2 T_2}{T_1(m_1+m_2)} + \frac{m_2 T_2 + m_1 T_1}{T_2(m_2+m_1)}$

$m_1 = m_2 = m$

$= mc_p \left[\ln \frac{T_1+T_2}{2T_1} + \ln \frac{T_1+T_2}{2T_2} \right]$

$= mc_p \ln \left\{ \frac{T_1+T_2}{2T_1 . 2T_2} \right\}$

$= mc_p \ln \left(\frac{T_1+T_2}{2\sqrt{T_1 T_2}} \right)$

$= 2 . mc_p \ln \frac{T_1+T_2}{2\sqrt{T_1 T_2}}$

$\therefore \Delta S = 2 . mc_p \ln \frac{T_1+T_2}{2\sqrt{T_1 T_2}}$

The value of entropy is positive

$\Delta S = 2mc_p \ln \frac{T_1+T_2}{2\sqrt{T_1 T_2}}$

$\ln \frac{T_1+T_2}{2\sqrt{T_1 T_2}}$ T_1+T_2 → Arithmatic mean, $2\sqrt{T_1T_2}$ → Geometric mean

$\frac{T_1+T_2}{2}$ → Arithmatic mean   Am>GM

$\sqrt{T_1 T_2}$ → Geometric mean

$T_1 = 20 \quad T_2 = 30$

$\frac{T_1+T_2}{T2} = \frac{50}{2} = 25$

$\sqrt{20 \times 30} = \sqrt{600} = 24.49$

The value is +ve

Entropy is ever increasing

Show that when a perfect gas changes from state $P_1V_1T_1$ to another state P_2, V_2, T_2 the increase in entropy per unit mass is given by

$$S_2 - S_1 = c_v \ln \frac{P_2}{P_1} + c_p \ln \frac{V_2}{V_1}$$

$$\delta q = du + pdv$$

$$\frac{\delta q}{T} = \frac{du}{T} + pdv$$

$$ds = \frac{mc_v dT}{T} + \frac{dv}{v}$$

$$S_2 - S_1 = mc_v \ln \frac{T_2}{T_1} + mR \ln \frac{V_2}{V_1}$$

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$$\frac{T_2}{T_1} = \frac{P_2V_2}{P_1V_1}$$ → Replaced in formula

$$S_2 - S_1 = C_v \ln \frac{P_2V_2}{P_1V_1} + mR \ln \frac{V_2}{V_1}$$

$$S_2 - S_1 = C_v \ln \frac{P_2V_2}{P_1V_1} + (C_p - C_v) \ln \frac{V_2}{V_1}$$

$$= C_v \ln \frac{P_2}{P_1} + C_v \ln \frac{V_2}{V_1} + C_p \ln \frac{V_2}{V_1} - C_v \ln \frac{V_2}{V_1}$$

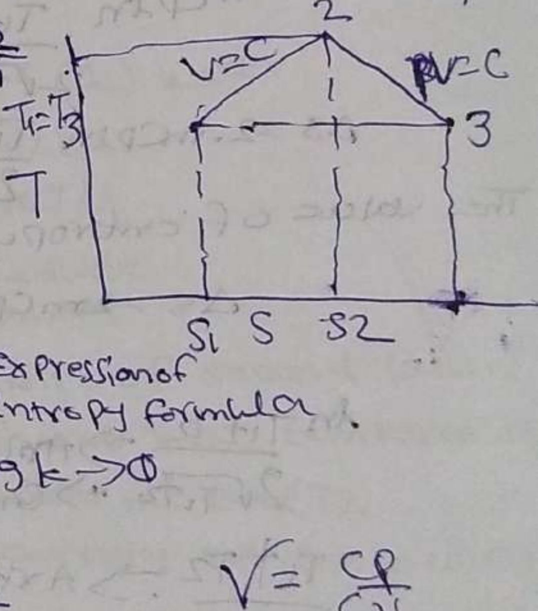
$$S_2 - S_1 = C_v \ln \frac{P_2}{P_1} + C_p \ln \frac{V_2}{V_1}$$

(ii) Index 'n' = ?

① constant volume

② $PV^n = C$

③ $T_1 = T_3$



$$S_2 - S_1 = mc_v \ln \frac{T_2}{T_1}$$ → Expression of entropy formula.

$$S_2 - S_1 = C_v \ln \frac{T_2}{T_1} \text{ kJ/kgK} \rightarrow ①$$

$$S_3 - S_2 = \frac{\gamma - n}{1 - n} C_v \ln \frac{T_3}{T_2} \qquad \gamma = \frac{C_p}{C_v}$$

$$= C_v \frac{\frac{C_p}{C_v} - n}{1 - n} \ln \frac{T_3}{T_2}$$

$$S_3 - S_2 = \frac{C_p - nC_v}{1 - n} \ln \frac{T_1}{T_2}$$

A/C to problem → $S_2 - S_1 = S_3 - S_2$

$$C_v \ln \frac{T_3}{T_1} = \frac{C_p - nC_v}{1 - n} \ln \frac{T_1}{T_2}$$

$$C_v \ln \frac{T_2}{T_1} = \frac{C_p - nC_v}{n - 1} \ln \frac{T_2}{T_1}$$

$$c_v = \frac{c_p - nc_v}{n-1}$$

$$c_v(n-1) = c_p - nc_v$$

$$nc_v - c_v = c_p - nc_v$$

$$nc_v + nc_v = c_p + c_v$$

$$2nc_v = c_p + c_v$$

$$\frac{c_p}{c_v} = \gamma$$

$$c_p = \gamma c_v$$

$$2n\,c_v = \gamma c_v + c_v$$

$$2n = \gamma + 1$$

$$n = \frac{\gamma+1}{2}$$

(iii)

① constant volume $= c_v(T_2 - T_1)$

② polytropic $= c_v(T_2 - T_1)$

polytropic:

$$Q_{2-3} = (u_3 - u_2) + w_{2-3}$$

$$\delta Q = \delta u + \delta w$$

$$w_{2-3} = \frac{p_2v_2 - p_3v_3}{n-1}$$

$$w_{2-3} = \frac{R(T_2 - T_3)}{n-1}$$

$$Q_{2-3} = c_v(T_3 - T_2) + \frac{R(T_2 - T_3)}{n-1}$$

$$= (T_2 - T_3)\left[\frac{R}{n-1} - c_v\right]$$

$$= (T_2 - T_3)\ c_p - c_v$$

$$= (T_2 - T_3)\left[\frac{c_p - c_v}{\frac{\gamma+1}{2} - 1} - c_v\right]$$

$$= (T_2 - T_3)\left[\frac{2(c_p - c_v)}{\gamma + 1 - 2} - c_v\right]$$

$$= (T_2 - T_3)\left[\frac{2c_p - 2c_v - \gamma c_v + c_v}{\gamma - 1}\right]$$

$$= (T_2 - T_3)\left[\frac{2c_p - c_v - \gamma c_v}{\gamma - 1}\right]$$

$$= (T_2 - T_3)\left[\frac{2\gamma c_v - c_v - \gamma c_v}{\gamma - 1}\right]$$

$$= (T_2 - T_3)\left(\frac{\gamma c_v - c_v}{\gamma - 1}\right)$$

$$= (T_2 - T_3)\left(\frac{c_v\cancel{(\gamma-1)}}{\cancel{\gamma-1}}\right)$$

$$= c_v(T_2 - T_3)$$

$$Q_{2-3} = c_v(T_2 - T_1)$$

$$\boxed{\therefore Q_{1-2} = Q_{2-3}}$$

$$cv = \frac{cp - ncv}{n-1}$$

$$cv(n-1) = cp - ncv$$

$$ncv - cv = cp - ncv$$

$$ncv + ncv = cp + cv$$

$$2ncv = cp + cv$$

$$\frac{cp}{cv} = \gamma$$

$$cp = \gamma cv$$

$$2n\, cv = \gamma cv + cv$$

$$2n = \gamma + 1$$

$$n = \frac{\gamma + 1}{2}$$

(iii)

① constant volume $= cv(T_2 - T_1)$

② polytropic $= cv(T_2 - T_1)$

polytropic:

$$Q_{2-3} = (u_3 - u_2) + w_{2-3}$$

$$\delta Q = \delta u + \delta w$$

$$w_{2-3} = \frac{p_2 v_2 - p_3 v_3}{n-1}$$

$$w_{2-3} = \frac{R(T_2 - T_3)}{n-1}$$

$$Q_{2-3} = cv(T_3 - T_2) + \frac{R(T_2 - T_3)}{n-1}$$

$$= (T_2 - T_3)\left[\frac{R}{n-1} - cv\right]$$

$$= (T_2 - T_3)\; cp - cv$$

$$= (T_2 - T_3)\left[\frac{cp - cv}{\frac{\gamma+1}{2} - 1} - cv\right]$$

$$= (T_2 - T_3)\left[\frac{2(cp - cv)}{\gamma + 1 - 2} - cv\right]$$

$$= (T_2 - T_3)\left(\frac{2cp - 2cv - \gamma cv + cv}{\gamma - 1}\right]$$

$$= (T_2 - T_3)\left[\frac{2cp - cv - \gamma cv}{\gamma - 1}\right]$$

$$= (T_2 - T_3)\left[\frac{2\gamma cv - cv - \gamma cv}{\gamma - 1}\right]$$

$$= (T_2 - T_3)\left(\frac{\gamma cv - cv}{\gamma - 1}\right)$$

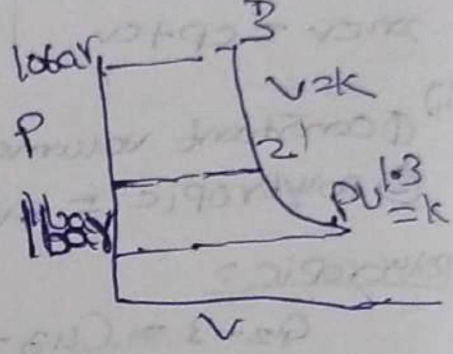
$$= (T_2 - T_3)\left(\frac{cv\cancel{(\gamma - 1)}}{\cancel{\gamma - 1}}\right)$$

$$= cv(T_2 - T_3)$$

$$Q_{2-3} = cv(T_2 - T_1)$$

$$\boxed{\therefore Q_{1-2} = Q_{2-3}}$$

① 0.2 m³ of air at 1 bar and 60°c is compressed to 0.05 m³ according the law $pv^{1.3} = c$. Now the heat is added at constant volume until its pressure is 10 bar calculate the change in entropy in each process undergoes



