STUDY MATERIAL

SUBJECT : BASIC MECHANICAL ENGG.(BME)

MODULE-I

SEMESTER : 1^{ST} / 2^{ND}

(ALL BRANCHES)

CONTENTS :

- OBJECTIVE TYPE QUESTIONS AND ANSWERS
- SHORT TYPE QUESTIONS AND ANSWERS
- LONG TYPE QUESTIONS AND ANSWERS

DEPARTMENT OF MECHANICAL ENGINEERING

Imp. Notes

- First law of thermodynamics: (a) When a small amount of work (dw) is supplied to a closed system undergoing a cycle, the work supplied will be equal to the heat transfer or heat produced (dQ) in the system. (b) If Q amount of heat is given to a system undergoing a change of state and W is work done by the system and transferred during the process, the net energy ($Q - W$) will be stored in the system named as internal energy or simply energy of the system (ΔU).
- In a steady flow process, thermodynamic properties at any section remain constant with respect to time; it can vary only with respect to space.
- In some flow process mass flow rate is not steady but varies with respect to time. In such a case, the difference in energy flow is stored in system as ΔE_v.
- Second law of thermodynamics: The Kelvin–Planck statement of the second law can be given as: It is impossible for any system to operate in a thermodynamic cycle and deliver a net amount of energy by work to its surroundings while receiving energy by heat transfer from a single thermal reservoir.
- It is impossible to construct a device that operates in a cycle and produces no effect other than the transfer of heat from a lower temperature body to higher temperature body.
- A process is said to be reversible if it is possible for its effects to be eradicated in the sense that there is some way by which both the system and its surroundings can be exactly restored to their respective initial states. (It is not physically possible; it is an idealization.)
- A process is irreversible if there is no means by which the system and its surroundings can be exactly restored to their respective initial states.
- The thermal efficiency of an irreversible power cycle is always less than the thermal efficiency of a reversible power cycle when each operates between the same two thermal reservoirs.
- All reversible power cycles operating between the same two thermal reservoirs have the same thermal efficiency.
- Entropy is degree of measurement of disorderness of a system.
- Third law of thermodynamics states that it is impossible to reduce any system to absolute zero in a finite series of operations.
- Boyle's law states that the volume and pressure of a sample of gas are inversely proportional to each other at constant temperature.
- Charles's law states that the volume of a sample of gas is directly proportional to the absolute temperature when pressure remains constant.
- Gay Lussac's law states that the pressure of a sample of gas is directly proportional to the absolute temperature when volume remains constant.
- The sum of all the microscopic forms of energy is called the internal energy of a system and is denoted by U.
- Due to different type of movements of molecules, such as translational, rotational and vibrational, kinetic energy in the system is developed.
- Internal energy may be presented in the form of binding force at atomic level.
- If external energy is supplied to break the bond and to change the phase from solid to liquid or liquid to solid, a certain amount of energy is stored as latent energy. This latent energy represents internal energy of the system.
- In constant volume process, work done is equal to zero.
- In adiabatic process, heat transfer is equal to zero.

MULTIPLE CHOICE QUESTIONS

1. A closed system is one, which
   (a) permits the passage of energy and matter across boundaries
   (b) does not permit the passage of energy and matter across boundaries
   (c) permits the passage of energy but does not permit the passage of matter
   (d) does not permit the passage of energy but permits the matter

2. An isolated system is one, which
   (a) permits the passage of energy and matter across boundaries
   (b) permits passage of energy only

(c) does not permit the passage of energy and matter across boundaries
(d) permits the passage of matter only

3. A system comprising of single phase is known as
(a) open system
(b) closed system
(c) homogeneous system
(d) heterogeneous system

4. Control volume refers to
(a) a specified mass
(b) a fixed region in space
(c) a closed system
(d) none of the above

5. Specific heat is the amount of heat required to raise the temperature
(a) by unit degree of a substance
(b) by unit degree of a unit mass
(c) of a unit mass by 5°C
(d) none of these

6. Internal energy of a perfect gas depends upon
(a) temperature only
(b) temperature and pressure
(c) temperature, pressure and specific heats
(d) none of these

7. For a closed system, the difference between the heat added to the system and work done by the gas is equal to the change in
(a) enthalpy (b) entropy
(c) internal energy (d) temperature

8. The properties of the system, whose value for the entire system is equal to the sum of their values for individual parts of the system, are known as
(a) thermodynamic properties
(b) extensive properties
(c) intensive properties
(d) none of the above

9. Temperature of a system is
(a) thermodynamic properties
(b) extensive properties
(c) intensive properties
(d) none of the above

10. When two bodies are in thermal equilibrium with a third body, they are also in thermal equilibrium with each other
(a) zeroth law of thermodynamics
(b) first law of thermodynamics
(c) second law of thermodynamics
(d) none of the above

11. The measurement of thermodynamic properties known as temperature is based on
(a) zeroth law of thermodynamics
(b) first law of thermodynamics
(c) second law of thermodynamics
(d) none of the above

