SUMMER – 19 EXAMINATION

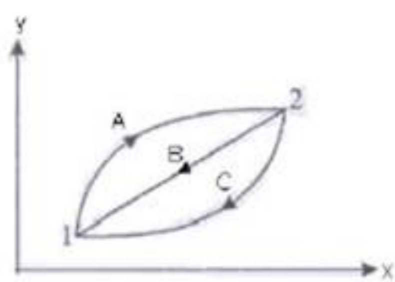
Subject Name: Thermal Engineering **Model Answer** **Subject Code: 17410**

Important Instructions to examiners:

1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling errors should not be given more Importance (Not applicable for subject English and Communication Skills.
4) While assessing figures, examiner may give credit for principal components indicated in the figure. The figures drawn by candidate and model answer may vary. The examiner may give credit for any equivalent figure drawn.
5) Credits may be given step wise for numerical problems. In some cases, the assumed constant values may vary and there may be some difference in the candidate's answers and model answer.
6) In case of some questions credit may be given by judgement on part of examiner of relevant answer based on candidate's understanding.
7) For programming language papers, credit may be given to any other program based on equivalent concept.

Q.1.		**Attempt any SIX of the following:**	**12 Marks**
a)	i)	**List the properties of system with example.**	
	Sol.	Properties of system- An intensive property is independent of the amount of mass. Temperature, pressure, specific volume, and density are examples of intensive properties These properties are the same regardless of how you vary the amount of mass of the substance.. Extensive property is dependent on mass. Enthalpy, Entropy, total volume are examples of extensive properties.	**02 marks**
	ii)	**State Boyle's law.**	
	Sol.	**Boyle's Law**: It states that under a constant temperature when the pressure on a gas increases its volume decreases. In other words according to Boyle's law volume is inversely proportional to pressure when the temperature and the number of molecules are constant.	**01 mark**
		$V \propto 1 / P$ $p = k_1 * 1/V$ k_1 here is a proportionality constant, V is the Volume and p is the pressure. according to Boyle's law: $P_1 \times V_1 = P_2 \times V_2 =$ constant (k_1)	**01 mark**
	iii)	**Explain Quasi static Process of thermodynamic.**	
	Sol.	**Quasi Static process:** A quasi-static process is a thermodynamic process that happens slowly enough for the system to remain in internal equilibrium. An example of this is quasi-static compression, where the volume of a system changes at a slow rate enough to allow the pressure to remain uniform and constant throughout the system. The process which take all isothermal and adiabatic operation very slowly know as Quasi static process.	**01 mark**
		Quasi means 'almost'. This process is a succession of equilibrium states and infinite slowness is its characteristic feature. Any reversible process is a quasi-static one.	**01 mark**

	iv)	**Write names of any two boiler mountings and two boiler accessories.**	
	Sol.	**Boiler mountings (Any two)** 1. Water level indicator (Water level gauge) 2. Pressure gauge 3. Safety valves 4. Stop valve 5. Blow off cock (Blow off valve) 6. Feed check valve **Boiler accessories (Any two)** 1. Air pre-heater 2. Super heater 3. Economizer 4. Feed pump 5. Injector	**01 mark** **01 mark**
	v)	**Classify cooling tower**	
	Sol.	**Classification of cooling towers** :(Any two classification criteria) Type of draught – Natural draught, Forced draught, Induced draught Type of martial- Timber, concrete, steel duct cooling tower Based on air flow pattern- Cross flow, counter flow	**01 mark** **01 mark**
	vi)	**Define vacuum efficiency of condenser.**	
	Sol.	**Vacuum efficiency of condenser:** It is the ratio of the actual vacuum at the steam inlet to the maximum obtainable vacuum in a perfect condensing plant, i.e., it is the ratio of actual vacuum to ideal vacuum. **Vacuum efficiency** = (Barometric pressure-Absolute pressure in condenser)/(Barometric pressure-Absolute pressure corresponding to temp of condensate) **Vacuum efficiency** = Actual vacuum at steam inlet to condenser / Ideal vacuum or maximum vacuum	**01 mark** **01 mark**
	vii)	**Explain Black body and Gray Body.**	
	Sol.	**Black body:** A black body is an object that absorbs all the radiant energy reaching its surface from all the direction with all the wavelengths. Gray body: **Gray Body:** A gray body is defined as a body whose absorptivity of a surface does not vary with variation in temperature and wavelength of the incident radiation. It absorbs a definite percentage of incident energy irrespective of wavelength. Its absorptivity lies	**01 mark** **01 mark**

