|| नमस्ते ||

SPECIFIC HEAT

Definition

- **The specific heat is the amount of heat per unit mass required to raise the temperature by one degree Celsius.**
- **The relationship between heat and temperature change is usually expressed in the form shown below where c is the specific heat.**
- **The relationship does not apply if a phase change is encountered, because the heat added or removed during a phase change does not change the temperature.**
- $Q = mc\Delta T$
- **Where,**
- **M is mass in moles**
- **C is specific heat constant**
- **T is temperature in Kelvin**

Specific heat for ideal Gases

1. Specific Heat at constant volume CV
2. Specific Heat at constant Pressure Cp

Specific Heat at constant volume CV

- The specific heat at constant volume is defined as the amount of heat energy transferred to change the temperature of the unit mass of a substance by one degree, when the volume of substance is maintained constant.
- $C_v = \left(\frac{du}{dT}\right)_v$
- Where,
- C_v is the specific heat at constant volume =0.718 kJ /kg.K
- du is change in internal energy
- dT is change in temperature.

Specific Heat at constant Pressure Cp

- The specific heat at constant pressure is defined as the amount of heat energy transferred to change the temperature of the unit mass of a substance by one degree, when the pressure of substance is maintained constant.
- $C_v = \left(\frac{dh}{dT}\right)_p$
- Where,
- C_p is the specific heat at constant Pressure =1.005 kJ /kg.K
- dh is change in enthalpy
- dT is change in temperature.

IDEAL GAS PROCESS

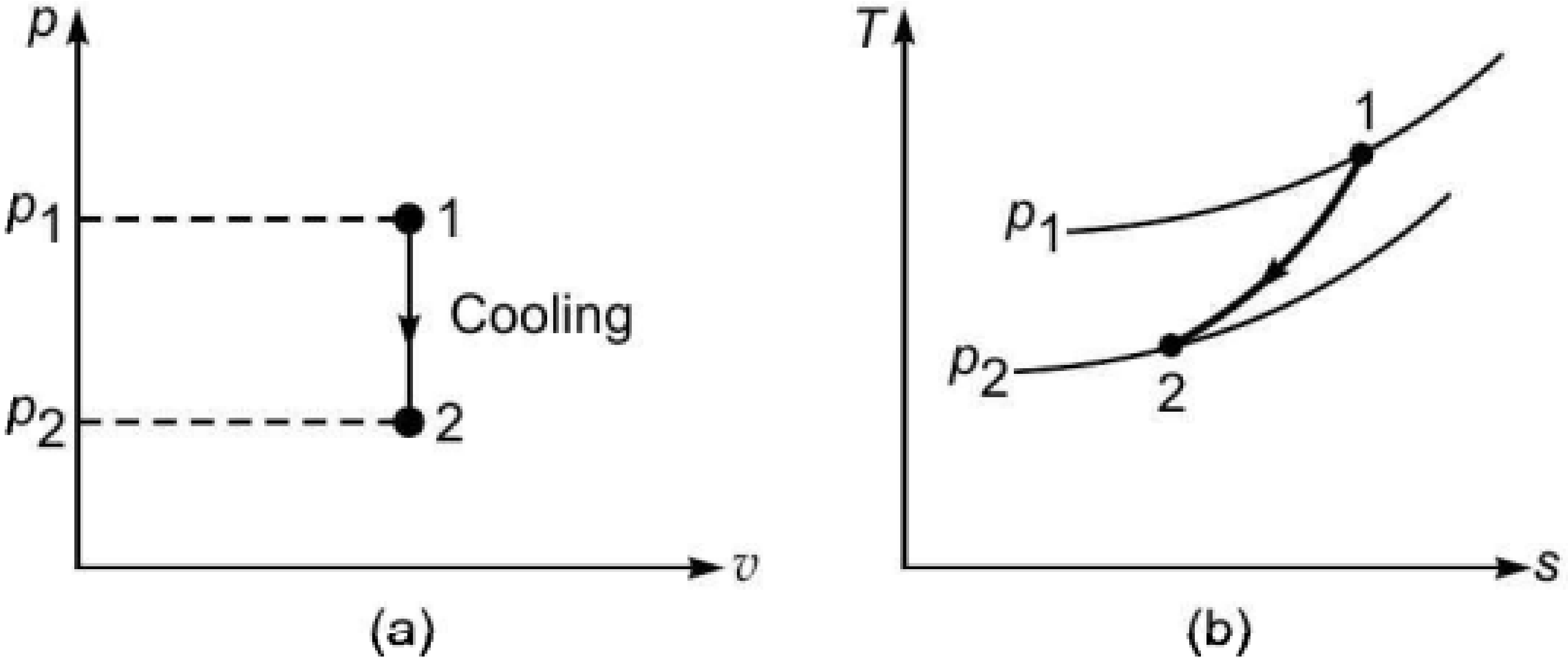
IDEAL GAS PROCESS

1. Constant Volume process (Isochoric Process)
2. Constant Pressure process (Isobaric Process)
3. Constant temperature process (Isothermal Process)
4. Constant Entropy process (Isentropic Process)
5. Polytrophic Process