12. Heat and work are mutually convertible. This statement is
(a) zeroth law of thermodynamics
(b) first law of thermodynamics
(c) second law of thermodynamics
(d) none of the above

13. Second law of thermodynamics defines
(a) enthalpy (b) entropy
(c) heat (d) work

14. Kelvin–Planck's law deals with
(a) conversion of work into heat
(b) conversion of heat into work
(c) conservation of work
(d) conservation of heat

15. According to Kelvin–Planck's statement, a perpetual motion machine
(a) of first kind is possible
(b) of first kind is impossible
(c) of second kind is impossible
(d) of second kind is possible

16. A perpetual motion machine of the first kind, i.e., a machine which produces power without consuming any energy is
(a) possible according to the first law of thermodynamics
(b) impossible according to first law of thermodynamics
(c) impossible according to second law of thermodynamics
(d) possible according to second law of thermodynamics

17. Heat flows from cold substance to hot substance with the aid of external work. This statement is given by
(a) Kelvin (b) Joule
(c) Gay Lussac (d) Clausius

18. Specific heat at constant volume is given by
(a) $\frac{R}{J(\gamma-1)}$ (b) $\frac{\gamma R}{J(\gamma-1)}$
(c) $\frac{R(\gamma-1)}{J}$ (d) $\frac{J(\gamma-1)}{R}$

19. Specific heat at constant pressure is given by
    (a) $\dfrac{R}{J(\gamma-1)}$ (b) $\dfrac{\gamma R}{J(\gamma-1)}$
    (c) $\dfrac{R(\gamma-1)}{J}$ (d) $\dfrac{J(\gamma-1)}{R}$

20. The condition for reversibility of a cycle is
    (a) $\oint\dfrac{dQ}{T}<0$ (b) $\oint\dfrac{dQ}{T}>0$
    (c) $\oint\dfrac{dQ}{T}=0$ (d) none of the above

21. The condition for irreversibility of a cycle is
    (a) $\oint\dfrac{dQ}{T}<0$ (b) $\oint\dfrac{dQ}{T}>0$
    (c) $\oint\dfrac{dQ}{T}=0$ (d) none of the above

22. If $\oint\dfrac{dQ}{T}>0$, the cycle is
    (a) reversible (b) irreversible
    (c) impossible (d) none of the above

23. Biogas is produced under anaerobic conditions by the fermentation of biological materials. What is the main constituent of biogas?
    (a) butane (b) ethane
    (c) methane (d) propane

24. A sample of neon gas occupies a volume of 2.8 l at 1.8 atm. What will its volume be at 1.2 atm?
    (a) 1.2 l (b) 1.8 l
    (c) 2.2 l (d) 4.2 l

25. The pressure required to compress 48 l of oxygen gas at 99.3 kPa in order to reduce its volume to 16 l is
    (a) 198 kPa (b) 278 kPa
    (c) 298 kPa (d) 320 kPa

26. Volume of sulphur dioxide gas at 0.989 atm is 59 ml. What will be its volume at 0.967 atm?
    (a) 60.3 ml (b) 68 ml
    (c) 80 ml (d) 108 ml

27. A sample of hydrogen gas at 6.5 atm pressure occupies a volume of 2.2 l. What will be its volume at 1.15 atm?
    (a) 10 l (b) 12 l
    (c) 14 l (d) 16 l

28. A balloon full of air has a volume of 2.75 l at a temperature of 291 K. What will be volume of the balloon at 318 K?
    (a) 2.10 l (b) 3.01 l
    (c) 3.5 l (d) 4.12 l

29. A sample of argon gas has a volume of 0.43 ml at 297 K. At what temperature will it have a volume of 0.57 ml?
    (a) 394 K (b) 294 K
    (c) 494 K (d) 194 K

30. When the atmospheric pressure is increased on a balloon, the volume of the balloon will
    (a) increase (b) decrease
    (c) stay the same (d) none of these

31. When the temperature of a gas is increased in a balloon, the volume of the balloon will
    (a) increase (b) decrease
    (c) stay the same (d) none of these

32. When the volume of a gas is decreased, the pressure of the gas will
    (a) increase (b) decrease
    (c) stay the same (d) none of these

33. A balloon is filled with helium gas to a pressure of 107 kPa when the temperature is 295 K. If the temperature changes to 318 K, what will be the pressure of the helium in the balloon?
    (a) 115 kPa (b) 125 kPa
    (c) 135 kPa (d) 145 kPa

34. An isothermal process is governed by
    (a) Boyle's law (b) Charle's law
    (c) Joule's law (d) Gay Lussac's law

35. When the expansion follows the law $PV^n = C$, the process is
    (a) isothermal process
    (b) adiabatic process
    (c) polytropic process
    (d) hyperbolic process