		between 0 to 1.	
	viii)	**State Steafan Boltzman law.**	
	Sol.	**Stefan-Boltzmann law:** It states that the total radiant heat energy emitted from a surface is proportional to the fourth power of its absolute temperature . If E is the radiant heat energy emitted from a unit area in one second and T is the absolute temperature (in degrees Kelvin), then $E = \sigma T^4$, the Greek letter sigma (σ) representing the constant of proportionality, called the Stefan-Boltzmann constant.	**01 mark** **01 mark**
b)		**Attempt any TWO of the following:**	**08 Marks**
	i)	**Define energy; prove that energy is a property.**	
	Sol.	**Energy:** It is capacity to do work, i. e. The thermodynamic free energy is a concept useful in the thermodynamics of chemical or thermal processes in engineering and science. Energy is a point function and also a property of the system. Considering first law or law of conservation of energy, We can also say that energy will always be conserved. Heat and work, these are two different forms of energy. If heat energy is provided to the system by the surrounding then system may provide the work energy to the surrounding and similarly if work is being done upon the system then system may deliver the energy in terms of heat to the surrounding. Consider first law of thermodynamics for an open system or control volume. Let us assume that we have one system which is undergoing a change of state from initial state 1 to another state 2 via following the path A as shown in following figure. System is returning to initial state i.e. state 1 from state 2 via following the path B. Here, we can say that system is undergoing in a cycle 1-2-1 as displayed in figure.  Let us recall the “first law of thermodynamics for a system undergoing a change of state” and apply for path A, where system is changing its state from state 1 to state 2. We will have following equation QA- WA= ΔEA Similarly, we will have following equation when system is changing its state from state 2	**01 mark** **01 mark** **01 mark**

		to state 1 via following the path B. $$Q_B - W_B = \Delta E_B$$ We have already seen that system is undergoing in a cycle 1-2-1 as displayed in above figure. Hence, we will use the concept of "first law of thermodynamics for a system undergoing a cycle". Let us see the equation for system which constitutes a cycle 1-2-1 and we will have following equation. $$\sum_{Cycle} W = \sum_{cycle} Q$$ $$W_A + W_B = Q_A + Q_B$$ $$W_B - Q_B = Q_A - W_A$$ $$-(Q_B - W_B) = Q_A - W_A$$ $$-(\Delta E_B) = \Delta E_A$$ Let us assume that system is returning to initial state 1 from state 2 via following the path C, in that case we will go ahead similarly as we have gone above and finally we will have following equation $$-(\Delta E_C) = \Delta E_A$$ Now if we will look the end result for first case where system is returning to initial state by following the path B and of second case where system is returning to initial state by following the path C, what we will secure here that change in system energy is same in both cases and it will not depend over the path followed by the system to return to its initial state. Therefore we can conclude that system energy will have some definite magnitude for each state of the system and it will not depend over the path followed by the system and hence energy will be considered as a point function and also a property of the system.	**01 mark**
	ii)	**State Kelvin-plank and Clausius statement of second law of thermodynamics.**	
	Sol.	**The Kelvin–Planck statement** (or the Heat Engine Statement) of the second law of thermodynamics states that it is impossible to construct a operating heat engine, the effect of which is to absorb energy in the form of heat from a single thermal reservoir and to deliver an equivalent amount of work. The Kelvin-Planck statement of the second law tells us that it is impossible to constructs a perpetual motion machine of the second kind. **The Clausius Statement:** It is impossible to construct a device which operates on a cycle and produces no other effect than the transfer of heat from a cooler body to a hotter body. It is impossible to construct a device which, operating in a cycle, will produce no effect	**02 marks** **02 marks**

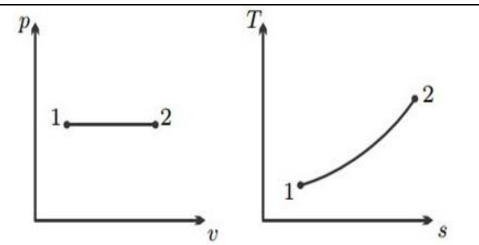
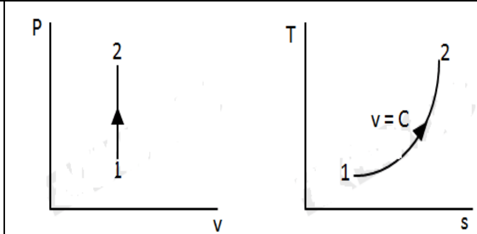
other than the transfer of heat from a low-temperature body to a high temperature body.