1.Constant Volume process (Isochoric Process)

- **Definition:-**
- **The any system of gas undergoes in such way that during the process , the volume of system remain constant, the process is called constant volume process or isochoric process.**
- $\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$
- **In above gas equation volume is constant i.e.** $V_1 = V_2$
- $\frac{P_1}{T_1} = \frac{P_2}{T_2}$

PV & TS diagram of Isochoric Process

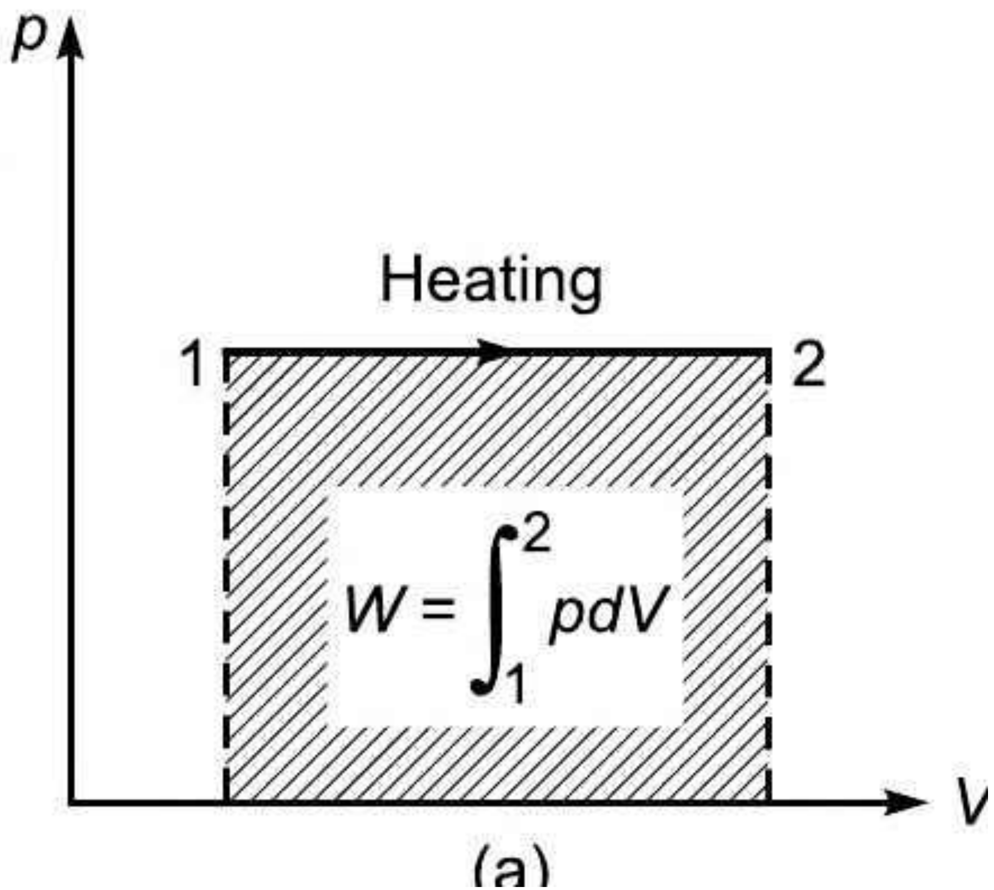


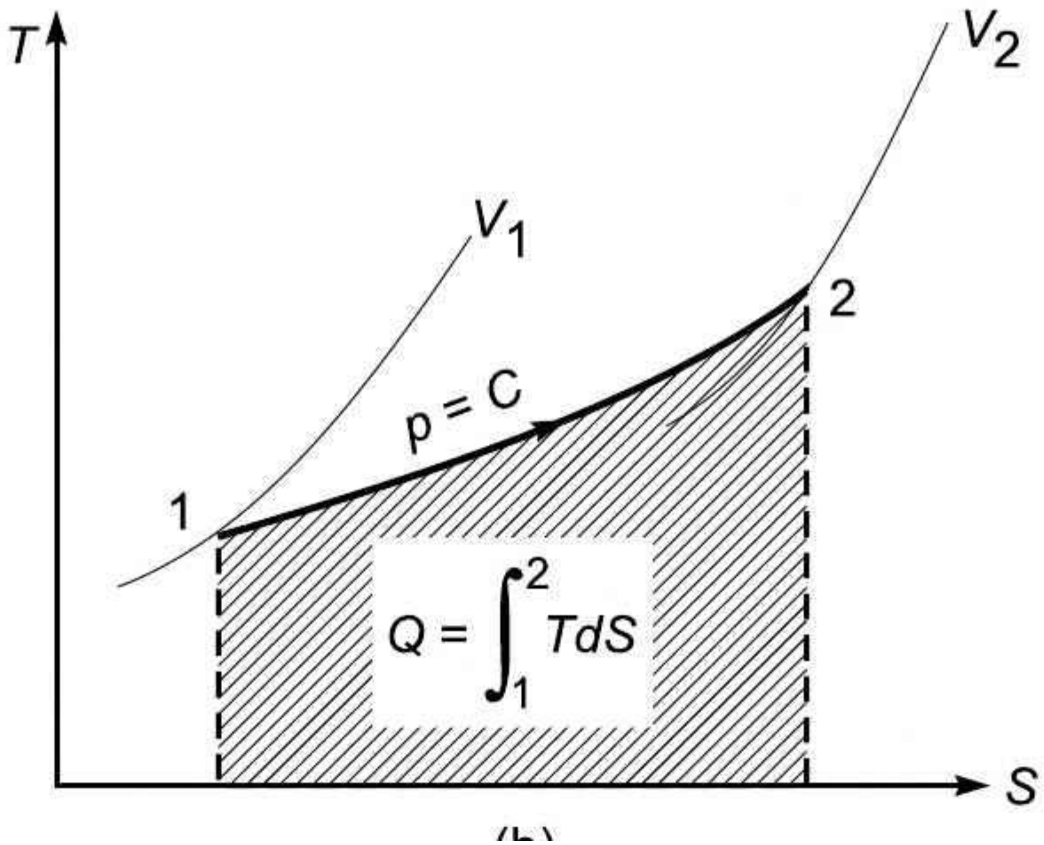
- **Work done**
- $W = P\,dv$
- But Volume is constant so dv=0
- W=0 so that in isochoric process work done is zero………Equ(1)
- **Change in Internal Energy**
- $\Delta U = C_v\,\Delta T$
- $\Delta U = C_v\,(T_2 - T_1)$ KJ
- **Heat transfer**
- $Q = \Delta U + W$ … … … … … . .w=0 as per equation (1)
- $Q = \Delta U$
- $Q = C_v\,\Delta T$
- $Q = C_v\,(T_2 - T_1)$ kJ/ kg

2.Constant Pressure process (Isobaric Process)

- **Definition:-**
- **The any system of gas undergoes in such way that during the process , the pressure of system remain constant, the process is called constant pressure process or isobaric process.**
- $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$
- **In above gas equation volume is constant i.e.** $P_1 = P_2$
- $\frac{V_1}{T_1} = \frac{V_2}{T_2}$