36. Real gas follows the relation
    (a) $PV = RT$ (b) $PV^n = RT$
    (c) $PV = nRT$ (d) $(PV)^n = C$

37. For real gas, $C_p = C_v$, at
    (a) absolute zero
    (b) critical temperature
    (c) triple point
    (d) all temperature

Answers

1. (c), 2. (c), 3. (c), 4. (b), 5. (b), 6. (a), 7. (c), 8. (b), 9. (c), 10. (a), 11. (a), 12. (b), 13. (b) 14. (b), 15. (c), 16 (b), 17. (d), 18. (a), 19. (b), 20. (c), 21. (a), 22. (c), 23. (c), 24. (d), 25. (c), 26. (a), 27. (b), 28. (b), 29. (a), 10 (b), 31. (a), 32. (a), 33. (a), 34. (a), 35. (c), 36. (c), 37. (a)

FILL IN THE BLANKS

1. The system and surrounding together constitute ___________ system.
2. In an adiabatic process, energy can be exchanged in the form of ___________.
3. For an ideal gas (dh/dT) is a measure of ___________ at constant pressure.
4. Second law of thermodynamics establishes the law of ___________.
5. The slope of constant volume line on T–S diagram is ___________ than that of constant pressure line.
6. The unit of entropy is ___________.
7. In case of free expansion enthalpy ___________.
8. The entropy of universe tends to be ___________.

Answers

1. Isolated, 2. Heat, 3. Specific heat, 4. Entropy, 5. More, 6. kJ/kg K, 7. Remains constant, 8. Maximum.

REVIEW QUESTIONS

1. What is prime mover? Discuss its importance in energy conversion.
2. Explain the various sources of energy mentioning renewable and non-renewable sources.
3. What do you mean by non-conventional energy sources? How does it differ from conventional sources?
4. Explain the scope of solar energy and its future applications.
5. Define: (i) property, (ii) state, (iii) system, (iv) control volume, and (v) process.
6. Discuss the concept of thermal equilibrium and state zeroth law of thermodynamics.
7. What do you understand by quasi-static process? How it is achieved?
8. Differentiate among temperature, heat, and internal energy.
9. Derive an expression for first law of thermodynamics applied to a closed system. Define the internal energy of a system.
10. Define work. Show that work done $W = PdV$.
11. Discuss the thermodynamics system, surrounding, and universe. Also discuss the various types of system with suitable example.
12. Prove that work and heat are the path function.
13. Derive the expression for work done in steady flow process.
14. Distinguish between the term 'change of state', 'path', and 'process'.
15. State the zeroth law of thermodynamics and first law of thermodynamics.
16. Explain and derive steady flow energy equation (SFEE).
17. State the Kelvin–Planck and Clausius statements of second law of thermodynamics. Explain the equivalence of Kelvin–Planck and Clausius statements.
18. State and explain Carnot theorem.
19. Write the statement of Boyle's law.
20. Write the statement of Charle's law.
21. Write the statement of Gay–Lussac's law.

Short Questions and Answers

MODULE 1

Thermodynamics

1.1. Define thermodynamic system.

A specified space or region containing matter or group of matter, where the transformation of mass and energy from one form to another is studied, is called thermodynamic system.

1.2 Define thermodynamic system Classify the following system as open/closed/isolated

(a) Mixture of ice and water in a metal container (b) A wind mill.

Thermodynamic system is defined as a space or constrained area upon which our attention is concentrated on. It is the region to be studied.

(a) Mixture of ice and water in a metal container - closed system

(b) A wind mill - open system

1.3 What is meant by thermodynamic system? How do you classify it?

Thermodynamic system is defined as any space or matter or group of matter where the energy transfer or energy conversions are studied.

It may be classified into three types.

(a) open system

(b) closed system

(c) isolated system.

1.4 What is meant by closed system? Give an example.

When a system has only heat and work transfer, but there is no mass transfer, it is called as closed system.

Example: Piston and cylinder arrangement with valves closed.

1.5 Define open system. Give an example.

When a system has heat, work and mass transfer, it is called as open system. Example: Air compressor.

1.6. What is surroundings?

The space or matter external to a thermodynamic system is called surroundings.

1.7 Differentiate closed and open system:

Closed System		Open System	
1.	There is no mass transfer. Only heat and work will transfer.	1.	Mass transfer will take place, in addition with heat and work transfer.
2.	System boundaries are real.	2.	System boundaries are often imaginary.
	Example: Piston & cylinder arrangement, Thermal power plant.		Air compressor, boiler.

1.8 Define an isolated system:

Isolated system is not affected by surroundings. No heat, work and mass transfer takes place. In this system total energy remains constant.

Example: Entire Universe.

1.9 What is meant by surroundings?

Any other matter outside of the system boundary is called as surroundings.

1.10 What is boundary?

System and surroundings are separated by an imaginary line which is called boundary.

1.11. Define property of a system.

Any characteristic used to identify the system and it can be measured directly or indirectly when the system is in equilibrium is known as property., (e.g) pressure, volume, temperature.