Apparently, the Kelvin Planck statement and the Clausius statement of the second law of thermodynamics are altogether different, but they are equivalent. A violation of Kelvin Planck statement leads to a violation of the Clausius statement too and vice-versa.

iii) Differentiate between Isobaric and Isochoric process (any four)

Sol. Differentiate between Isobaric and Isochoric Process:

01 mark each

Parameter	Isobaric	Isochoric
Definition	Constant pressure process	Constant volume process
Law	Obeys Charle's Law	Obeys Gay Lussac's law
P-V-T relation	$V_1/T_1 = V_2/T_2 = C$	$P_1/T_1 = P_2/T_2 = C$
Work done	$W= P(V_2-V_1) = mRT_1$	0
Q1-2	$mCp(T_2-T_1)$	$mCv(T_2-T_1)$
P-V and T-s Diagram		

Q.2. Attempt any <u>FOUR</u> of the following: **16 Marks**

a) Explain the term boiler drought. Why it is necessary?

Sol. Boiler draught : **02 marks**

Boiler draught may be defined as the small difference between the pressure of outside air and that of gases within a furnace or chimney at the grate level, which causes the flow of air/hot flue gases to take place through the boiler.

Necessity: **02 marks**

The draught is necessary to force air through the fuel bed/ grate to aid in proper combustion of fuel and to remove the products of combustion i.e. flue gases to the atmosphere after they have given their heat to water being evaporated in the boiler. Draught also provides velocity to flue gases and so increases the heat transfer coefficient in the boiler. This draught is essentially required in a boiler and can be produced by a number of methods. Types of draught are natural (chimney draught), forced draught, induced draught.

	b)	**Explain the various losses in steam turbine.**	
	Sol.	Losses in steam turbines (Any four losses to be explained briefly) The steam turbine is not a perfect heat engine. Energy losses tend to decrease the efficiency and work output of a turbine. This inefficiency can be attributed to the following causes. • **Residual Velocity Loss**- The velocity of the steam that leaves the turbine must have certain absolute value (Vex). The energy loss due to absolute exit velocity of steam is proportional to (Vex2/2). This type of loss can be reduced by using multistage turbine. • **Presence of Friction**- In real thermodynamic systems or in real heat engines, a part of the overall cycle inefficiency is due to the frictional losses by the individual components (e.g. nozzles or turbine blades) • **Steam Leakage**- The turbine rotor and the casing cannot be perfectly insulated. Some amount of steam leaks from the chamber without doing useful work. • **Loss Due to Mechanical Friction in Bearings**- Each turbine rotor is mounted on two bearings, i.e. there are double bearings between each turbine module. • **Pressure Losses in Regulating Valves and Steam Lines**- There are the main steam line isolation valves (MSIVs), the throttle-stop valves and control valves between steam generators and main turbine. Like pipe friction, the minor losses are roughly proportional to the square of the flow rate. The flow rate in the main steam lines is usually very high. Although throttling is an isenthalpic process, the enthalpy drop available for work in the turbine is reduced, because this causes an increase in vapor quality of outlet steam. • **Losses Due to Low Quality of Steam**- The exhausted steam is at a pressure well below atmospheric and the steam is in a partially condensed state, typically of a quality near 90%. Higher content of water droplets can cause the rapid impingement and erosion of the blades which occurs when condensed water is blasted onto the blades. • **Radiation Loss**-Steam turbine may operate at steady state with inlet conditions of 6 MPa, t = 275.6°. Since it is a large and heavy machine, it must be thermally insulated to avoid any heat loss to the surroundings.	**01 mark each**
	c)	**Explain the function of steam nozzle? State it's any two applications in industry.**	
	Sol.	**Steam nozzle:** Nozzle is a duct by flowing through which the velocity of a fluid increases at the expense of pressure drop. If the fluid is steam, then the nozzle is called as Steam nozzle. The flow of steam through nozzles may be taken as adiabatic expansion. The steam possesses a very high velocity at the end of the expansion, and the enthalpy decreases as expansion occurs. A nozzle is often a pipe or tube of varying cross sectional area, and it can be used to direct or modify the flow of a fluid (liquid or gas). Nozzles are frequently used to control the rate of flow, speed, direction, mass, shape, and/or the pressure of the	**02 mark**