$pv^{1.3} = k$

constant volume process

$s_2 - s_1$ & $s_3 - s_2$

mass of air $= \frac{p_1 v_1}{RT_1}$

$= \frac{1 \times 10^2 \times 0.2}{0.287 \times (273 + 60)}$

$\boxed{m = 0.209 \text{ kg}}$

$p_1 v_1^n = p_2 v_2$

$p_2 = \frac{p_1 v_1^n}{v_2^n}$

$= 1\left(\frac{0.02}{0.05}\right)$

$p_2 = 6.062$ bar

$\frac{T_1}{T_2} = \left(\frac{p_2}{p_1}\right)^{\frac{\gamma}{n}}$

$T_2 = (273 + 60)\left(\frac{6.062}{1}\right)$

$T_2 = 504.65 k$

$s_2 - s_1 = mR \frac{\gamma - n}{\gamma - 1} \ln \frac{T_2}{T_1}$

$= 0.2092 \left(\frac{1.4 - 1.3}{1.4 - 1}\right) \frac{0.287}{\frac{0.05}{0.2}}$

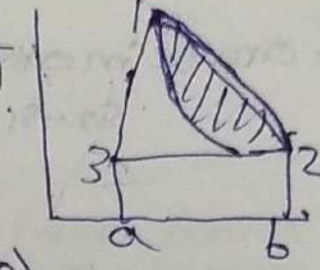
$s_2 - s_1 = -0.0208 \text{ kJ/kg}$

$s_3 - s_2 = mc_v \ln \frac{p_3}{p_2}$

$= 0.209 \times 0.718 \ln \frac{10}{6.062}$

$s_3 - s_2 = 0.0619 \text{ kJ/k}$

$\delta a = \frac{\delta q}{T}$



Heat abosrbed = Area of Δ + Area of rectangle

$Q_{Approximate} = \frac{1}{2}(S_1 - S_2)(T_2 - T_1) + (S_1 - S_2)(T_1 - 0)$

$= S_1 - S_2\left(\frac{T_2 - T_1}{2} + T_1\right)$

$Q_{Approximate} = S_1 - S_2\left(\frac{T_1 + T_2}{2}\right)$

$S_1 - S_2 = \frac{Q_{Appr}}{\frac{T_1 + T_2}{2}} = \frac{Q_{appr}}{T_M}$

(b) Initial conditions → $T_1 V_1 P_1$
Final conditions → $T_2 V_2 P_2$

$P_1 V_1 = mRT_1$

$V_1 = \frac{mRT_1}{P_1}$

$= \frac{0.25 \times 0.318\,(273 + 20)}{1 \times 10^2}$ $= V_1 = 0.232\,m^3$

$T_2 = T_1 \times \left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}}$

$= (273 + 20)\left(\frac{8}{1}\right)^{\frac{0.25}{1.25}}$

$\boxed{T_2 = 444.1\,k}$

$V_2 = V_1\left(\frac{P_1}{P_2}\right)^{1/n} = 0.232\left(\frac{1}{8}\right)^{\frac{1}{0.25}}$

$V_2 = 0.439\,m^3$

W.D during Polytropic $= \frac{P_1 V_1 - P_2 V_2}{n-1}$

$= \frac{1 \times 10^2 \times 0.232 - 8 \times 10^2 \times 0.043}{1.25 - 1}$

$W.D = -47.2\,kJ$

③ Heat transfer $= \frac{\gamma - n}{\gamma - 1} \times W.D$

$= \frac{1.437 - 1.25}{1.437 - 1}(-47.2)$

$q = -20.19\,kJ$

4. change in entropy

$$S_2 - S_1 = mc_v \frac{\gamma - n}{n-1} \ln \frac{P_1}{P_2}$$

$$= 0.025 \times 0.727 \times \frac{1.437 - 1.25}{1.25 - 1} \ln \frac{1}{8}$$

$$S_2 - S_1 = -0.056 \text{ kJ}$$

⑤ $S_2 - S_1 = \frac{Q_{app}}{T_m}$

$$S_2 - S_1 = \frac{-20.19}{\frac{293 - 1444.1}{2}}$$

$$S_2 - S_1 = -0.0544$$

$$\text{Error} = \frac{0.0564 - 0.0544}{0.0564} \times 100$$

$\%$ Error $= 3.546 \%$

Calculate the decrease in available energy when 25kg water at 95°C mix with 35kg of water at 35°C The pressure being taken as constant and the temperature of surrounding being 15°C Cp of water = 4.2kJ/kg

The available energy of a system is given by 25kg

$$mc_p \int_{T_0}^{T} \left(1 - \frac{T_0}{T}\right) dT \qquad \boxed{\frac{25\text{kg}}{95^\circ C}}$$

$$(A.E)_{25} = 25 \times 4.2 \int_{273+15}^{273+95} \left[1 - \frac{273+15}{T}\right] dT$$

$$= 105 \left(T - 288 \ln T\right)_{288}^{368}$$

$$= 105 \left(368 - 288 - 288 \ln \frac{368}{288}\right)$$

$$(A.E)_{25} = 987.49 \text{ kJ}$$

The available energy of a system is given by 35kg

$$(A.E)_{35} = 35 \times 4.2 \int_{273+15}^{273+75} \left(1 - \frac{273+15}{T}\right) dT$$

$$= 35 \times 4.2 \left(308 - 288 \cdot \ln \frac{308}{288}\right)$$

$$(A.E)_{35} = 97.461 \text{ kJ}$$

$(AE)_{35} \sim (AE)_{25}$

$= 987.49 - 97.46$

$= 890.03$ kJ

A system at 500K recieves 7200 kJ/min from a source at 1000K. The temperature of atmosphere in 300K. Assuming that the temperature of system and source remain constant during heat transfer find out :

(i) The entropy produced during heat transfer

(ii) The decreases in available energy after heat transfer

i) Net change in entropy :-

Source $= \frac{-Q}{T_1} = \frac{-7200}{1000} = -7.2$ kJ/min k.