1.12 What is meant by thermodynamic property?

Thermodynamic property is any characteristic of a substance which is used to identify the state of the system and it can be measured, when the system remains in an equilibrium state.

1.13. How do you classify the property?

Thermodynamic property can be classified into two types.

1. Intensive or Intrinsic property
2. Extensive or Extrinsic property.

1.14. Define intensive and extensive properties.

The property of a thermodynamic system which is independent of its mass is called intensive property. (e.g) pressure, temperature. The property of a thermodynamic system which is dependent or proportional to its mass is called extensive property. (e.g) volume

1.15. Differentiate Intensive and Extensive properties.

Intensive Properties		**Extensive Properties**	
1.	Independent on the mass of the system.	1.	Dependent on the mass of the system.
2.	If we consider part of the system, these properties remain same.	2.	If we consider part of the system it will have a lesser value.
	e.g. pressure, Temperature, specific volume etc.		e.g. Total energy, Total volume, weight etc.,

1.16. Define the term process.

It is defined as the change of states undergone by a fluid due to energy flow.

1.17. Define the term Cycle.

When a system undergoes a series of processes and return to its original state, it is known as cycle.

1.18. What is meant by open and closed cycle?

In a closed cycle, the same working substance will recirculate again and again.

In an open cycle, the working substance will be exhausted to the surroundings after expansion.

1.19 What is meant by reversible and irreversible process?

If a process traces the same path in the reverse direction when the process is reversed, then it is called reversible process. It is possible only when the system passes through a continuous series of equilibrium state.

If a system does not passes through continuous equilibrium state, then the process is said to be irreversible. All the processes in the world are irreversible processes.

1.20 Explain point function and path function.

Point function is independent of the path that the system follows during the change of state, and depends only on the initial and final states, (e.g) Thermodynamic properties like volume, pressure, temperature etc.

Path function depends on the path that the system follows during the change of state, and does not depend on the initial and final states of system (e.g) Work transfer and Heat transfer.

1.21 Define Heat.

Heat is the energy crossing the boundary due to the temperature difference between the system and surroundings.

1.22 What is the meant by thermodynamic work?

It is the work done by the system (or) work done on the system when the energy transferred across the boundary of the system. It is mainly due to intensive property difference between the system and surroundings.

1.23 State the law of Conservation of energy.

Energy can neither be created nor destroyed, but it can be transferred from one form to another.

1.24. What do you understand by the term thermodynamic equilibrium?

A system is said to exist in a state of thermodynamic equilibrium, when no change in any macroscopic property is registered.

The system in thermodynamic equilibrium must essentially be in

(i) **Mechanical equilibrium:** Absence of any unbalanced forces within the system itself and also between system and surroundings. (pressure remains constant)

(ii) **Thermal equilibrium:** Temperature at all points of system must be same.

(iii) **Chemical equilibrium:** No chemical reaction within the system.

1.25. Define quasi-static process.

When a process proceeds in such a slow manner that the system remains infinitesimally close to an equilibrium state at all times, it is called quasi-static process.

1.26 State Zeroth law of thermodynamics.

When a body A is in thermal equilibrium with a body B and also separately with a body C, then B and C will be in thermal equilibrium with each other.

1.27 Define 'process' and 'cycle' with one example each.

Any change that a system undergoes from one equilibrium state to another is called a process (eg). constant pressure process.

The series of processes whose end states are identical, then it is called cycle (eg): conversion of water into ice and vice-versa.

In this fig., 1-2 is a process

2-1 is a process

1-2-1 is a cycle

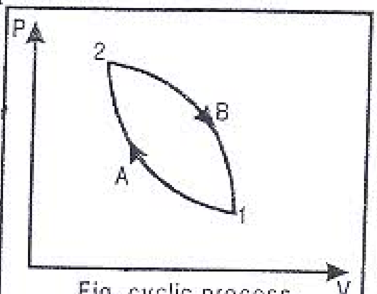


Fig. cyclic process.

1.28 Differentiate macroscopic viewpoint and Microscopic viewpoint.

Macroscopic viewpoint	Microscopic viewpoint
1. It is also called as classical thermodynamics.	It is also called as statistical thermodynamics.
2. Behaviour of each molecule need not to be determined.	Behaviour of each molecule need to be determined.
3. Molecular effects can be perceived by human senses.	Molecular effects cannot be perceived by human senses.
4. Classical thermodynamics, however can be derived from statistical thermodynamics.	Statistical thermodynamics cannot be determined using classical thermodynamics.
5. eg: Pressure, Temperature	eg: Enthalpy, Entropy

1.29 What is meant by homogeneous and heterogeneous systems?

A system, which contains only a single phase, is called as Homogeneous system.

Eg. Mixture of air and water vapour.

A system, which consists of more than one phase, is called as Heterogeneous system.

Eg. Mixture of water and steam.