		stream that emerges from them. **Applications:** Spray painting, steam turbines, turbo machines, jet propulsion, flow measurement, injectors, ejector condensers	**02 mark**
	d)	**Find the condenser efficiency, when cooling water enters in condenser at a temperature of 28^0C and leaves at 39^0C. the vacuum produced is 705 mm of Hg and barometer reads 760 mm of Hg.**	
	Sol.	Condenser efficiency :- Data : hv = Vacuum gauge pressure =705 mm of Hg hb = Barometric pressure =760 mm of Hg Two= 39ºC ; Twi= 28ºC Absolute pressure in condenser Pc = hb - hv = 760-705 = 55 mm of Hg = (55/760) X 1.1035 = 0.0733 bar From steam tables, saturation temp. corresponding to 0.0733 bar is 40ºC (T_{sat}) Condenser efficiency = (Two - Twi)/ (T_{sat} - Twi) = 0.9166 = 91.66 %	**01 mark** **01 mark** **01 mark** **01 mark**
	e)	**State the Sources of air leakage in condenser.**	
	Sol.	The sources of air in the condenser are due to the following: i. Leakage through packing glands and joints of the parts which are at a pressure less than atmospheric pressure. ii. Leakage through condenser accessories, such as atmospheric relief value, etc. iii. Air associated with exhaust steam may also liberate at low pressure. iv. In the jet condenser, the dissolved air in the cooling water liberates at low pressures.	**01 mark each**
	f)	**Numerical on heat transfer; (please refer question paper)**	
	Sol.	Composite wall Heat flow rate per m^2 area Q/A = (T1-T3)/ [(L1/K1) +(L2/K2) +(L3/K3)] =500/(0.02/370)+(0.003/150)+(0.045/74) =92.49 W/m^2	**01 mark** **02 mark** **01 mark**

Q.3.		Attempt any FOUR of the following:	16 Marks
	a)	One kg of gas at 1.2 bar and 50^0C having 1 m^3 volume is heated at constant pressure till its volume becomes 1.8 m^3.Calculate the work done and change in internal energy. Assume C_p=1.1 KJ/KgK.	

Sol.

Soln :

Given data :

01 mark

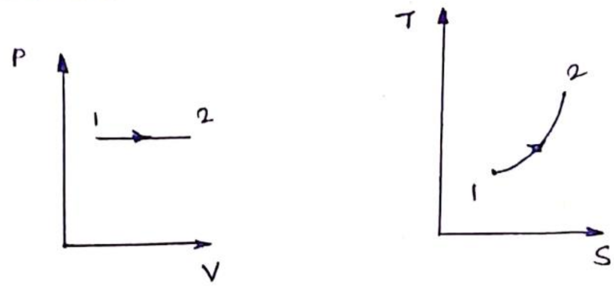


Figure : P-V & T-S diagram for Isobaric process.

mass = 1 kg **01 mark**

pressure $= P_1 = P_2 = 1.2$ bar $= 1.2 \times 10^5$ N/m^2

01 mark

Temperature $= T_1 = 50 + 273 = 323$ K

Volume of gas at inlet $= V_1 = 1 m^3$ **01 mark**

Volume of gas at outlet $= V_2 = 1.8 m^3$

$C_p = 1.1$ kJ/kg K

∴ We know that :

$$P_1V_1 = mRT_1$$

$$\therefore R = \frac{P_1V_1}{mT_1} = \frac{1.2\times10^5\times1}{1\times323} \Rightarrow 371.51 \text{ J/kg K}$$

∴ Charecteristic gas constant $R = 0.371$ kJ/kg K.

∴ We know that :

$$C_p - C_v = R$$

$$\therefore C_v = C_p - R \Rightarrow 1.1 - 0.371 = 0.729 \text{ kJ/kg K.}$$

$$\therefore \frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

at constant pressure process

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

$$\therefore \frac{1}{323} = \frac{1.8}{T_2} \Rightarrow T_2 = \frac{323 \times 1.8}{1}$$