System $= \frac{Q}{T_2} = \frac{7200}{500} = 14.4$ kJ/min k

Net change in entropy $= -7.2 + 14.4 = 7.2$ kJ/min

(ii) Decrease in available energy :-

$(A.E)_{at\ source} = (1000 - 300) \times 7.2 = 5040$ kJ

$(A.E)_{System} = (500 - 300) \times 14.4 = 2880$ kJ

Decrease in A.E $= 5040 - 2880$

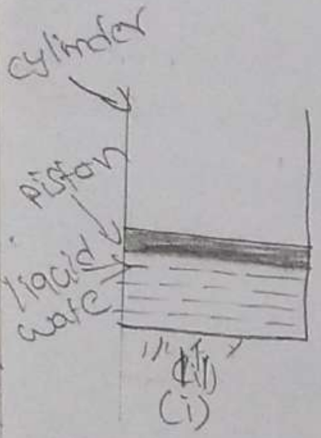
$= 2160$ kJ

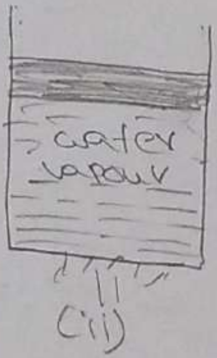
Unit-IV

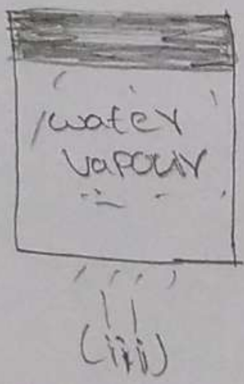
Properties of pure substance

Defin of pure substance:- A pure substance is a system which is

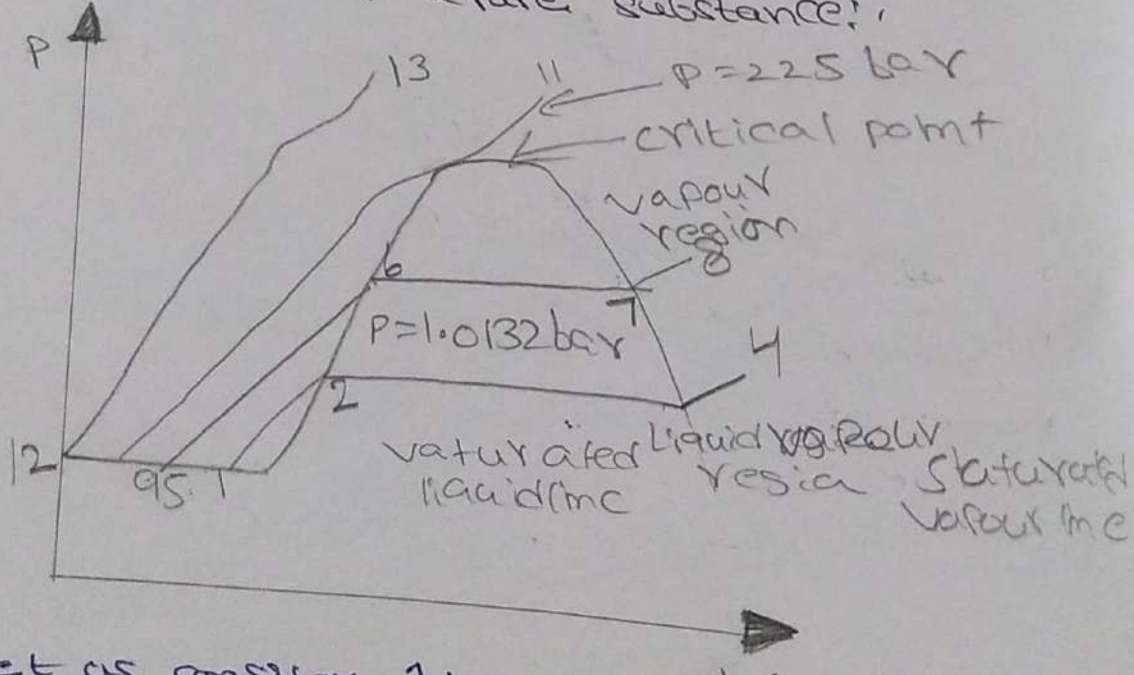
1. Homogenius in composition
2. Homogenius in chemical agrigation
3. In variable in chemical agrigatio







Phase change of a pure substance:



Let as consider 1 kg of liquid at temperature 20°C when the water is heated slowly the temperature of liquid water becomes 100°C and is indicated by the line 1-2. The volume increases slightly when liquid attains 100°C if heating is contianed it undergoes a change in phase represented by the line 2-3.

* when all the liquid have evaprated if heat is for that added the temperatur

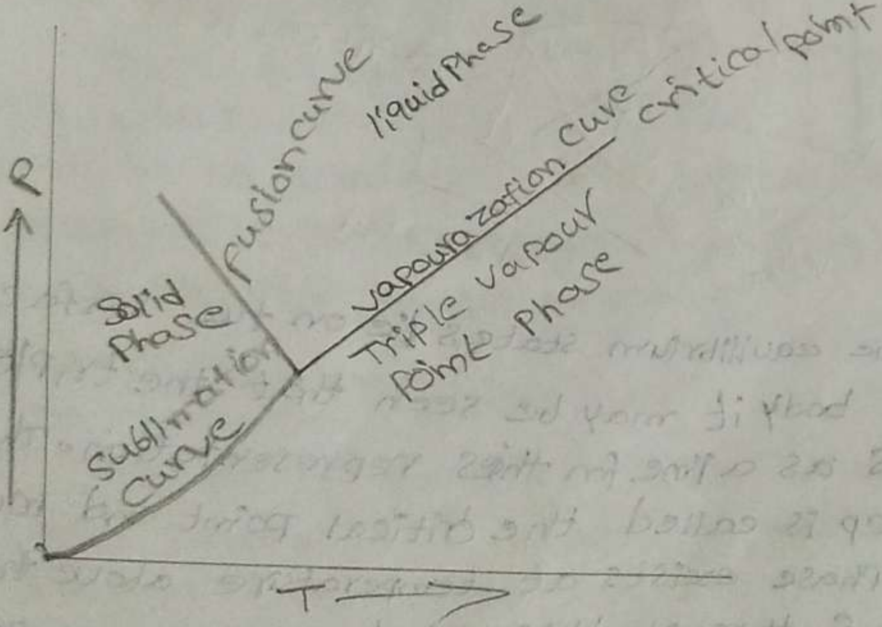
vapour increases and is represented by the line 3-4.

* If the heating takes place at 12 bar with an initial temperature of 20°c until the liquid water is converted into super heated steam then curve 5-6-7-8 will represented the process.

* If heating is done at constant pressure of 225 bar it is represented by the curve 9-10-1

* The curve 12-13 represents a constant pressur heating process when the pressure is greater than constant pressure, At this state the liquid water is directly converted into super heated steam.

P-T diagram for a pure substance



The points representing the co-existing of solid and vapour line on the sublimation curve.

* Liquid and vapour line on the vapourisation curve.

* Liquid and solid line on the fusion curve.

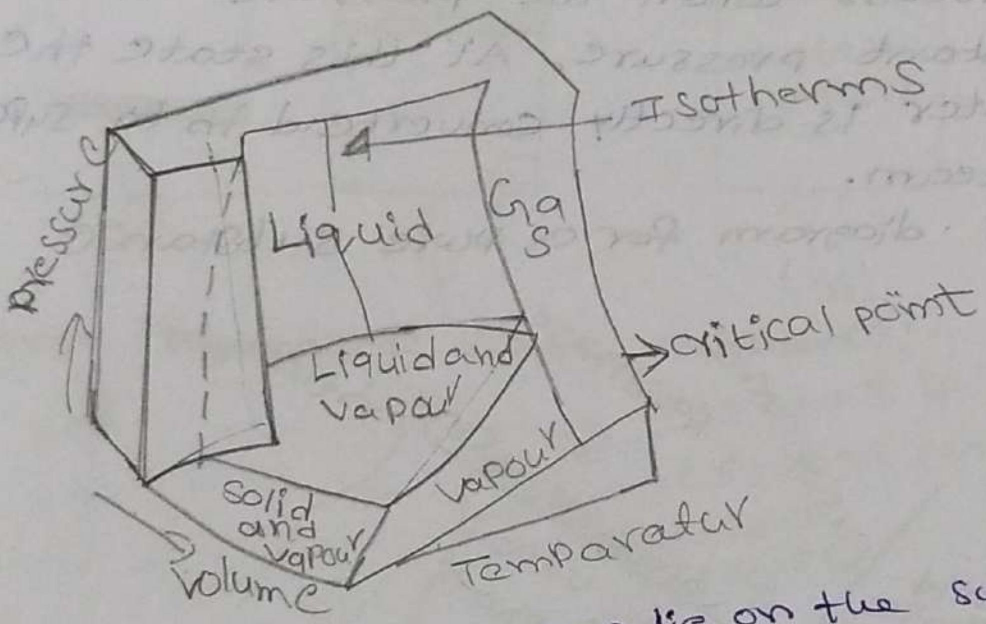
The slopes of sublimation and vapourisation curves for all the substance are positive. The slope of the fusion curve may be positive or negative.

The fusion curve of most substance have a positive slope water is on of the important Exceptions:

Triple point:-

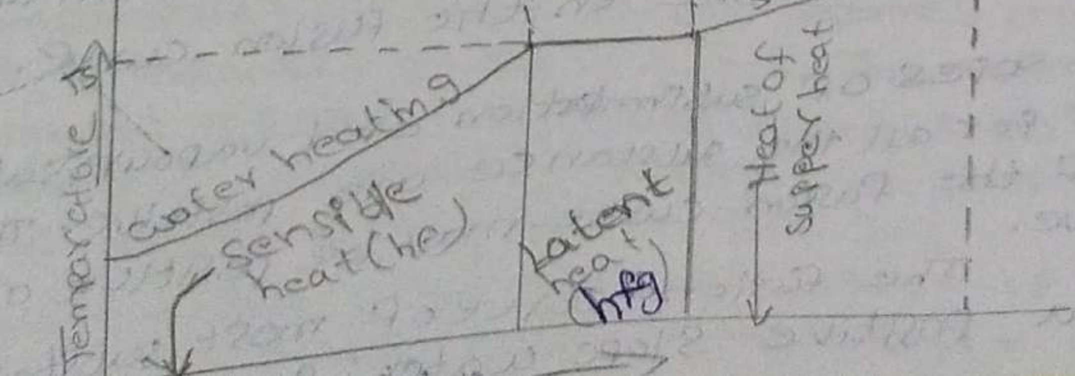
It is the point of intersection a sublimation and vapourisation curves on P-T diagram the triple point is represented by a point on P.T diagram it is a line and an uv diagram it is a triangle

P.V.T - diagram - Isometric View:



All the eauilibrium states lie on the surface of the body it may be seen that the triple appears as a line in this representation. The Point cp is called the critical point and how liquid phase exists at temperature above the isotherms through this point. The term evaporatio is meaning less at this situation

Graphical represention of formation of Steam



Important terms relating steam formation:-

1. Sensible heat of water (h_f)

It is defined as the quantity of heat observed by 1kg of water, when it is heated from 0°c. It is called enthalpy of water.

It is counted from 0°c where sensible heat is taken as 0°c. If 1kg of water is heated from 0°c to 100°c the sensible heat added to it will be,

$$\underset{C_p}{\underbrace{4.18}}(100-0)=418\ kJ$$

But if the water is at same 20°c. Then the sensible heat added will be

$$4.18(100-20)=334.4\ kJ$$

2. Latent heat (h_{fg})

It is the amount of heat reacuired to convert water at a given temperature and pressure in to steam at same pressure and temparature it is expressed by (h_{fg}) and value is available in steam table.

3. Dryness fraction (x) :-

The term dryness fraction is related with wet steam. It is defined as the ratio of the mass of actual dry steam to the mass of steam contining it. It is usually expressed by the symbol (x)

$$x=\frac{m_s}{m_s+m_w}$$

$$x=\frac{m_s}{m_s+m_w}$$

m_s = mass of dry steam

m_w = mass of wet steam

note:- no steam can be completely dry unsaturated / so all as it is in contact with water.