1.30 Distinguish between reversible process and irreversible process.

Reversible process	Irreversible process
(i) Reversible process is an ideal process	Irreversible process is a natural process. (i.e.) all the processes occurring in nature are irreversible.

Reversible process	Irreversible process
(ii) Reversible process attains equilibrium state at all the stages of the operation.	Irreversible process is in equilibrium only at the initial and final stages of operation.
(iii) It is a extremely slow process.	It occurs at measurable speed.
(iv) It takes infinite time for the process to occur.	It takes place in finite time.
(v) Workdone by a reversible process is greater than the corresponding irreversible process.	Workdone by an irreversible process is lesser than the corresponding reversible process.
(vi) It does not increase the entropy of the universe.	It increases the entropy of the universe (system & surroundings).

1.31 State first law of thermodynamics applied to cycle.

If a system executes a cycle transferring work and heat through its boundary, then the net work transfer is equivalent to the net heat transfer.

$$\oint dW = \oint dQ$$

1.32 State the corollary of the first law applied to a closed system process, with reference to internal energy.

In first law, there exists a property of a system called internal energy such that a change in its value is equal to the difference between the heat supplied and work done during any change of state.

$$Q - W = dU$$

1.33 Define the term internal energy.

Internal energy of a gas is the energy stored in a gas due to its molecular interactions.

It is also defined as the energy possessed by a gas at a given temperature.

1.34 Define enthalpy.

Enthalpy of a substance is defined as the sum of flow work and the internal energy contained in it.

Enthalpy $h = u + pv$ $\quad u =$ Internal energy, $pv =$ Flow work

1.35 Define Specific heat capacity at constant pressure.

It is defined as the amount of heat energy required to raise or lower the temperature of unit mass of the substance through one degree when the pressure is constant. It is denoted by C_p. $\left[C_p = \dfrac{dh}{dT}\right]$

1.36 Define Specific heat capacity at constant volume.

It is defined as the amount of heat energy required to raise or lower the temperature of unit mass of the substance through one degree when volume is constant. It is denoted by C_v. $\left[C_v = \dfrac{du}{dT}\right]$

1.37 Define PMM of first kind.

PMM of first kind delivers work continuously without any input. It violates first law of thermodynamics. It is impossible to construct an engine working with this principle.

1.38 What is meant by internal energy?

Internal energy is defined as the sum of all microscopic forms of energy of a system. It is the energy associated with the molecular structure and the molecular activity of the constituent particles of the system.

1.39 Distinguish between heat and temperature.

The temperature is a thermal state of body which distinguishes a hot body from a cold body. The temperature of a body is proportional to the stored molecular energy.

Heat is something which appears at the boundary when a system changes its state due to a difference in temperature between the system and surroundings.

1.40 Which property is constant in throttling process?

Enthalpy.

1.41 A rigid tank is insulated around both its ends. It is separated initially into two equal volumes by a partition. When one side contains 1 kg of gas at 100 kPa and 345°C, the other side remains evacuated. If the partition is removed, find final pressure and temperature.

Solution

Let us represent the initial and final states by suffix i, f. This is a case of free expansion. For free expansion $\delta w = 0$

From first law of Thermodynamics $\delta Q = du + \delta w$

$\delta Q = 0$ since the chamber is insulated $0 = du + 0 \Rightarrow du = 0$

Change in internal energy $dv = mC_v(\Delta T)$

$$\Rightarrow \Delta T = 0 \Rightarrow T_i - T_f = 0$$

$$\therefore T_i = T_f$$

$\therefore$ final state temperature = 345°C. $\dfrac{P_1V_1}{T_1} = \dfrac{P_2V_2}{T_2} \Rightarrow P_1V_1 = P_2(2V_1)$

$$\therefore \quad P_2 = \frac{P_1}{2} = 50 \text{ kPa}$$

1.42 What is the difference between steady flow and non-flow process?

During the steady flow process, the rate of flow of mass and energy across the boundary remains constant.

In case of non-flow process, there is no mass flow across the system and boundary.

1.43 Write down the steady flow equation and define the terms in it.

The SFEE is,

$$\dot{m}\left[gZ_1 + \frac{C_1^2}{2} + h_1\right] + \dot{Q} = \dot{m}\left[gZ_1 + \frac{C_2^2}{2} + h_2\right] + \dot{W}$$

where

Z_1 and Z_2 - Height above the datum at inlet and exit. (m)

C_1 and C_2 - Velocity of flow at inlet and exit. (m/s)

h_1 and h_2 - enthalpy of fluid at inlet and exit. (J/kg)

$\dot{Q}$ - heat transfer during the flow through the system. (Watts)

$\dot{W}$ - Work transfer during the flow through the system. (Watts)

$\dot{m}$ - mass flow rate. (kg/s)