PV & TS diagram of Isobaric Process



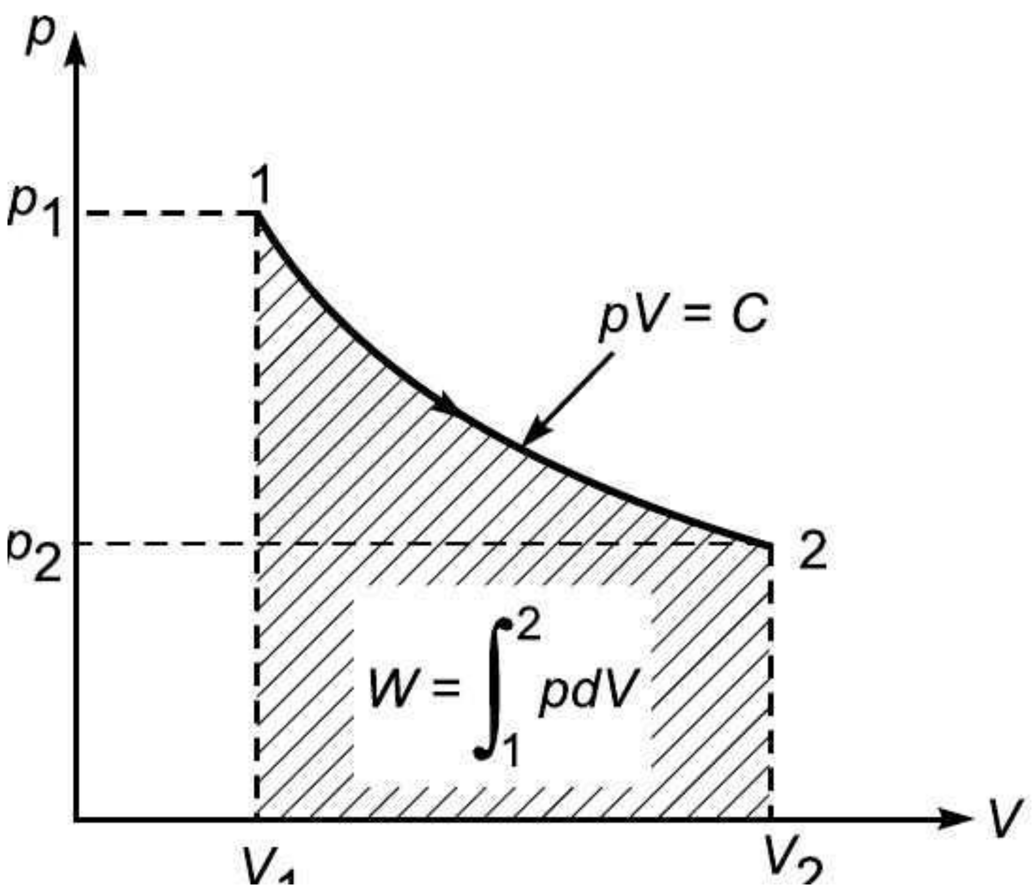


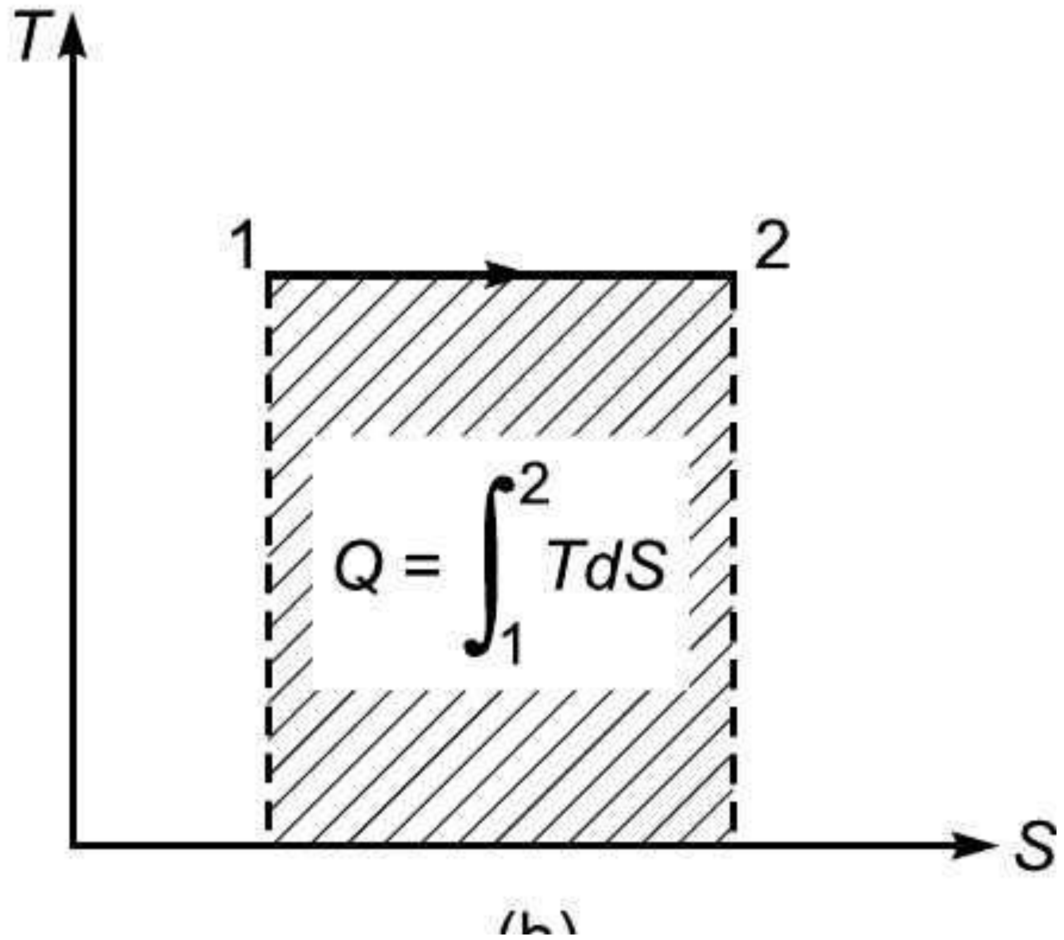
- **Work done**
- $W = \int_1^2 P\,dv$
- $W = P(V_2 - V_1)$ kJ
- **Change in Internal Energy**
- $\Delta U = C_v\,\Delta T$
- $\Delta U = C_v\ (T_2 - T_1)$ kJ
- **Heat transfer**
- $Q = C_p\,\Delta T$
- $Q = C_p\,(T_2 - T_1)$ kJ /Kg

3.Constant Temperature process (Isothermal Process)

- **Definition:-**
- **The any system of gas undergoes in such way that during the process , the temperature of system remain constant, the process is called constant temperature process or isothermal process.**
- $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$
- **In above gas equation volume is constant i.e.** $T_1 = T_2$
- $P_1V_1 = P_2V_2$