$$T_2 = 581.4\ K$$

$$\therefore \text{Work done} = mR(T_2 - T_1)$$

$$= 1 \times 0.371 \times (581.4 - 323)$$

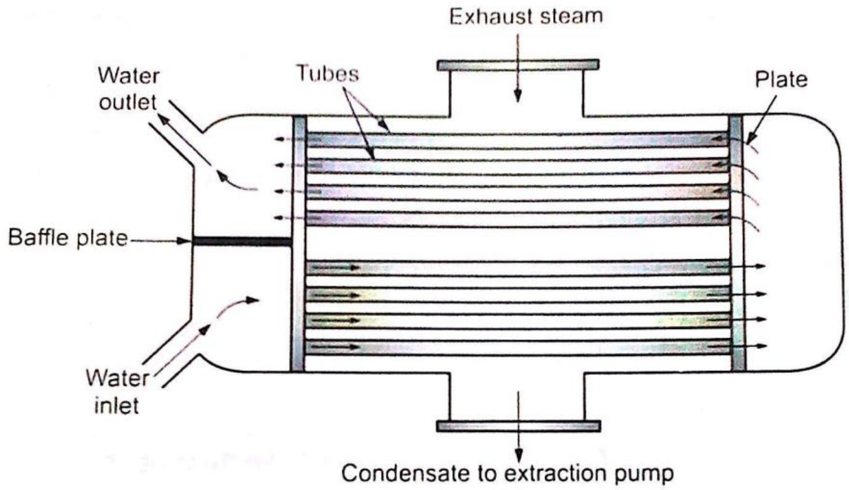
$$W = 95.86\ KJ$$

$$\text{Internal Energy} = mC_v(T_2 - T_1)$$

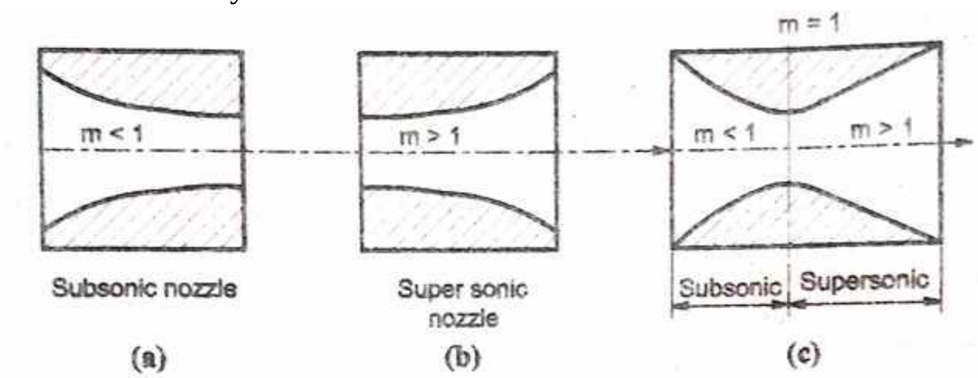
$$= 1 \times 0.729 \times (581.4 - 323)$$

$$\Delta U = 188.37\ KJ$$

	b)	**A heat exchanger is to be selected for pasteurization of milk. Which type of heat exchanger should be selected? Justify your answer.**	
Sol.		**Type of heat exchanger:** Plate type heat exchanger **Material used:** Stainless steel corrugated parallel plates **Justification:** 1] Non-reactive material 2] Leak proof joint 3] No mixing of two fluid 4] Non-toxic material 5] Non corrosive material	**02 marks** **02 marks**

	c)	Draw a neat labelled sketch of surface condenser.	
Sol.		 **Figure: Surface Condenser**	**02 marks for Sketch** **02 marks for label.**
	d)	**Discuss the important provision made in IBR.**	
Sol.		**I**BR is Indian Boiler Regulations, which was created on 15th September 1950 in implementation of the powers conferred by section 28 & 29 of the Indian Boilers Act. The Indian Boilers Act was formed in 1923, 23^{rd} February to consolidate and amend the law relating to steam boilers. Following are the important provision made in IBR; **Which steam boilers and steam pipes are regulated by IBR?** **Steam boiler**: Steam boilers under IBR means any closed vessel exceeding 22.75 liters in capacity and which is used expressively for generating steam under pressure and includes any mounting or other fitting attached to such vessel which is wholly or partly under pressure when the steam is shut off. **Steam pipes**: IBR steam pipe means any pipe through which steam passes from a boiler to a prime mover or other user or both if pressure at which steam passes through such pipes exceeds 3.5 kg/cm2 above atmospheric pressure or such pipe exceeds 254 mm in internal diameter and includes in either case any connected fitting of a steam pipe. **How to register a new Boiler?** [As per section 7 of Indian Boiler Act, 1923] 1. The owner of any boiler which is not registered under the provisions of this Act may apply to the inspector to have the boiler register. Every such application shall be accompanied by prescribed fee. On receipt of an application under subsection (1),the inspector shall fix a date, within thirty days or such shorter period as may be prescribed from the date of the receipt, for the examination of the boiler and shall give the owner there of not less than ten day notice of the date so fixed. 2. On the said date the inspector shall proceed to measure and examine the boiler and to determine in the prescribed manner the maximum pressure. If any, at which such boiler, may be used, and shall report the result of the examination to the Chief Inspector in the prescribed from.	**02 marks for each point** **Any two point**

