2. BASIC CONCEPTS

WORKING FLUID: Fluid which is used thermodynamic analysis.

GAS	VAPOUR
$T_{substance} > T_{critical}$	$T_{substance} < T_{critical}$
Atmospheric Air is mixture of different gases Eg. O2, N2, H2, He, Ar, etc... So each Gas will be under same surrounding condition	

Substance	Critical temperature		Critical pressure		Boiling temperature (1 atm)		
	[°F]	[°C]	[psi], [lb/in^2]	[bar]	[°F]	[°C]	
Air	-220.94	-140.52	549.08	37.858	-	-	Here All gas Have less than atmospheric temperature so all will be in **GAS** in atmospheric condition. And Water will be in **VAPOUR** phase.
Argon	-188	-122	705.6	48.7	-302.5	-.85.8	
Hydrogen (H)	-400	-240	188.2	13.0	-423	-253	
Nitrogen (N)	-232.6	-147	492.4	34.0	-321	-195	
Oxygen (O_2)	-181.5	-118.6	732	50.5	-297	-183	
Helium (He)		-268		2.27			
Water	705	374	3206.2	220.5	212	100	

IDEAL GAS: No intermolecular forces. (No Molecular Attractive Forces, Repulsive forces and other forces)
$(F_{Intermolecular})_{Solid} >> (F_{Intermolecular})_{Liquid} >> (F_{Intermolecular})_{Gas}$

KINETIC THORY OF GAS:
1) $V_{GAS} <<<< V_{Container}$
2) $F_{Intermolecular} = 0$
3) Collision between molecules are perfectly elastic ==> Zero Kinetic Energy loss/Gain

GAS BEHAVES AS IDEAL GAS: Pressure $\vee$, Volume $\wedge$, Temperature $\vee$ And MFP $\vee$ **(Z = 0)**
At Atmospheric Condition, $P_{atm} = 101.325$ KPa, $T_{atm} = 25$ °C

Types of Ideal Gas	
Perfect Ideal Gas	**Semi Perfect Ideal Gas**
Variation of specific heats (KJ/kg K) are not considered. OR specific heats are constant. Eg. Air $C_p = 1.005$ KJ/kg K, $C_v = 0.718$ KJ/kg K	Variation of specific heats (KJ/kg K) Can't ignore. So that Analysis at each and every temperature.

	Boyle's Law	Charles' Law	Gay-Lussac Law
For given mass	$P_{abs} \propto 1/V_{gas}$ (@T=C)	$V_{gas} \propto T$ (@P_{abs}=C)	$P_{abs} \propto T$ (@V_{gas} = C)

PERFECT/ IDEAL GAS EQUATION:

$P_{abs}v_{gas} = RT$ Where, P_{abs} = Absolute pressure of Gas (Pa) v_{gas} = Specific Volume of Gas (m^3/kg), T = Absolute Temperature of Gas (K) R = Characteristic Gas Constant (J/Kg K) $P_{abs}V_{gas} = mRT$ Where, V = Total Volume of Gas (m^3) m = Mass of the gas (kg) $P_{abs} = \rho_{gas}RT$ Where, ρ_{gas} = Density of Gas (kg/ m^3)	If P (Pa), R (J/kg K). If P (KPa), R (KJ/kg K). R = 287 J/kg K (for Air)

MOLAR ANALYSIS:

Mole(n): Amount of substance. 1 mol = 6.023 * 10^{23} Molecules
Molar Volume ($\bar{V}$): $\bar{V} = V_{gas}/n$ (m^3 / Kmol)
Molar Mass ($\bar{m}$) Molar weight (M): $M = \bar{m} = m_{gas}/n$ (kg / Kmol)
Molar Gas Constant or Universal gas constant ($\bar{R}$): $\bar{R} = \bar{m}\,R = M\,R$ (KJ / Kmol K)

$P_{abs}\bar{V} = \bar{m}\,RT$	$P_{abs}\bar{V} = \bar{R}T$	$P_{abs}\,V_{gas} = n\bar{R}T$