PV & TS diagram of Isochoric Process





- **Work done**
- $W = mRT_1 \ln\left(\frac{P_1}{P_2}\right)$
- **Change in Internal Energy**
- $\Delta U = C_v \Delta T$
- Here change is temperature is 0 i.e. $\Delta T = 0$
- $\boldsymbol{\Delta U = 0}$
- $\Delta U = C_v \ (T_2 - T_1)$ kJ = 0 …Zero change in internal Energy
- **Heat transfer**
- $Q = mC\Delta T$ **or** $\boldsymbol{\Delta s = \frac{Q}{T}}$ **or** $\boldsymbol{Q = \Delta U + W}$
- $\boldsymbol{Q = W \dots \dots \dots due\ to\ \Delta U = 0}$.
- $Q = W = mRT_1 \ln\left(\frac{P_1}{P_2}\right) = mRT_1 \ln\left(\frac{V_2}{V_1}\right)$

Work done calculation for isothermal Process

$$W_{1-2} = \int_1^2 p dV$$

For an isothermal process,

$$pV = C$$

$$\therefore \qquad p = \frac{C}{V}$$

Then $$W_{1-2} = \int_1^2 \frac{C}{V} dV = C \int_{V_1}^{V_2} \frac{dV}{V}$$

$$= C \ln\left(\frac{V_2}{V_1}\right)$$

Using $$C = p_1 V_1$$

we get $$W_{1-2} = p_1 V_1 \ln\left(\frac{V_2}{V_1}\right)$$

Further, $$p_1 V_1 = m\,R\,T_1$$

Then $$W_{1-2} = m\,R\,T_1 \ln\left(\frac{V_2}{V_1}\right)$$

From properties relation, we have

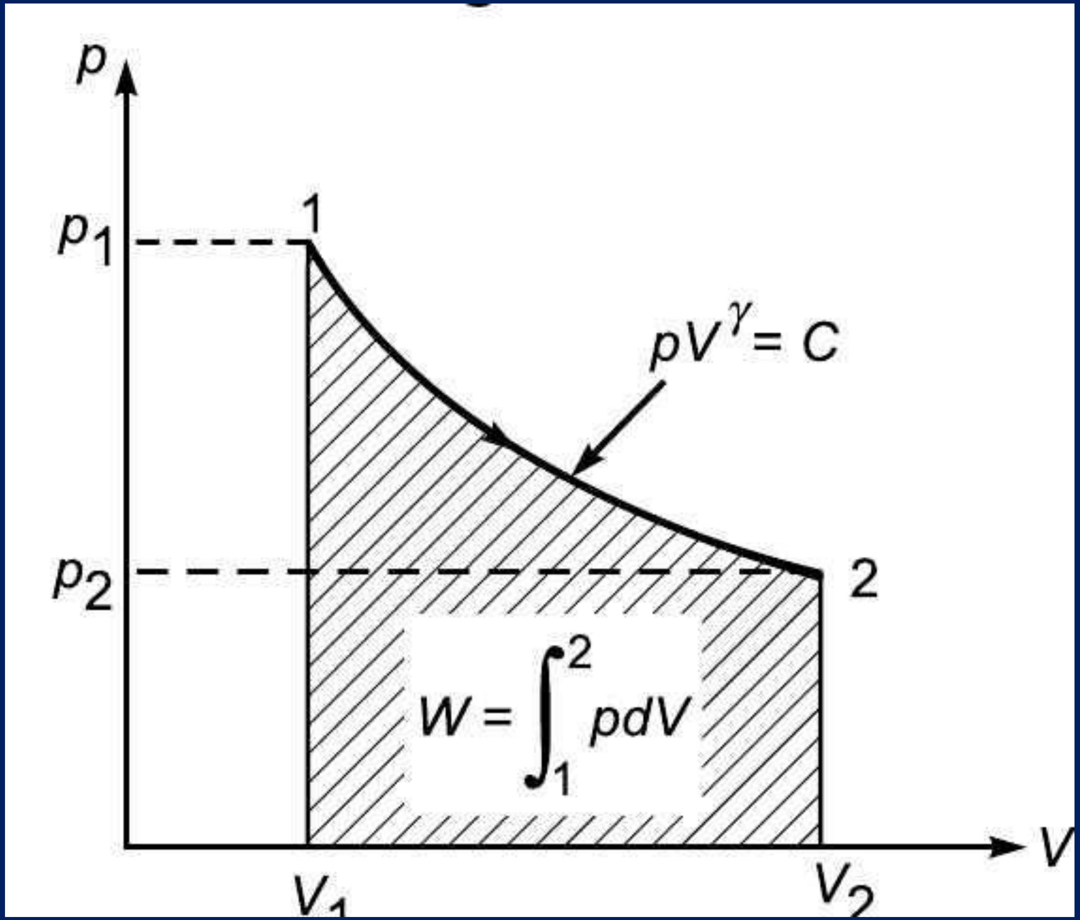
$$\frac{V_2}{V_1} = \frac{v_2}{v_1} = \frac{p_1}{p_2}$$