	3. The Chief Inspector, on receipt of the report, may - Register the boiler and assign a register number there to either forthwith or after satisfying himself that any structural alteration, addition or renewal which he may deem necessary has been made in or to the boiler or any steam-pipe attached, or Refuse to register the boiler - Provided that where the Chief Inspector refuses to register a boiler, he shall forthwith communicate his refusal to the owner of the boiler together with the reasons. 4. The Chief Inspector shall, on registering the boiler, order the issue to the owner of a certificate in the prescribed form authorizing the use of the boiler for a period not exceeding twelve months at a pressure not exceeding such maximum pressure as he thinks fit and as is in accordance with the regulations made under this Act. The Inspector shall forthwith convey to the owner of the boiler the orders of the Chief Inspector and shall in accordance therewith issue to the owner any certificate of which the issue has been ordered, and, where the boiler has been registered, the owner shall within the prescribed period cause the register number to be permanently marked there on in the prescribed manner. **When and how the renewal of certification of a boiler is done?** 1. A certificate authorizing the use of a boiler shall cease to be in force under the following: a) On the expiry of the period for which it was granted. b) When any accident occurs to the boiler. c) When the boiler is moved (excluding vertical boilers with heating surface less than 200 sq. ft., (portable boilers or vehicular boilers). d) When any structural alteration, addition or renewal is made in or to the boiler. e) If the Chief Inspector in any particular case so directs when any structural alteration, addition or renewal is made in or to any steam pipe attached to the boiler. f) On the communication to the owner of the boiler of an order of the Chief Inspector or Inspector prohibiting its use on the ground that it or any steam pipe attached thereto is in a dangerous condition. 2. When a certificate ceases to be in force the owner of the boiler may apply to the inspector for a renewal thereof for such period not exceeding twelve months as he may specify in the application. [Provided that where the certificate relates to an Economizer or an unfired boiler which forms an integral part of a processing plant in which steam is generated solely by use of oil, asphalt or bitumen as a heating medium, the application for its renewal may be for a period not exceeding twenty-four months]. 3. An application under Sub Section (3) shall be accompanied by the prescribe fee and, on receipt thereof, the Inspector shall fix a date, within thirty days or such shorter period as may be prescribed from the date of the receipt, for the examination of the boiler. 4. Provided that, where the certificate has ceased to be in force owing to the making of any structural alteration, addition or renewal, the Chief Inspector may dispense with the payment of any fee. 5. On the said date, the Inspector shall examine the boiler in the prescribed manner and if he is satisfied that the boiler has a steam pipe or steam pipes attached thereto are in good	

		condition shall issue a renewed certificate authorizing the use of the boiler for the specified period at a pressure not exceeding such maximum pressure as he thinks fit and as is in accordance with the regulations made under this Act.	
	e)	**Explain the concept of Mach number.**	
Sol.		**Mach number:** It is the ratio of velocity of fluid to the sonic velocity of compressible fluid. Mathematically; **M=V/a** **Where;** V= Velocity of Fluid A= Sonic velocity  **M< 1** -----Subsonic Velocity If Velocity of fluid is less than the sonic velocity of fluid. Then it's a subsonic velocity. **M> 1** -----Supersonic Velocity If Velocity of fluid is greater than the sonic velocity of fluid. Then it's a supersonic velocity. **M=1** means the velocity of fluid is equal to the sonic velocity.	**02 marks** **02 marks**
	f)	**State the function of boiler mounting and accessories.**	
Sol.		**Mountings:** These are the fittings which are mounted on the boiler for its proper functioning. They include water level indicator, pressure, gauge, safety valve etc. It may be noted a boiler cannot function safely without the mounting. **Accessories:** These are the devices, which form an integral part of a boiler, but are not mounted on it. They include super heater, economizer, feed pump etc. It may be noted that the accessories help in controlling & running the boiler efficiently.	**02 marks** **02 marks**
Q.4.		**Attempt any <u>FOUR</u> of the following:**	**16 Marks**
	a)	**Represent ideal gas processes on P-V and T-S diagram:** **i. Isothermal process** **ii. Isentropic process**	
Sol.		i. <u>Isothermal Process:</u>	**01 mark for each figure**