4. Total heat (or) Enthalpy of wet steam:

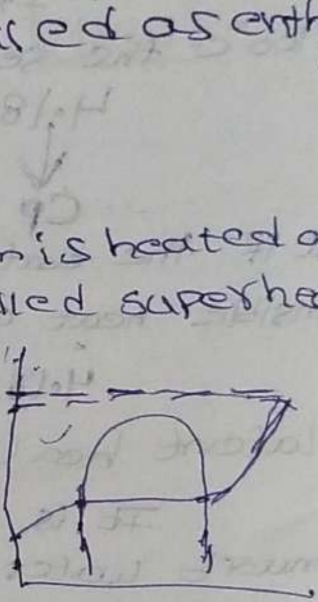
It is defined as the quantity of required to convert 1kg of water at 0°c into wet steam at constant pressure. It is the sum of total heat of water and the latent heat and this called as enthalpy

$$h = h_f + x \cdot h_{fg}$$

Super heated steam:- when steam is heated after it has becomes dry and saturated it is called superheated steam

$$h = h_f + x\, h_{fg}$$

$h = h_f + h_y + C_{P3}($[illegible]$-$[illegible]$)$



calculate the dryness fraction inpackes (quality of steam which has 1.5kg of water in suspension with 50kg of steam.

$$x = \frac{m_s}{m_s + m_w} = \frac{50}{50 + 1.5} = 0.97$$

A vessel having a capacity of 0.05 m³ contains a mixture of saturated water and saturated steam at temperature of 245°c the mass of liquid present is 10kg find the following

1) The pressure
2) The mass
3) The specific volume
4) The specific enthalpy
5) The specific internal energy

$p = 36.5$ bar

$v_f = 0.001240\ m^3/kg$

$v_g = 0.054606\ m^3/kg$

$h_f = 1061.6\ kJ/kg$

$h_{fg} = 1740.0\ kJ/kg$

$s_f = 2.748\ kJ/kgK$

$s_g = 3.358\ kJ/kgK$

i) 36.5 bar

ii) volume of liquid $= V_f = \cancel{m_f} v_f$

$= 10 \times 0.00124$

$V_f = 0.0124\ m^3$

$V = V_f + V_g$

$0.05 = 0.0124$

$V_g = 0.05 - 0.012$

$V_g = 0.0376m$

volume of vapour $= V_g = 0.05 - 0.0124$ (calc)

$= 0.0376\ m^3$

$$m_g = \frac{V_g}{v_g} = \frac{0.0376}{0.054606} = 0.68$$

$m = m_f + m_g$

$= 10 + 0.68$

$\boxed{m = 10.68}$ kg

iii) specific volume

$v = v_f + x v_{fg}$

$$x = \frac{0.68}{0.68 + 10} = 0.063$$

$v = 0.00124 + 0.063 \times 0.05$

$v = 0.00424\ m^3/kg$

iv) $h = h_f + x h_{fg}$

$= 1061.6 + 0.063 \times 1740.0$

$h = 1171.22\ kJ/kg$

v) $s = s_f + x s_{fg}$

$s = 2\cdot9575$ kJ/kgk

(vi) $u = h - PV$

$$= 1171\cdot22 - \frac{36.5 \times 10^5 \times 0.00427}{1000}$$

$u = 1155.74$ kJ/kg

Determine the amount of heat which should be supplied to 2kg of water at 25°c to convert it into steam at 5 bar and point 9 dry

Given data

$\dot{m}_w = 2$ kg

$t_w = 25°$c

$p, x = 5$ bar, 0.9 bar

$h_f = 640.1$ kJ/kg

$h_{fg} = 21.074$ kJ/kg

$h = h_f + x h_{fg} = 2536.76$ kJ/kg

Sensible heat $= m_w c_{pw} (25-0)$

$= 1 \times 4.18 (25-0)$

$= 104.5$ kJ

Quantity of heat supplied per kg

$2536.76 - 104.5$

$= 2432.26$ kJ

$= 2 \times 2432.26 = 4864.52$ kJ

what amount of heat would be required to produced 4.4 kg of steam at pressure of 6 bar and temperature of 250°c from water at 30°c take $C_{ps} = 2.12$

6 bar and 250°C

$t_s = 158.8$°C

$h_f = 670.4$ kJ/kg

$h_{fg} = 2085.0$ kJ/kg

$h_{sup} = h_f + h_{fg} + c_{ps}(T_{sup} - T_s)$

$= 670.4 + 2085.0 + 2.2(250 - 158.8)$

$h_{sup} = 2956.04$ kJ

$2956.04 - 125.4$

$= 2830.64$

Total amount of heat required

$= 44 \times 2830.64 = 12454.81$ kJ

Find the specific vallume, enthrophy and internal energy of wet steam at pressure is 18 drayness fraction x = 0.85

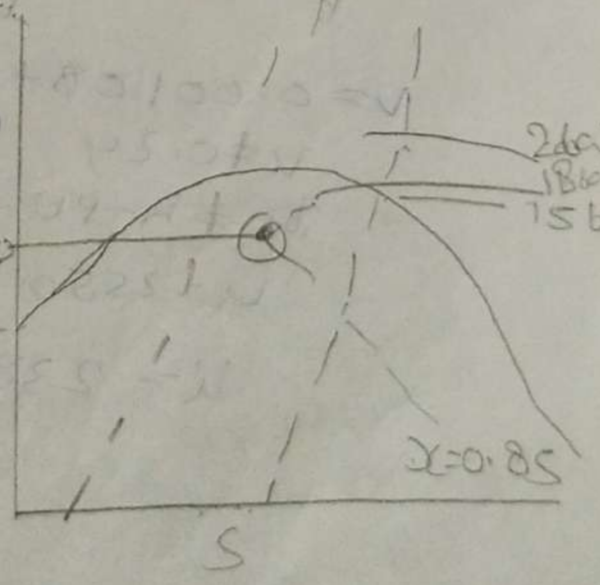
Sp vol = 0.09, 00935 m^3/kg

h = 2510 kJ kg

u = h − pV

$= 2510 - \frac{18\times10^5\times 009}{1000}$

u = 2348 kJ/kg



$v = v_f + x v_{fg}$

$h = h_f + x h_{fg}$

$v = 0.00168$ $fg = 0.109162$ m^3/kg

$h_f = 884.5$ $h_{fg} = 19103$ kJ/kg

Find the drayness fraction, specific volume and internal energy of a steam at 7 Bar and enthalpy 2550 kg/kg

Given data

Pressure $(P) = 7$ bar

Entholpy $(h) = 2550$

$hf = 697.1$

$hfg = 2064.9$

$h = hf + x \cdot hfg$

~~2550 = 697.1 + x.2064.9~~

$2550 = hf + x \cdot hfg$

$\frac{2550}{hfg} = x + hf$

~~697.1 + x 2064.9 =~~

$x = \frac{2550}{hfg} - hf$

~~2550 = h~~

$x = \frac{2550}{2064.9} - 697.1$

$x = 0.89$

$v = vf + x \cdot vfg$

$vfg = 0.27268 - 0.001108$

$vfg = 0.27152$

$v = 0.001108 + (0.89)\, 0.27152$

$v = 0.24$

$u = h - PV$

$u = 2550 - \left(\frac{7 \times 105 \times 0.24}{1000}\right)$ -168

$u = 2382 \frac{kJ}{kg}$

Unit- 4
Chapter-2
Maxwells relation
U; H, G, F

Givps free energy function:- It is defined as the difference b/w the enthlophy and the product of temperature and entrophy

$G = H - TS$

Hemholtz's free energy function:- It is defined as the difference b/w the internal energy and entrophy and the product of temperature

$F = U - TS$

Differential relation for U, H, G, F with the help of first and second law of thermodynamic

$\delta q - \delta w = du$

$\frac{\delta Q}{T} = \frac{pdv}{T} = \frac{du}{T}$

$ds = \frac{pdv}{T} + \frac{du}{T}$

$Tds = pdv + du$

$du = Tds - pdv \rightarrow ①$

$Tds = pdv + du$

$\boxed{H = U + PV}$

$= pdv + d(H - PV)$

$= \cancel{pdv} + dH - \cancel{pdv} - vdP$

$H = U + PV$

$U = H - PV$

$Tds = dH - vdP$

$H = U + PV$

$H = U + PV$

$dH = Tds + vdP - ②$

$U \; H - PV$

$G = H - TS$

$dG = dH - Tds - SdT$

$= \cancel{Tds} + vdp - \cancel{Tds} - SdT$

$dG = Vdp - SdT \rightarrow ③$

$F = U - TS$

$dF = du - Tds - SdT$

$= \cancel{Tds} - pdv - \cancel{Tds} - SdT$

$dF = -(pdv + SdT) \rightarrow ④$

~~daf~~ From eq ① we can say u is a function of S, V

And differentaiting paratillay:

$du = \left(\frac{\partial u}{\partial S}\right)_V dS + \left(\frac{\partial u}{\partial V}\right)_S dV$

But $du = TdS - PdV$

$Tds - pdv = \left(\frac{\partial u}{\partial s}\right)_v ds + \left(\frac{\partial u}{\partial v}\right)_S \cancel{pdv}$

On comparing ds and dv terms

$\left(\frac{\partial u}{\partial s}\right)_v = T \quad \left(\frac{\partial u}{\partial V}\right)_S = -p \rightarrow ⑤$

From eq ② H is a function of S, P

Applying partiall derivatives

$H = f(S, P)$

$dH = \left(\frac{\partial H}{\partial S}\right)_P dS + \left(\frac{\partial H}{\partial P}\right)_S dP$