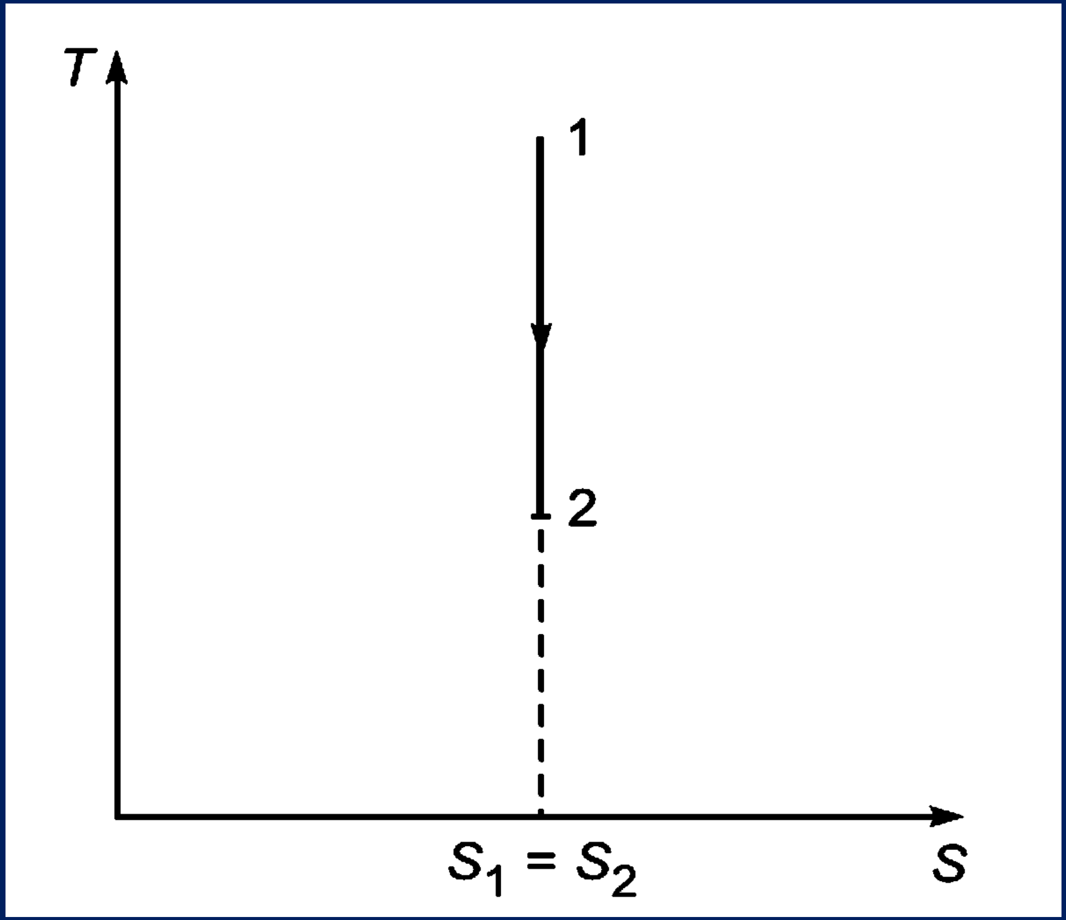
Then $$W_{1-2} = m\,R\,T_1 \ln\left(\frac{p_1}{p_2}\right)$$

4.Isentropic Process / Reversible Adiabatic

- **Definition:-**
- The process of expansion and compression is carried out without exchange of heat between system and surrounding this operation conducted in insulator so this process is called adiabatic process.
- During this process system neither receives or rejects the heat.
- When process is reversible and frictionless then that process is called Isentropic process or constant entropy process.

PV & TS diagram of Isentropic Process





- **Work done**
- $W = \int_1^2 pdv$
- $\boldsymbol{W} = \frac{\boldsymbol{P_2V_2 - P_1V_1}}{\boldsymbol{1-\gamma}}$ **=** $\frac{\boldsymbol{mR(T_2 - T_1)}}{\boldsymbol{1-\gamma}}$
- **Change in Internal Energy**
- $\Delta U = C_v \, \Delta T$
- $\Delta U = C_v \, (T_2 - T_1)$ kJ
- **Heat transfer**
- $Q = mC\Delta T$ **or** $\boldsymbol{\Delta s = \frac{Q}{T}}$ **or** $\boldsymbol{Q = \Delta U + W}$
- $Q = 0$

For an isentropic process,

$$pV^{\gamma} = C \quad \text{or} \quad pv^{\gamma} = C$$

or

$$p_1V_1^{\gamma} = p_2V_2^{\gamma}$$

or

$$\frac{p_2}{p_1} = \left(\frac{V_1}{V_2}\right)^{\gamma} = \left(\frac{V_2}{V_1}\right)^{-\gamma} = \left(\frac{v_2}{v_1}\right)^{-\gamma}$$

or

$$\frac{v_2}{v_1} = \frac{V_2}{V_1} = \left(\frac{p_2}{p_1}\right)^{-\frac{1}{\gamma}}$$