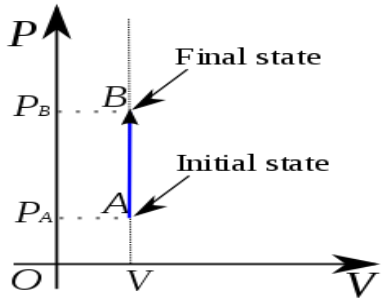
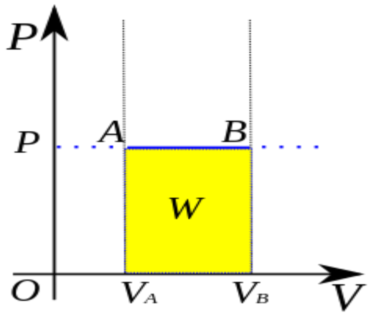
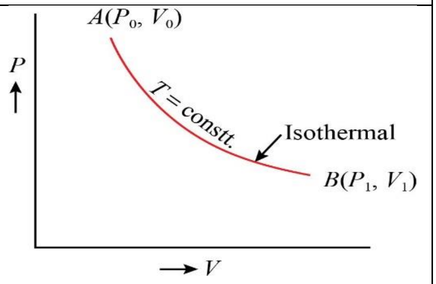
AVOGADRO'S LAW: "Equal volume of all gases contains equal number of molecules at the same pressure and same temperature"

STP => P_{stp} = 1 atm = 101.325 KPa, T_{stp} = 0 °C = 273 K, V = 22.4 m^3, n = 1Kmol => $\bar{R}$ = 8.314 KJ/Kmol K

Difference between Characteristic Gas constant and Universal Gas Constant:

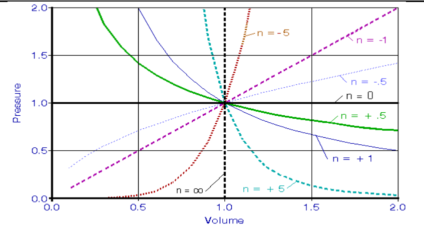
Gas	**Molar Mass (M) (kg/mol)**	**Universal gas constant ($\bar{R}$) (KJ / Kmol K)**	**Characteristic Gas constant (R) (KJ / kg K)**
Air	28.9	8.314	0.287
O2	32	8.314	0.259
N2	28	8.314	0.296

IDEAL GAS EQUATION FOR VARIOUS THERMODYNAMIC PROCESS:

Reversible Constant Volume/ Isochoric Process: Rigid Tank, V_{gas} = Constant, Q_{supply} / $Q_{rejected}$, Eg. Football, Pressure Cooker, Automobile tyre, Automobile car, Both direction Locked Piston cylinder.	$P_{abs} \propto T$ (@V_{gas} = C) **Gay-Lussac Law**	
Reversible Constant Pressure/ Isobaric Process: Assumptions: 1) Very Slow Process 2) Friction is neglected 3) No effect on gas due to weight of piston. W_P = 0 Rigid Tank, P_{gas} = Constant, Q_{supply} / $Q_{rejected}$ (Expansion/Contraction) Eg. Piston Cylinder Mechanism with weight less piston, Water heated in atmosphere,	$V_{gas} \propto T$ (@P_{abs}= C) **Charles' Law**	
Combination of Constant Volume and Constant Pressure Process: Assumptions: 1) Very Slow Process 2) Friction is neglected 3) Effect on gas due to weight of piston. $W_P \neq 0$. Two Process happed in index mentioned below when heat is supplied or rejected on one side locked piston: 1) Constant Volume Process 2) Constant Pressure Process	**Process 1:** $P_{abs} \propto T$ (@V_{gas} = C) Gay-Lussac Law **Process 2:** $V_{gas} \propto T$ (@P_{abs}= C) Charles' Law	**Rectangle Triangle diagram.**
Reversible Constant Temperature/ Isothermal Process: In order to maintain constant temperature, Heat should be supplied or reject simultaneously. This is not practically possible because: 1) Simultaneously Q_{supply} / $Q_{rejected}$ is not possible. 2) Process is very slow process. Eg. **Boiling Water** In atmosphere, Human Body (37 °C)	$P_{abs} \propto 1/V_{gas}$ (@T = C) **Boyle's Law**	(P–V Diagram) **Rectangular Hyperbola**
Reversible Adiabatic Process: No heat Transfer (Q_{supply} / $Q_{rejected}$ = 0) γ = adiabatic index	**PV^{γ} = Constant** **$TV^{\gamma-1}$ = Constant** **$TP^{\frac{\gamma}{\gamma-1}}$ = Constant** (because $T \propto PV$)	γ = 1.67 (for mono-atomic Gas Eg. He, Ar) γ = 1.4 (for die-atomic Gas Eg. H2, O2, N2) γ = 1.33 (for Poly-atomic Gas Eg. CO2, CH4)