$dH = TdS + VdP$

$TdS + VdP = \left(\frac{\partial H}{\partial S}\right)_P dS + \left(\frac{\partial H}{\partial P}\right)_S dP$

$\left(\frac{\partial H}{\partial S}\right)_P = T \quad \left(\frac{\partial H}{\partial P}\right)_S = V \rightarrow ⑥$

From eq ③ G is a function of P, T

Applying partial derivatives

$G = (P, T)$

$dG = \left(\frac{\partial G}{\partial P}\right)_T dP + \left(\frac{\partial G}{\partial T}\right)_P dT$

$dG = VdP - SdT$

$VdP - SdT = \left[\frac{\partial G}{\partial P}\right]_T dP + \left[\frac{\partial G}{\partial T}\right]_P dT$

$\left[\frac{\partial G}{\partial P}\right]_T = V \quad \left[\frac{\partial G}{\partial T}\right]_P = -S$ — ⑦

From eq ④ F is a function of V, T

Applying partial derivatives

$F = (V, T)$

$dF = \left(\frac{\partial F}{\partial V}\right)_T dV + \left(\frac{\partial F}{\partial T}\right)_V dT$

But

$dF = -(P\,dV + S\,dT)$

$-(P\,dV + S\,dT) = \left(\frac{\partial F}{\partial V}\right)_T dV + \left(\frac{\partial F}{\partial T}\right)_V dT$

$\left(\frac{\partial F}{\partial V}\right)_T = -P, \quad \left(\frac{\partial F}{\partial T}\right) = -S \rightarrow$ ⑧

comparing ~~6~~, 7, 8.

~~$P = \frac{\partial H}{\partial S}$~~ $\quad -P = \left(\frac{\partial U}{\partial S}\right)_S =$

$T = \left(\frac{\partial U}{\partial S}\right)_V$ ✓

$T =$ $\quad T = \left(\frac{\partial H}{\partial S}\right)_P$

$V = \left(\frac{\partial H}{\partial P}\right)_S$

$V = \left(\frac{\partial G}{\partial P}\right)_T$

$-S = \left(\frac{\partial G}{\partial T}\right)_P$

$\left(\frac{\partial F}{\partial V}\right)_T = P$

From eq ⑤

$$\left(\frac{\partial u}{\partial s}\right)_v = T \quad \& \quad \left(\frac{\partial u}{\partial v}\right)_s = -P$$

Differentiating eq ⑤ s's first term with respect to V treating s's constant and second term with respects to s treating v constant

$$\frac{\partial^2 u}{\partial v \partial s} = \left(\frac{\partial T}{\partial v}\right)_s \quad \& \quad \frac{\partial^2 u}{\partial v \partial s} = -\left(\frac{\partial P}{\partial s}\right)_v$$

$$\left(\frac{\partial T}{\partial v}\right)_s = -\left(\frac{\partial P}{\partial s}\right)_v \rightarrow ⑨$$

~~From eq ⑥~~

Eq ⑨ is ~~[illegible]~~ known as maxwells relation u.

From eq ⑥

$$\left(\frac{\partial H}{\partial S}\right)_P = T \quad \& \quad \left(\frac{\partial H}{\partial P}\right)_S = V$$

Differenting first term with respect to P treating S as constant and second term with respect to S treating P constant

$$\frac{\partial^2 H}{\partial P \partial S} = \left(\frac{\partial T}{\partial P}\right)_S \quad \& \quad \frac{\partial^2 H}{\partial P \partial S} = \left(\frac{\partial V}{\partial S}\right)_P$$

$$\left(\frac{\partial T}{\partial P}\right)_S = \left(\frac{\partial u}{\partial S}\right)_P \rightarrow ⑩$$

eq ⑩ is known as maxwells relation from H

From eq ⑦

$$\left(\frac{\partial G}{\partial P}\right)_T = V \quad \left(\frac{\partial G}{\partial T}\right)_P = -S$$

Differenting first term with respect to T treating P as constant and second term with respects to P treating T as constant

$$\frac{\partial^2 G}{\partial T \partial P} = \left(\frac{\partial V}{\partial T}\right)_P \quad \& \quad \frac{\partial^2 u}{\partial T \partial P} = \left(\frac{-\partial S}{\partial P}\right)_T$$

$$\left(\frac{\partial V}{\partial T}\right)_P = -\left(\frac{\partial S}{\partial P}\right)_T \rightarrow ⑪$$

Eq ⑪ is known as maxwells relation from g

from eq ⑧

$(\frac{\partial F}{\partial V})_T = -P$ & $(\frac{\partial F}{\partial T})_V = -S$

Differentims first term with respect to T treating V as constant and second term with respect to V treating T as constant

$\frac{\partial^2 F}{\partial V \partial T} = -(\frac{\partial P}{\partial T})_V$ & $\frac{\partial^2 F}{\partial T \partial V} = -(\frac{\partial S}{\partial V})_T$

$-(\frac{\partial P}{\partial T})_V = -(\frac{\partial S}{\partial V}) \to$ ⑫

The above eq 12 is the maxwells relation from F

T, V
T, P
P, V

various forms of TDS equation

Let asme as S a fonction of (T, V)

$ds = (\frac{\partial S}{\partial T})_V dT + (\frac{\partial S}{\partial V})_T dV$

$(\frac{\partial S}{\partial T})_V = \frac{C_V}{T}$ $(\frac{\partial S}{\partial V})_T = (\frac{\partial P}{\partial T})_V$

(T, V)
(T, V)
T, P
P, V

$ds = \frac{CV}{T} \cdot dT + (\frac{\partial P}{\partial T})_V dV$

$Tds = CV dT + (\frac{\partial P}{\partial T})_V dV$ T

The above equation as first TDS equation

T, V
T, P

$S = f(T, P)$

$ds = (\frac{\partial S}{\partial T})_P ds + (\frac{\partial S}{\partial P})_T dP$

$(\frac{\partial S}{\partial T})_P = \frac{CP}{T}$ $(\frac{\partial S}{\partial P})_T = -(\frac{\partial V}{\partial T})_P$

$ds = \frac{CP}{T} dT - (\frac{\partial V}{\partial T})_P dP$

$Tds = CP dT - (\frac{\partial V}{\partial T})_P dP$ T

The above eq was second T.D.S equation

$s = f(P, V)$

$$\partial s = \left(\frac{\partial S}{\partial P}\right)_V dP + \left(\frac{\partial S}{\partial V}\right)_P dV$$

Asume

$$\left(\frac{\partial S}{\partial P}\right)_V \left(\frac{\partial P}{\partial T}\right)_V \left(\frac{\partial T}{\partial S}\right)_V = 1 \qquad \boxed{S, P, T}$$

$$\left(\frac{\partial S}{\partial P}\right)_V = \left(\frac{\partial T}{\partial P}\right)_V \left(\frac{\partial S}{\partial T}\right)_V$$

$$\left(\frac{\partial S}{\partial P}\right)_V = \left(\frac{\partial T}{\partial P}\right)_V \frac{C_V}{T} \rightarrow ①$$

T, V
T, P
P, V

$$\left(\frac{\partial S}{\partial V}\right)_P \left(\frac{\partial V}{\partial T}\right)_P \left(\frac{\partial T}{\partial S}\right)_P = 1 \qquad S, V, T$$

$$\left(\frac{\partial S}{\partial V}\right)_P = \left(\frac{\partial T}{\partial V}\right)_P \left(\frac{\partial S}{\partial T}\right)_P$$

$$\left(\frac{\partial S}{\partial V}\right)_P = \left(\frac{\partial T}{\partial V}\right)_P \frac{C_P}{T} \rightarrow ②$$

substituting ① and ② TDS

$$ds = \frac{C_V}{T}\left(\frac{\partial T}{\partial P}\right)_V dP + \frac{C_P}{T}\left(\frac{\partial T}{\partial V}\right)_P dV$$

$$Tds = C_V\left(\frac{\partial T}{\partial P}\right)_V dP + C_P\left(\frac{\partial T}{\partial V}\right)_P dV \rightarrow ③$$

The above eq③ has the Third TDS equation.