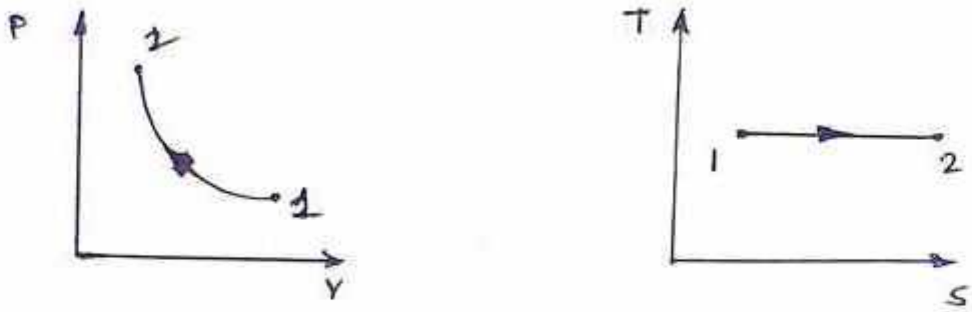


Figure: P-V & T-S diagram of Isothermal Process

ii. Isentropic Process:

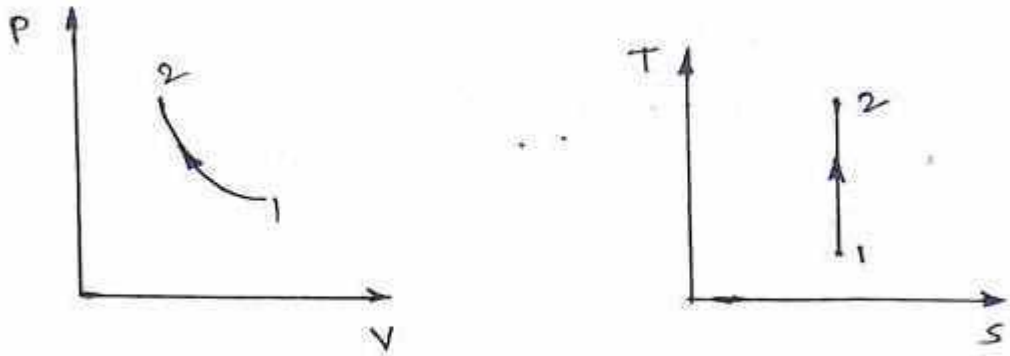


Figure: P-V & T-S diagram of Isentropic Process

b) State the characteristic gas constant and universal gas constant

Sol.

Characteristic gas constant :

Characteristics equation of a gas is; **02 marks**

$$PV = mRT$$

Where;

R is known as characteristic gas constant or simply gas constant.

The value of gas constant (R) is different for different gases. In S.I. units, its value foe atmospheric air is taken 287 J/KgK or 0.287 KJ/KgK. **02 marks**

Universal gas constant:

The universal gas constant or molar constant of a gas is the product of the gas constant and molecular mass of the gas.

Mathematically;