Substituting Eq. (4.25) in Eq. (4.24), we get

$$\frac{T_2}{T_1} = \left(\frac{V_2}{V_1}\right)^{-\gamma}\left(\frac{V_2}{V_1}\right) = \left(\frac{V_2}{V_1}\right)^{1-\gamma} = \left(\frac{v_2}{v_1}\right)^{1-\gamma}$$

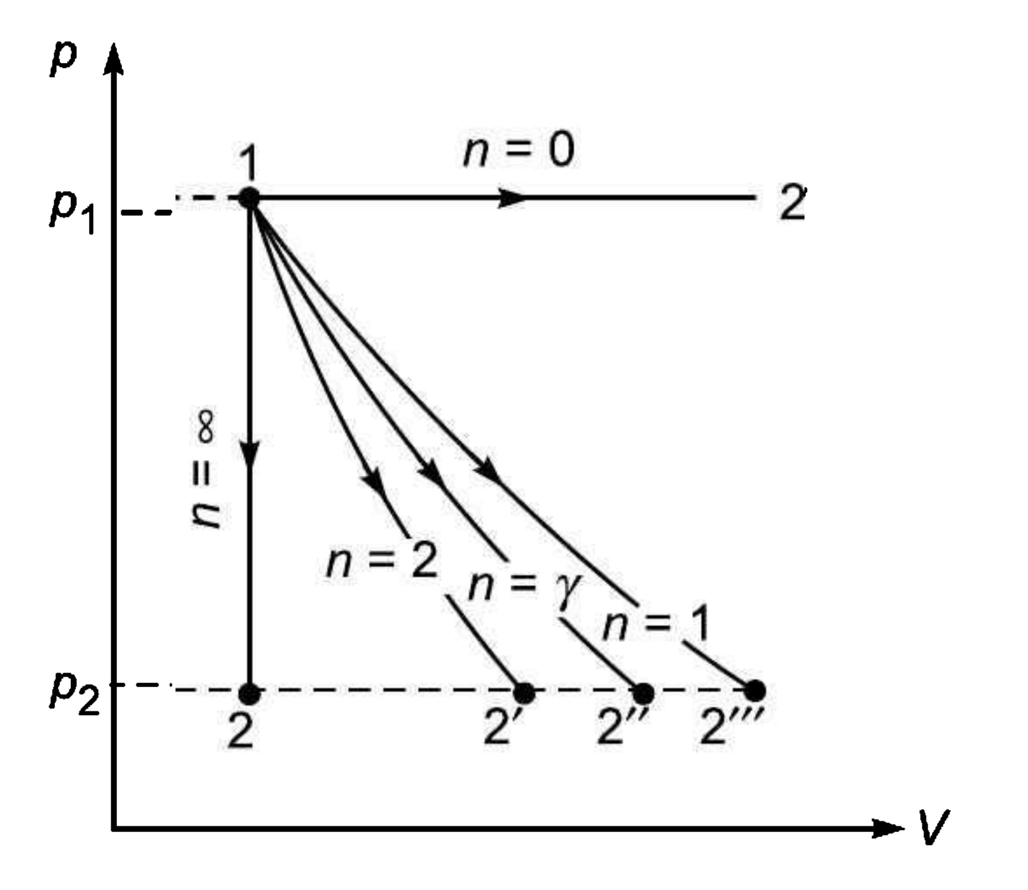
Using Eq. (4.26) in Eq. (4.24), we get

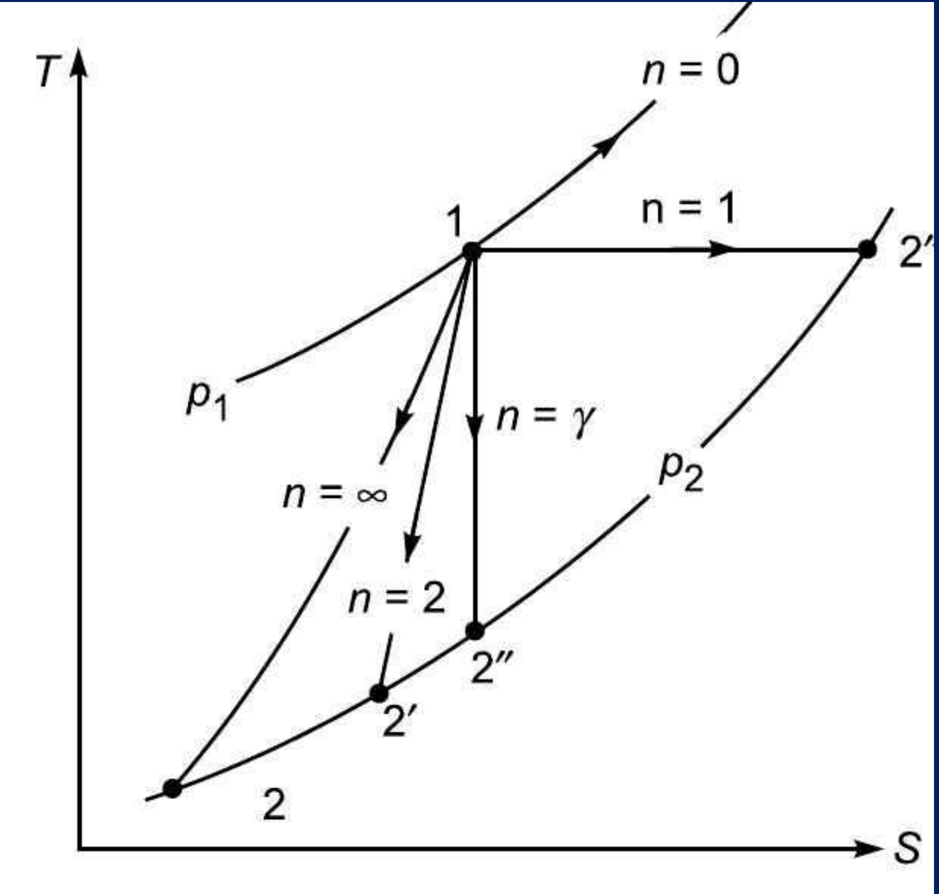
$$\frac{T_2}{T_1} = \left(\frac{p_2}{p_1}\right)\left(\frac{p_2}{p_1}\right)^{-\frac{1}{\gamma}} = \left(\frac{p_2}{p_1}\right)^{\frac{\gamma-1}{\gamma}}$$