1.44 Give the SFEE applicable to nozzle.

The SFEE for nozzle is $\dfrac{C_1^2}{2} + h_1 = \dfrac{C_2^2}{2} + h_2$

where h is in $\dfrac{\text{J}}{\text{kg}}$

So $V_2 = \sqrt{2(h_1 - h_2) + V_1^2}$

1.45 Write down the SFEE applicable to the following system.
(i) Boiler (ii) Compressor (iii) Turbines

The SFEE for

(i) Boiler $h_1 + Q = h_2 \Rightarrow Q = h_2 - h_1$

(ii) Compressor

(a) reciprocating $h_1 + Q = h_2 + W \Rightarrow W = (h_1 - h_2) + Q$

(b) Rotary $h_1 = h_2 + W \Rightarrow W = h_1 - h_2$

(iii) Turbine $h_1 = h_2 + W \Rightarrow W = h_1 - h_2$

1.46 In the equation $PV^n = C$, the value of $n = \infty$, then the process is called ________.

Constant Volume process.

1.47 The polytropic index (n) is given by ________.

$$n = \frac{\ln\left(\frac{P_2}{P_1}\right)}{\ln\left(\frac{V_1}{V_2}\right)}$$

1.48 Work transfer is equal to heat transfer in case of ________ process.

Isothermal Process.

1.49 Write down the characteristic gas equation.

Characteristic gas equation is $PV = mRT$

where $P =$ pressure

$V =$ Volume

$R =$ Characteristic gas constant

$T =$ Temperature in kelvin K.

1.50 State second law of thermodynamics.

Kelvin-planck statement:

It is impossible for a heat engine to produce net work in a complete cycle if it exchanges heat only with bodies at a single fixed temperature.

Clausius statement:

It is impossible to construct a device operating in a cycle, which will transfer heat from a cooler to a hotter body without consuming external work.

1.51 State Kelvin-Plank statement of second law of thermodynamics.

Kelvin-Plank states that it is impossible to construct a heat engine working on cyclic process, whose only purpose is to convert all the heat energy given to it, into an equal amount of work.

1.52 State Clausius statement of second law of thermodynamics.

It states that heat can flow from hot body to cold body without any external aid but heat cannot flow from cold body to hot body without any external aid.

1.53 Define heat pump.

A heat pump is a device which operating in a cycle maintains a body at a temperature higher than the temperature of the surroundings.

1.54 What is meant by heat engine?

A heat engine is a device which is used to convert the thermal energy into mechanical energy.

1.55 Define refrigerator.

A refrigerator is a device which operating in a cycle maintains a body at a temperature lower than the temperature of the surroundings.

1.56 Define the term COP.

Coefficient of performance is defined as the ratio of desired effect (heat added or removed) to work input.

$$COP = \frac{\text{Heat extracted or rejected}}{\text{Work input}} = \frac{\text{Desired Effect}}{\text{Work Input}}$$

1.57 Write the expression for COP of a heat pump and a refrigerator.

$$\text{COP for heat pump } COP_{HP} = \frac{\text{Heat added}}{\text{Work input}} = \frac{Q_1}{W}$$

$$\text{COP for refrigerator } COP_{ref} = \frac{\text{Heat removed}}{\text{input}} = \frac{Q_2}{W}$$

1.58 Define the term efficiency for any heat engine and for a carnot engine.

The efficiency of any heat engine is the ratio between work output and heat input.

$$\text{Efficiency} = \frac{Q_1 - Q_2}{Q_1} = \frac{W_{net}}{Q_1}$$

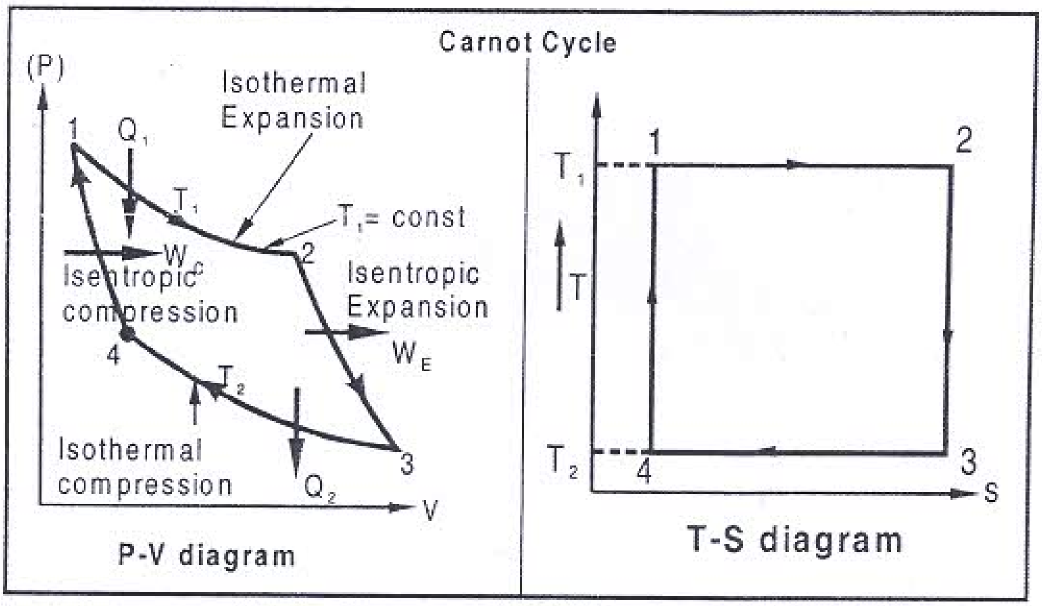
$$\text{Carnot efficiency} = \frac{T_1 - T_2}{T_1} \left[\text{Also } \eta_{carnot} = \frac{Q_1 - Q_2}{Q_1} = \frac{W_{net}}{Q_1} \right]$$