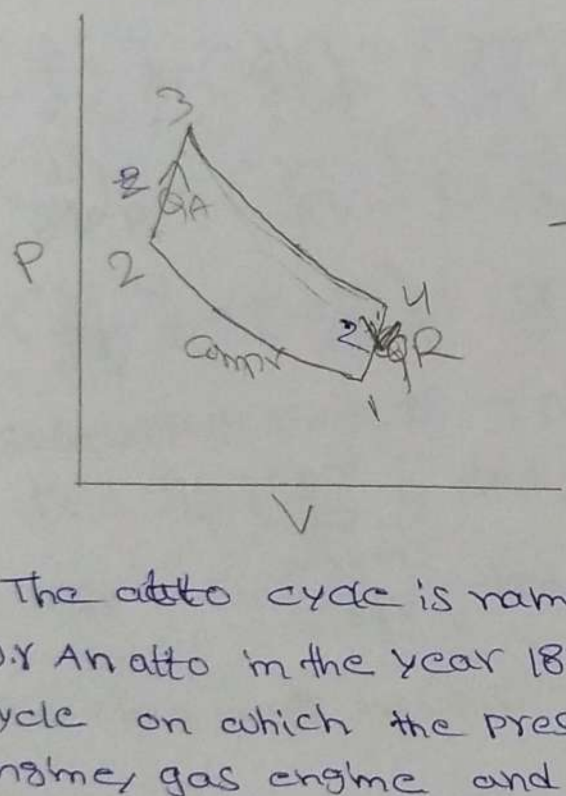
Unit-V

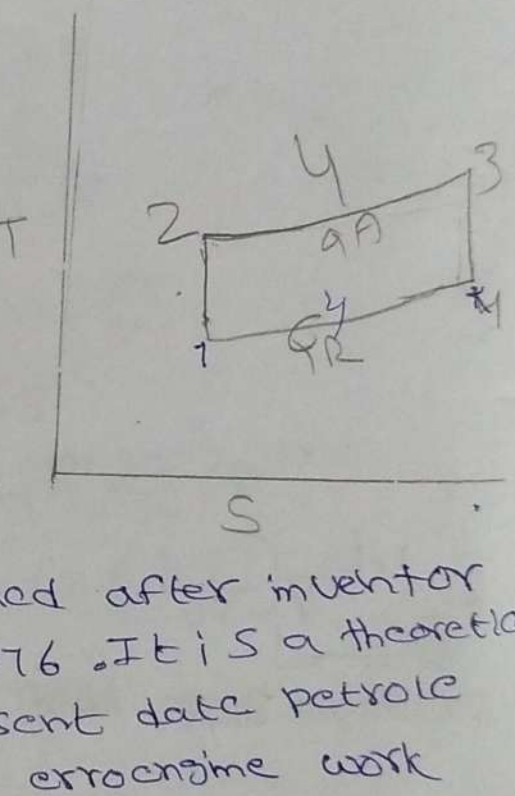
Chapter-2

Gas power cycles

1) carnot cycle
2) otto cycle
3.) Diesel cycle
4) Dual cycle
5) compreson of cycles

otto cycle :-





The otto cycle is named after inventor D.r An atto in the year 1876. It is a theoretical cycle on which the present date petrole engine, gas engine and erroengine work

$$Q_A = Q_{2-3} = C_v(T_3 - T_2)$$

$$Q_R = Q_{4-1} = C_v(T_4 - T_1)$$

$$W.D = Q_A - Q_R$$

$$W.D = C_v(T_3 - T_2) - C_v(T_4 - T_1)$$

$$\eta_{th} = \frac{W.D}{H.S} = \frac{C_v(T_3 - T_2) - C_v(T_4 - T_4)}{C_v(T_3 - T_2)} = 1 - \frac{T_4 - T}{(T_3 - T_2}$$

$$\underbrace{\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} = \left(\frac{V_1}{V_2}\right)^{\gamma-1}}$$

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} = \left(\frac{V_1}{V_2}\right)^{\gamma-1}$$

$$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{\gamma-1}$$

$\frac{V_1}{V_2} = r$ (compression ratio)

$$T_2 = T_1 (r)^{\gamma-1}$$

$$\frac{T_3}{T_4} = \left(\frac{V_4}{V_3}\right)^{\gamma-1}$$

$\frac{V_4}{V_3} = r$ (Expansion ratio)

$$T_3 = T_4 (r)^{\gamma-1}$$

$$\eta_{th} = 1 - \frac{T_4 - T_1}{T_4 r^{\gamma-1} - T_1 r^{\gamma-1}}$$

$$= 1 - \frac{1}{r^{\gamma-1}} \frac{T_4 - T_1}{T_4 - T_1}$$

$$\eta_{th} = 1 - \frac{1}{r^{\gamma-1}}$$

$$MEP = \frac{W.D}{V_1 - V_2}$$

$$MEP = \frac{C_V(T_3 - T_2) - C_V(T_4 - T_1)}{V_1 - V_2}$$

$$V_1 - V_2 = V_1 - \frac{V_1}{r} \quad \left(\frac{V_1}{V_2} = r\right)$$

$$= V_1 \left(1 - \frac{1}{r}\right)$$

$$= V_1 \left(1 - \frac{1}{r}\right)$$

$$V_1\left(1 - \frac{1}{r}\right)$$

$$V_1 - V_2 = \frac{RT_1}{P_1}\left(\frac{r-1}{r}\right)$$

$$P_1 V_1 = RT_1$$

$$V_1 = \frac{RT_1}{P_1}$$

$$MEP = \frac{C_V(T_3 - T_2) - C_V(T_4 - T_1)}{\frac{RT_1}{P_1}\left(\frac{r-1}{r}\right)}$$

$$= \frac{C_v[(T_3-T_2)-(T_4-T_1)]}{\frac{RT_1}{P_1}\left(\frac{r-1}{r}\right)}$$

$$= \frac{R}{\gamma-1}\left[\frac{(T_3-T_2)-(T_4-T_1)}{\frac{RT_1}{P_1}\,\frac{r-1}{r}}\right]$$

$$= \frac{1}{\gamma-1} \times \frac{P_1}{T_1} \times \frac{r}{r-1}\left[(T_3-T_2)-(T_4-T_1)\right]$$

1-2.

$$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{\gamma-1}$$

$$\boxed{T_2 = T_1 (r)^{\gamma-1}}$$

2-3

$$\frac{P_2 \cancel{V_2}}{T_2} = \frac{P_3 \cancel{V_3}}{T_3}$$

$$T_3 = \frac{P_3}{P_2} \times T_2$$

$$\frac{P_3}{P_2} = \alpha p$$

$$T_3 = \alpha p \times T_2$$

$$\boxed{T_3 = \alpha p \times T_1\, r^{\gamma-1}}$$

$$\frac{T_4}{T_3} = \left(\frac{V_3}{V_4}\right)^{\gamma-1}$$

$$\frac{T_4}{T_3} = \left(\frac{1}{r}\right)^{\gamma-1}$$

$$T_4 = \frac{T_3}{r^{\gamma-1}}$$

$$= \frac{\alpha p\, T_1\, \cancel{r^{\gamma-1}}}{\cancel{r^{\gamma-1}}}$$

$$\boxed{T_4 = \alpha p\, T_1}$$

$C_p - C_v = R$

$\frac{C_p}{C_v} = \gamma$

$C_p = C_v \gamma$

$C_v \gamma - C_v = R$

$C_v(\gamma-1) = R$

$C_v = \frac{R}{\gamma-1}$

$$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{r-1}$$

$$T_2 = T(r)^{\gamma-1}$$

2-3

$$\frac{P_2 \cancel{V_2}}{T_2} = \frac{P_3 \cancel{V_2}}{T_3}$$

$$T_3 = \frac{P_3}{P_2} \times T_2$$

$$T_3 = \alpha p \times T_2$$

$$\boxed{T_3 = \alpha p \times T_1\, r^{\gamma-1}}$$

$$\frac{T_4}{T_3} = \left(\frac{V_3}{V_4}\right)^{\gamma-1}$$

$$\frac{T_4}{T_3} = (r)^{\gamma-1}$$

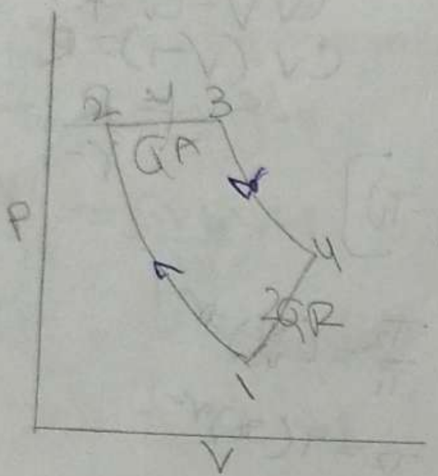
$$T_4 = T_3 (r)^{\gamma-1}$$

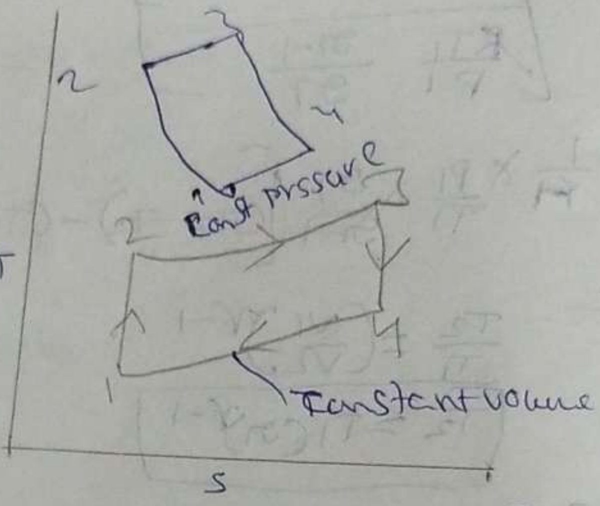
$$T_4 = \frac{\alpha p \times T_1 \cancel{r^{\gamma-1}}}{\cancel{r^{\gamma-1}}}$$

$$T_4 = \alpha p\, T_1$$

$$MEP = \frac{P_1 r(\alpha\rho-1)(r^{\gamma-1}-1)}{(r-1)(\gamma-1)}$$

Diesel cycle (constant pressure cycle)





The cycle is named as after inventer roudolf disel in 1893 who diviced this cycle for compresson, ignesion, engines

$Q_A = C_p(T_3 - T_2)$

$Q_R = C_v(T_4 - T_1)$

$$\eta_{th} = \frac{W.D}{H.S} = \frac{C_p(T_3-T_2) - C_v(T_4-T_1)}{C_p(T_3-T_2)}$$

$$\eta_{th} = 1 - \frac{T_4 - T_1}{\gamma(T_3-T_2)}$$

let $r = \frac{V_1}{V_2}$ = compre ratio

$r = \frac{V_4}{V_3} = \frac{V_1}{3}$ = Ex ratio

1-2 $\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{\gamma-1}$

$$\boxed{T_2 = T_1(r)^{\gamma-1}}$$

2-3 $\frac{\cancel{P_2}V_2}{T_2} = \frac{\cancel{P_2}V_3}{T_3}$

$T_3 = \frac{V_3}{V_2} \times T_2$

$\frac{V_3}{V_2} = \alpha_c$ (cutoff ratio)