5.Polytrophic Process

- **Definition:-**
- **The any reversible process on any open or closed system of gas or Vapour which involves both heat and work transfer such that specified combination of properties are maintained constant throughout process.**
- $\mathrm{P}V^{n} = C$
- **P-Pressure**
- **V- Volume**
- **n – Polytrophic index**

PV & TS diagram of Polytrophic Process





	Value of ‘n’	Process
1	When n = 0	Constant pressure process
2	When n=1	Constant Temperature process
3	When n=y	Isentropic Process
4	When n= infinity	Constant Volume process

- **Work done**
- $W = \int_1^2 pdv$
- $\boldsymbol{W = \frac{P_1V_1}{1-n}\left\{\left(\frac{P_2}{P_1}\right)^{1-\frac{1}{n}} - 1\right\}}$
- **Change in Internal Energy**
- $\Delta U = C_v \, \Delta T$
- $\Delta U = C_v \ (T_2 - T_1)$ kJ
- **Heat transfer**
- $Q = \frac{(\gamma-n)}{(n-1)} \times \frac{mR(T_2-T_1)}{(1-\gamma)}$

Work Done For a non-flow process, the polytropic work transfer is calculated as

$$W_{1-2} = \int_1^2 pdV$$

The pressure p can be expressed as

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

Hence $$W_{1-2} = \int_1^2 CV^{-n}dV = C\int_{V_1}^{V_2} V^{-n}dV$$

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

Using $$C = p_1V_1^n = p_2V_2^n$$

we get $$W_{1-2} = \frac{p_2V_2 - p_1V_1}{1-n}$$

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

where, $p_2V_2 = mRT_2$ and $p_1V_1 = mRT_1$

Using $$\frac{V_2}{V_1} = \left(\frac{p_2}{p_1}\right)^{-\frac{1}{n}}$$

then $$W_{1-2} = \frac{p_1V_1}{1-n}\left\{\left(\frac{p_2}{p_1}\right)^{1-\frac{1}{n}} - 1\right\}$$

(*f*) ***Heat Transferred*** According to the first law of thermodynamics,

$$Q = \Delta U + W$$

$$= m\,C_v\,(T_2 - T_1) + \frac{m\,R(T_2 - T_1)}{1-n}$$

$$= m\,(T_2 - T_1)\left\{C_v + \frac{R}{1-n}\right\}$$

Using $R = C_p - C_v$

we get $$Q = m(T_2 - T_1)\,\frac{(C_v - nC_v + C_p - C_v)}{1-n}$$

$$= m\left(\frac{C_p - nC_v}{1-n}\right)(T_2 - T_1)$$

or $$Q = m\,C_n(T_2 - T_1)$$

where $$C_n = \frac{C_p - nC_v}{1-n}$$

C_n is called *polytropic specific heat.*

Again rearranging the above equation, we have

$$Q = mC_v \frac{\left(\frac{C_p}{C_v} - n\right)}{1-n} \times (T_2 - T_1)$$

Using $\frac{C_p}{C_v} = \gamma$ and $C_v = \frac{R}{\gamma - 1}$, we get

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

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

$$= \frac{\gamma - n}{\gamma - 1} \times \text{Polytropic work transfer}$$

Rearranging, we get

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

$$= \frac{\gamma - n}{n-1} \times \text{Adiabatic work transfer}$$


ANY
QUESTIONS?

Today's Amazing Fact!!

This tree is 10 years old

(One Ring means One Year)

धन्यवाद

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