where Q_1 = heat supplied ; Q_2 = heat rejected

T_1 = Maximum temperature of the cycle

T_2 = Minimum temperature of the cycle

1.59 Sketch the carnot cycle on P-V and T-S diagram.



1-2, Reversible Isothermal expansion

2-3, Reversible Adiabatic expansion.

3-4, Reversible Isothermal compression.

4-1, Reversible Adiabatic compression.

1.60 Why Carnot cycle cannot be realized in practice?

(i) In a Carnot cycle, all the four processes are reversible but in actual practice no process is reversible.

(ii) For isothermal process, the piston moves very slowly and for adiabatic process the piston moves as fast as possible. This speed variation during the same stroke of the piston is not possible.

(iii) It is not possible to avoid friction between moving parts completely.

1.61 Name two alternative methods by which the efficiency of a Carnot cycle can be increased.

(i) Efficiency can be increased when the higher temperature T_1 increases.

(ii) Efficiency can be increased, when the lower temperature T_2 decreases.

1.62 Write the expression for efficiency of the carnot cycle engine.

$$\eta_{carnot} = \frac{T_1 - T_2}{T_1} = \frac{Q_1 - Q_2}{Q_1}$$

1.63 Define entropy.

There exists a property of a system whose value at the final state (f) minus its value at the initial state (i) is equal to dQ/T. This property is called entropy. It is a measure of degree of molecular disorder.

1.64 What are the two major conclusions deduced from the carnot principles?

The carnot principles are the two conclusions pertaining to the thermal efficiency of reversible (ideal) and irreversible (actual) heat engines, drawn from the Kelvin - Planck and clasius statements of the second law of thermodynamics. The carnot principles are:

1. The efficiency of an irreversible heat engine is always less than the efficiency of a reversible one, operating between the same two thermal reservoirs.
2. The efficiencies of all reversible heat engine operating between the same two thermal reservoirs are the same.

The first principle is called carnot theorem and the second is the corollary of the carnot theory.

1.65 What is the principle of increase of Entropy?

For an Isolated system $\Delta S_{isolated} \geq 0$

This equation can be expressed as the entropy of an isolated system during a process always increases or, in the limiting case of a reversible process remains constant. In otherwords, it never decreases. This is known as the increase of entropy principle.

1.66 Define an isentropic process.

Isentropic process is also called as reversible adiabatic process. It is a process which follows the law of $pV^{\gamma} = C$. During this process, entropy remains constant and no heat enters or leaves the system.

1.67 State Carnot's theorem.

No heat engine operating in a cyclic process between two fixed temperatures, can be more efficient than a reversible engine operating between the same temperature limits.

1.68 What are the Corallaries of Carnot theorem.

(i) All the reversible engines operating between the two given thermal reservoirs with fixed temperature, have the same efficiency.

(ii) The efficiency of any reversible heat engine operating between two reservoirs is independent of the nature of the working fluid and depends only on the temperature of the reservoirs.

1.69 What is PMM-2?

Perpetual motion machine of second kind is a heat engine working in a cycle which draws heat continuously from a single reservoir and converts it into equal amount of work.

1.70 State Fower-Guggenheim statement of the third law.

It states that "It is impossible by any procedure, no matter how idealized, to reduce any system to the absolute zero of temperature in a finite number of operations".

1.71 State Nernst-Simon statement of the third law.

It states that "The entropies of all systems and the entropy changes in all reversible isothermal process tend to zero as the temperature approaches zero".

1.72 Explain the process of steam generation.

I Stage: By heating, the temperature of water rises to its boiling temperature known as saturation temperature.