$T_3 = \alpha_c \times T_2$

$$\boxed{T_3 = \alpha_c \times T_1 r^{\gamma-1}}$$

$$T_4 = T_3 \left(\frac{V_3}{V_4}\right)^{\gamma-1}$$

$$= T_3 \left(\frac{V_3}{V_2} \times \frac{V_2}{V_4}\right)^{\gamma-1}$$

$$= T_3 \left(\alpha_c \times \frac{1}{r}\right)^{\gamma-1} \quad \boxed{V_0 = V}$$

$$= \alpha_c \times T_1 \cancel{r^{\gamma-1}} \left(\alpha_c^{\gamma-1} \times \frac{1}{\cancel{r^{\gamma-1}}}\right)$$

$$\boxed{T_4 = \alpha_c^{\gamma} \times T_1}$$

$$\eta_{th} = 1 - \frac{1}{\gamma} \frac{(T_4 - T_1)}{(T_3 - T_2)}$$

$$\eta_{th} = 1 - \frac{1}{\gamma} \frac{(\alpha_c^{\gamma} T_1 - T_1)}{\alpha_c T_1 r^{\gamma-1} - T_1 r^{\gamma-1}}$$

$$= 1 - \frac{1}{\gamma} \frac{(\alpha_c^{\gamma} - 1)}{r^{\gamma-1}(\alpha_c - 1)}$$

$$= 1 - \frac{1}{r^{\gamma-1}} \cdot \frac{(\alpha_c^{\gamma} - 1)}{\gamma(\alpha_c - 1)}$$

$$MEP = \frac{\text{work done}}{\text{Displacemen volume}}$$

$$MEP = \frac{C_P(T_3 - T_2) - C_V(T_4 - T_1)}{V_1 - V_2}$$

$$V_1 - V_2 = V_1\left(1 - \frac{V_2}{V_1}\right)$$

$$= V_1\left(1 - \frac{1}{r}\right)$$

$$V_1 - V_2 = V_1\left(\frac{r-1}{r}\right)$$

$$P_1 V_1 = R T_1$$

$\therefore v_1 = \frac{RT_1}{P_1}$

$v_1 - v_2 = \frac{RT_1}{P_1}\left(\frac{r-1}{r}\right)$

$$\boxed{v_1 - v_2 = \frac{C_v(\gamma-1)\times T_1}{P_1}\left(\frac{r-1}{r}\right)}$$

$MEP = \frac{C_p(T_3-T_2) - C_v(T_4-T_1)}{\frac{C_v(\gamma-1)}{P_1}\times T_1\left(\frac{r-1}{r}\right)}$

$MEP = \frac{P_1 r}{(r-1)(\gamma-1)}\left[\gamma r^{\gamma-1}(\rho_c-1) - (\rho_c^{\gamma}-1)\right]$

~~$\omega \cdot D$~~ $=$

$MEP = \frac{\omega \cdot D}{v_1 - v_2}$

$v_1 - v_2$

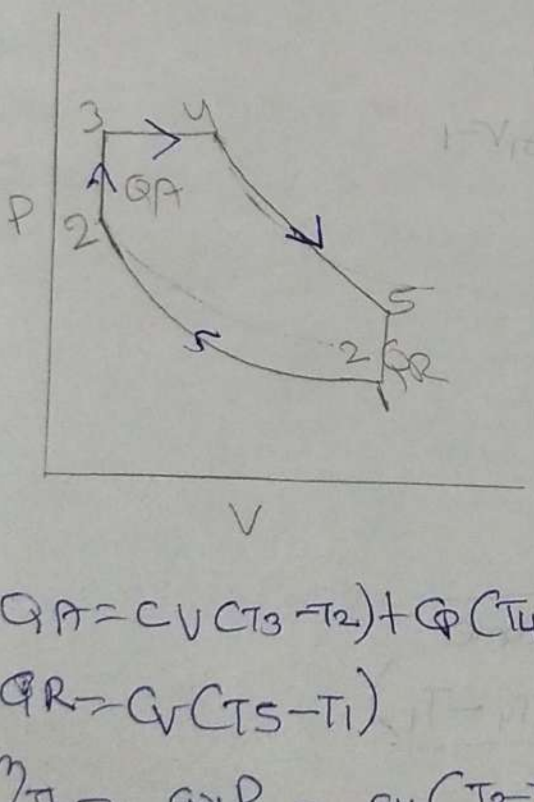
$v_1\left(1 - \frac{v_2}{v_1}\right)$

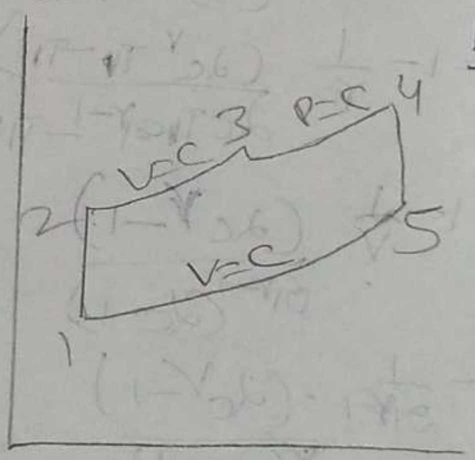
$v_1\left(1 - \frac{1}{r}\right)$

$P_1 v_1 = RT$

$v_1 = \frac{RT}{P_1}$

Dual combustion cycle (limited pressure cycle)





$\frac{RT_1}{P_1}\left(\frac{r-1}{r}\right)$

$Q_A = C_v(T_3 - T_2) + C_p(T_4 - T_3)$

$Q_R = C_v(T_5 - T_1)$

$\eta_{Th} = \frac{\omega \cdot D}{H \cdot S} = \frac{C_v(T_3-T_2) + C_p(T_4-T_3) - C_v(T_5-T_1)}{C_v(T_3-T_2) + C_p(T_4-T_3)}$

$= 1 - \frac{T_5 - T_1}{(T_3-T_2) + \gamma(T_4-T_3)}$

Take $r_p = \frac{P_3}{P_2}$

Cutoff ratio $\rho_c = \frac{V_4}{V_3} = \frac{V_4}{V_2}$

$r = \frac{V_1}{V_2}$

1-2

$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{\gamma-1}$

$\boxed{T_2 = T_1 r^{\gamma-1}}$

2-3

$\frac{P_2 \cancel{V_2}}{T_2} = \frac{P_3 \cancel{V_3}}{T_3}$

$T_3 = T_2 \frac{P_3}{P_2}$

$= T_2 a_p$

$\boxed{T_3 = T_1 r^{\gamma-1} a_p}$

3-4

$\frac{\cancel{P_3} V_3}{T_3} = \frac{\cancel{P_4} V_4}{T_4}$

$T_4 = T_3 \times \frac{V_4}{V_3}$

$= T_3 \times \frac{V_4}{V_2}$

$T_4 = T_1 r^{\gamma-1} a_p a_c$

$\frac{T_5}{T_4} = \left(\frac{V_4}{V_5}\right)^{\gamma-1}$

$= \left(\frac{V_4}{V_2} + \frac{V_2}{V_5}\right)^{\gamma-1}$

$= \left(a_c \times \frac{V_2}{V_1}\right)^{\gamma-1}$

$\frac{T_5}{T_4} = a_c^{\gamma-1} \times \frac{1}{r^{\gamma-1}}$

$T_5 = T_1 \cancel{r^{\gamma-1}} a_p a_c a_c^{\gamma-1} \frac{1}{\cancel{r^{\gamma-1}}}$

$\boxed{T_5 = T_1 a_p a_c^{\gamma}}$

Substns the values of T_1, T_2 T_3, T_4 and T_5 in expression of thermal efficiency

$$\eta_{th} = 1 - \frac{1}{r^{\gamma-1}}\left[\frac{a_p a_c^{\gamma} - 1}{(a_p - 1) + \gamma a_p (a_c - 1)}\right]$$

~~ap~~ = 1

$$MEP = \frac{W.D}{V_1 - V_2}$$

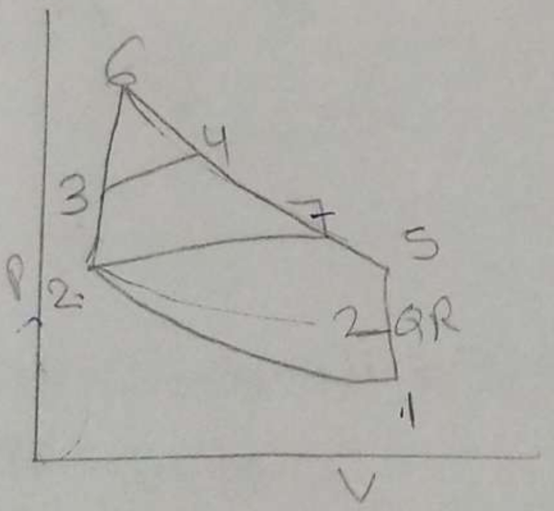
$$= \frac{P_1 r}{(r-1)(\gamma-1)}\left[r^{\gamma-1}(a_p - 1) + \gamma a_p (a_c - 1) - a_p (a_c^{\gamma} - 1)\right]$$