Reversible Polytropic Process:
Poly = many, Tropic = changes
$Q_{supply} / Q_{rejected} \neq 0$
n = polytropic index

PV^n = Constant
TV^{n-1} = Constant
$TP^{\frac{1-n}{n}}$ = Constant
(because $T \propto PV$)



Adiabatic/ Polytropic index = $\ln(P_1/P_2)/\ln(V_2/V_1)$
Generally, $1 \leq n \leq \gamma$.   Actually, $-\infty \leq n \leq \infty$

Slope of Various Processes = dP/dV				
n = 0	n = 1	n = γ	n = n	n = ∞
P = Constant	T = Constant	-	-	V = Constant
Isobaric	Isothermal	Adiabatic	Polytropic	Isochoric
$\left[\frac{dP}{dV}\right]_P = 0$	$\left[\frac{dP}{dV}\right]_T = -\left(\frac{P}{V}\right)$	$\left[\frac{dP}{dV}\right] = -\gamma\left(\frac{P}{V}\right) = \gamma\left[\frac{dP}{dV}\right]_T$	$\left[\frac{dP}{dV}\right] = -n\left(\frac{P}{V}\right) = n\left[\frac{dP}{dV}\right]_T$	$\left[\frac{dP}{dV}\right]_V = \infty$

THERMODYNAMICS TERMINOLOGY:

1. System: Quantity of Matter concentrated or under study.
2. Surroundings: Outside the system and effect on system is present.
3. Boundary: Surface which separates system and surroundings.

Types of Boundary			
Fixed	Moving	Imaginary	Real

4. Universe: (System + Surroundings) put together.

FUNDAMENTAL DEFINATIONS IN THERMODYNAMICS:

1. State: Condition of system. (Denotes by point in diagrams)
2. Process: Change in State.
3. Path: Line which connects various state points.
4. Quasi Static Process: (Quasi = Almost, Static = Fixed) Extremely slow Process.
Each state is in equilibrium condition. dP = dV = 0 (For each successive states)
5. Reversible Process:
It's Idealized or Hypothetical process.
When process is reversed follows same path. (Denotes by Solid/ Continuous line in diagram)
Condition for reversibility: 1) Quasi Static Process 2) Zero Friction loss 3) No effect of surrounding on system.
1) Integration is possible 2) Area Can be find for work obtain.
6. Irreversible Process: Process Which can't reverse. System and surrounding presently affected.
(Denotes by Dotted/ Discontinuous line in diagram)
Condition for irreversibility: 1) Extremely Fast Process 2) Friction loss is present.
7. Thermodynamic Cycle: Series of processes which restores initial condition.

Thermodynamic Cycle	
Reversible Thermodynamic Cycle	**Irreversible Thermodynamic Cycle**
All process in cycle must be reversible.	At least one process is Irreversible.
Thermodynamic Cycle	
Work Producing Cycle (Clock wise)	Work Consuming Cycle (Anti-Clock wise)

8. Thermodynamic Equilibrium:

Thermodynamic Equilibrium	Thermal Equilibrium	Same Temperature throughout the system
	Mechanical Equilibrium	Same Forces throughout the system
	Chemical Equilibrium	No Chemical Reaction

PROPERTIES:

PROPERTIES	
Extensive Property	Intensive Property
Depending on Mass and Size	Not Depending on Mass and Size
Mass, Volume, kinetic energy, Potential energy	Pressure, Temperature, Density, Viscosity, Thermal Conductivity, Electric Conductivity
1) Intensive Property = (Extensive Property/Extensive Property) **2) All Specific Property are Intensive property**	

Essential Features of Properties:
1) All Properties are point function. 2) Changes in property does not depend on path. 3) Properties are exact differentials. Eg. dP, dV,…

TYPES OF SYSTEM		
Closed System	**Open System**	**Isolated System**
No Mass Transfer Allowed Energy Transfer Allowed	Mass Transfer Allowed Energy Transfer Allowed	No Mass Transfer Allowed No Energy Transfer Allowed **But Work Transfer is allowed.**
Eg. Closed Cointainer, Vessel, Balloons, Piston cylinder when valves are closed	Eg. Turbine, Compressor, Nozzle, Pipe Line.	Eg. Thermos Flask.

Controlled Volume: Region in the space consider for study.
Controlled Surface: Separates region from surroundings.