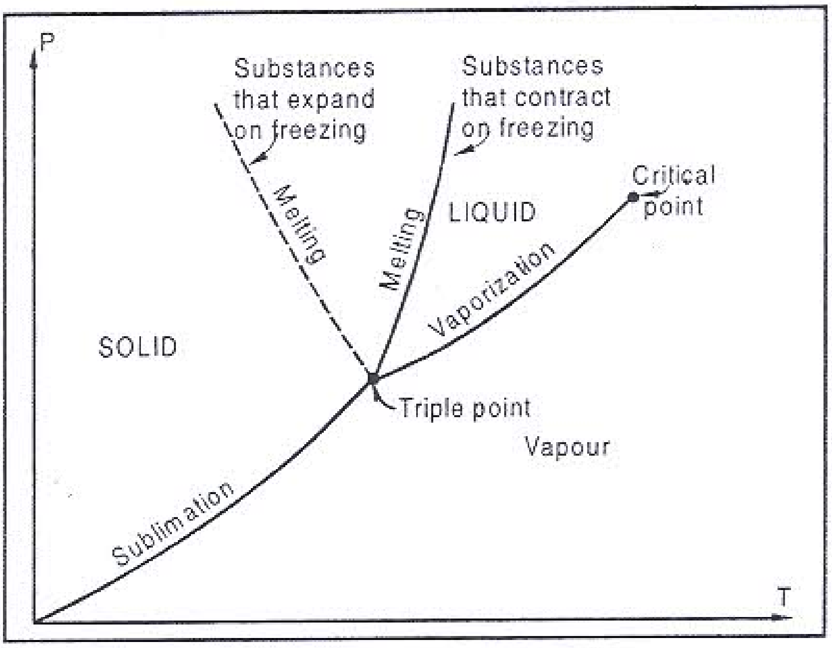
II Stage: Steam begins to form at this constant temperature until all water is converted into dry saturated steam. Till then, it will be wet steam.

III Stage: Further heating causes the temperature of the dry steam to rise, forming superheated steam, which behaves more or less like a gas.

1.73 What is meant by triple point?

Triple point is the point on the P-V diagram of a pure substance where all the three phases solid, liquid and gas exist in equilibrium.

Triple point of water: 4.58 mm of Hg and 273.160 K.



1.74 *What is meant by dry steam?*

It is the condition of steam, at which any addition of heat leads to increase in temperature and any extraction of heat, brings a change in phase. Also,the dry steam does not contain any water particles.

1.75 *What is known as Superheated Steam?*

When the temperature of steam is greater than saturation temperature corresponding to the given pressure the steam is said to be superheated steam. When given $t > t_{sat}$, then steam is superheated steam.

1.76 *What is meant by dryness fraction of steam?*

The ratio of the mass of dry vapour to the total mass of the mixture.

$$x = \text{mass of dry steam / mass of mixture } = \frac{m_g}{(m_f + m_g)}$$

1.77 *Define quality of steam. What are the methods of determining quality of steam?*

The quality of steam is designated by the term dryness fraction of steam, which is defined as the mass of steam present in 1 kg of mixture (mixture = water + steam).

Methods of determining quality of steam:

(i) Tank or Barrel Calorimeter

(ii) Separating calorimeter

(iii) Throttling calorimeter

(iv) Separating and Throttling Calorimeter.

1.78 What is a sub-cooled liquid?

At 20°C and 1 atm pressure, (state 1. **Fig. 5.3**). water exists in the liquid phase, and it is called a **compressed liquid**, or a **subcooled liquid,** meaning that **is not about to vaporize**.

1.79 What is saturation temperature and pressure?

At a given pressure, the temperature at which a pure substance changes its phase is called the **saturation temperature** T_{sat}. Likewise, at a given temperature, the pressure at which a pure substance changes its phase is called the **saturation pressure** P_{sat}. At a pressure of 101.325 kPa, T_{sat} is 100°C. Conversely, at a temperature of 100°C, P_{sat} is 101.325 kPa.

1.80 Define latent heat of fusion and latent heat of vaporization.

The amount of energy absorbed during melting is called the **latent heat of fusion** and is equivalent to the amount of energy released during **freezing.** Similarly, the amount of energy absorbed during vaporization is called the **latent heat of vaporization** and is equivalent to the energy released during **condensation.**

1.81 What is equation of state? Write the same for an ideal gas.

The equation which relates the properties P, v, T is known as an Equation of state.

$$\text{(ie)} \quad f(P, v, T) = 0$$

The simplest form of equation of state for the ideal gas is given below.

Equation of state: $P\bar{v} = \bar{R}T$

where $\bar{R}$ = universal gas constant in kJ/kgmole.K

$\bar{v}$ = molar volume in m^3/kg mol

Also: $Pv = RT$

where R = Characteristic gas constant in kJ/kgk

v = Specific volume in m^3/kg

The above equation – Equation of state is also called as characteristic gas equation.

1.82 Have you ever encountered any ideal gas? If so, where,

Ideal gas do not have intermolecular attractive forces. These ideal gases obey the equation of state at all ranges of pressure and temperature.

Practically, no ideal gas exists in nature. However, hydrogen, oxygen, nitrogen and air behave as an ideal gas at higher temperatures and lower pressures.

1.83 What is characteristic gas constant?

$$R = \frac{\overline{R}}{\mu}$$

Example: $R_{O_2} = \dfrac{\overline{R}}{\mu_{O_2}} = \dfrac{8.3143}{32} = 0.262$ KJ/kg K