Comparisson of otto; disel and duel cycles on the basis of

The three cycle compared on eigther

1) the same compreshsion ratio
2) same pressure and temperature

1) For same compreshsion and heat ratio



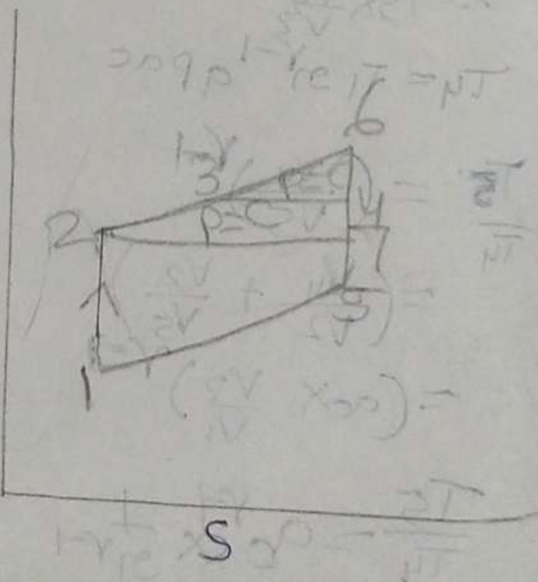
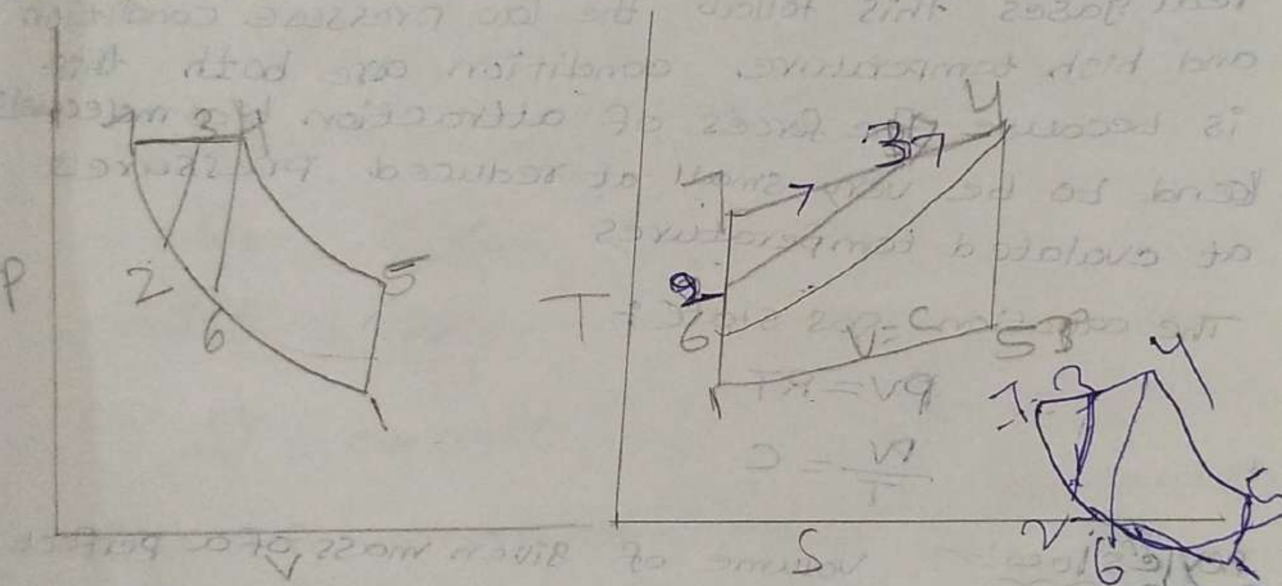


Figure shows the compreshion of otto, disel and duel cycles for the same comprehsion rati and heat regection Heay 1,2,6,5 represents auto cycle 1,2,7,5 represents desiel cycle 1,2,4 represent Duel cycle

$$\eta_{th} = 1 - \frac{Q_R}{Q_A}$$

Area under T,S diagram gives the heat transfe for heat reiected higher the QA higher is the cycle efficiency. In the T-S diagram area under 2,6 represents QA for ottocycle area under 2,7 represents QA for disel cycle under area 2,3,4 represents QA for duel cycle Therefore for same comprhesion ratio for heat ratio $\eta_{otto} > \eta_{Duel} > \eta_{Diesel}$

For the same pressure and temperature ~~maximum~~ compreshsion



A compreshion of otto, diseland duel air standart cycle for the same pressure ($P_7 = P_4$) and for the same temperature (T_4) In given figure

1,6,4,5,1 represents auto ottocycle 1,2,3c4,5,1 represents disel represegents duel cycle 1,7,4,5,1 represents cycle the are a under 7,4 represents heat added QA during the disel cycle. Area under 2,3,4 represents the heat added QA during the duel cycle under the area 6,4 represents the heat added during otto cycle

$\eta_{Diesel} > \eta > \eta_{duel} > \eta_{otto}$

~~Chapter~~ Unit-5

Chapater-1

* **Ideal gas**:- An ideal gas is defined as gas having no forcess ~~of~~ intermolecular attraction the gases which follows the gas laws at all ranges of pressure and temperature are considered as ideal gases

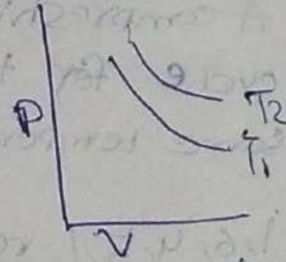
Real gas:- No gases present in nature are real gases this follow the low pressure condition and high temperature condition are both this is because the forces of attraction b/w moleculs tend to be very small at reduced pressures at evalated temperatures

The eauation gas state :-

$$PV = RT$$

$$\frac{PV}{T} = C$$

Boyle's law:- volume of given mass of a perfect gas varies inversally has absolute pressure when temperature is constant.

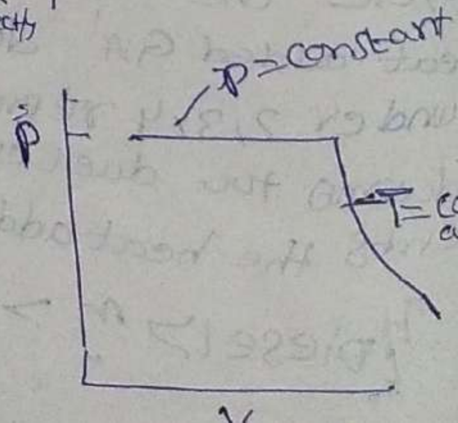


$$V \propto \left(\frac{1}{P}\right)_T$$

$$P_1V_1 = P_2V_2$$

Charle's law:- If any gas is heated at constant pressure it's volume changes directly has it's obsulute temperature V is $\propto_{\text{directly}}$ T

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$



To derive an equation the state of gas

① from PV diagram process 1-2 constant pressure

② from process 2-2 constant temeparature

1-2' $\frac{V_1}{T_1} = \frac{V_2'}{T_2'}$

since

$T_2' = T_2$

$\frac{V_1}{T_1} = \frac{V_2'}{T_2} \rightarrow ①$

2-2' $P_2'V_2' = P_2V_2$

$P_1V_2' = P_2V_2$

$V_2' = \frac{P_2V_2}{P_1} \rightarrow ②$

substms the value ② and ①

$\frac{V_1}{T_1} = \frac{P_2V_2}{P_1 \times T_2}$

$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$

$\frac{PV}{T}$ = constant

$\frac{PV}{T} = R$ where R is called as specific gas constant

The above is called as equation of the state

Avagadro's law:- A more of a substances has mass equal to the molecular weight of a Substance

1 gram mole of oxygen ~~molecular~~ has mass of 32 grams

1kg mole of oxygen has mass of 32 kg,

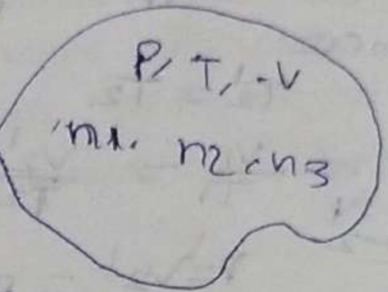
1kg of rate of nitrogen has mass of 28 kg

Avagadro law states that the volume a gram mole of all gases at a pressure of 760 millimete of Hg and temperature of 0°c is the same and is equal to 22.4 litters

$1 \text{ kg mole} = 22.4 \, m^3$

Dalton's law of partial pressures :-

Let us a imagine a homogenous mixture an inert ideal gases at temperature T pressure P volume V.



Let us suppase there are n_1 moles of gas A_1, n_2 moles of gas A_2 and up to n_c mole of gas A_3 since there is no chemical reaction the mixture is in the state of equilibrium

~~$\bar{R} = 8\ 3143\ k$~~

$$PV = (n_1 + n_2 + \dots + n_c)\bar{R}T$$

$$\bar{R} = 8\,3143 \ kJ/kg \ mol \ k$$

$$P = \frac{n_1 \bar{R} T}{V} + \frac{n_2 \bar{R} T}{V} + \frac{n_c \bar{R} T}{V}$$

$$P_1 = \frac{n_1 \bar{R} T}{V} \quad P_2 = \frac{n_2 \bar{R} T}{V} \quad P_c = \frac{n_c \bar{R} T}{V}$$

$$P = P_1 + P_2 + \dots P_c$$

Dalton's law of pantial pressure

Let us imagine a ahom.

wh:

$$PV = (n_1 + n_c + \dots n_c)\bar{R}T$$

$$\bar{R} = 83143 \ kJ/kg \ mol$$

$$P = \frac{n_1 \bar{R} T}{V} + \frac{n_2 \bar{R} T}{V} + \frac{n_c \bar{R} T}{V}$$

$$P_1 = \frac{n_1 \bar{R} T}{V} \quad P_2 = \frac{n_2 \bar{R} T}{V} \quad P_c = \frac{n_c \bar{R} T}{V}$$

$$P = P_1 + P_2 + P_c$$