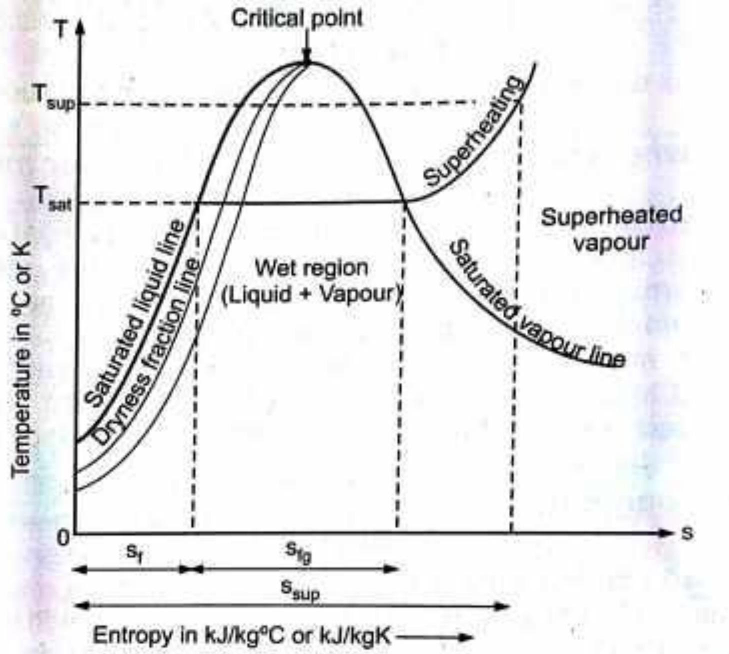
$$R_u = MR$$

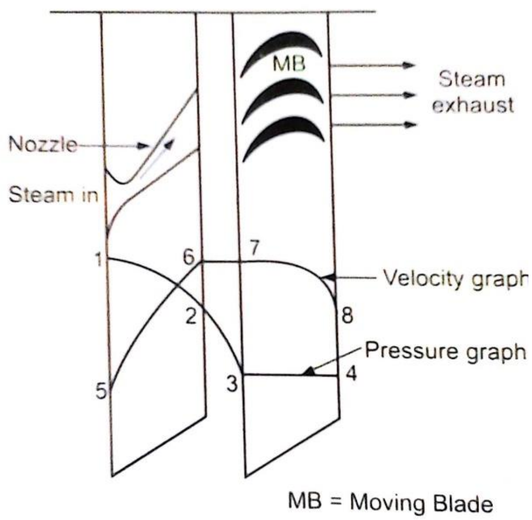
Where;

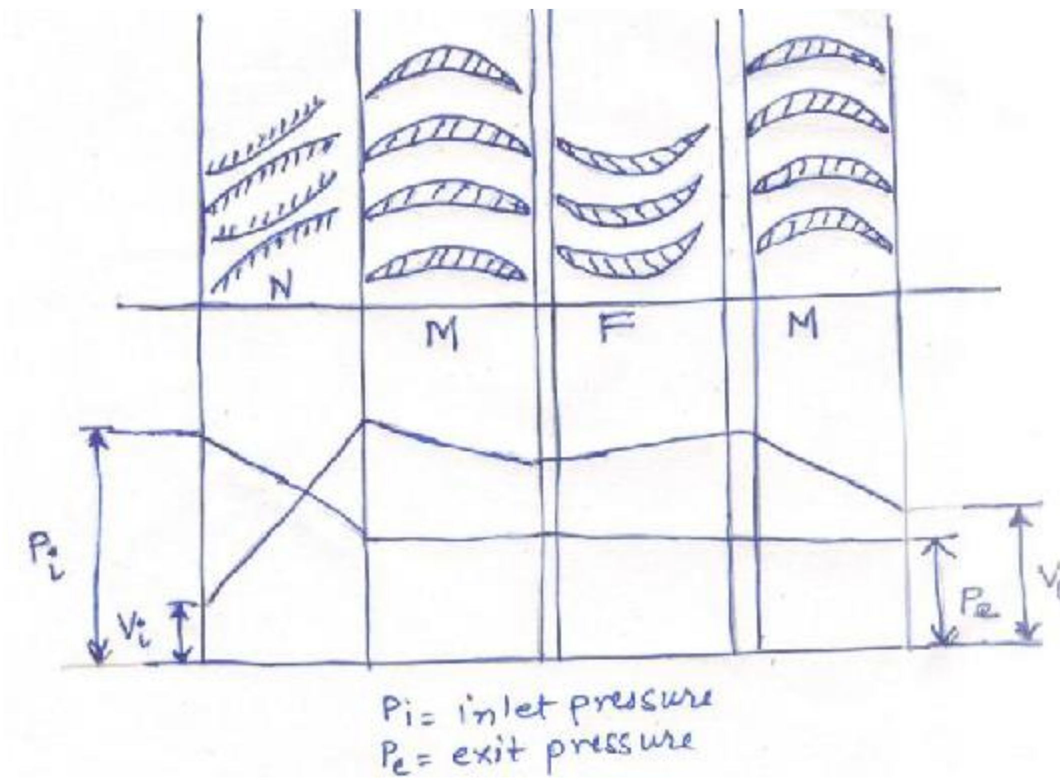
M= Molecular mass of the gas expressed in Kg-mole

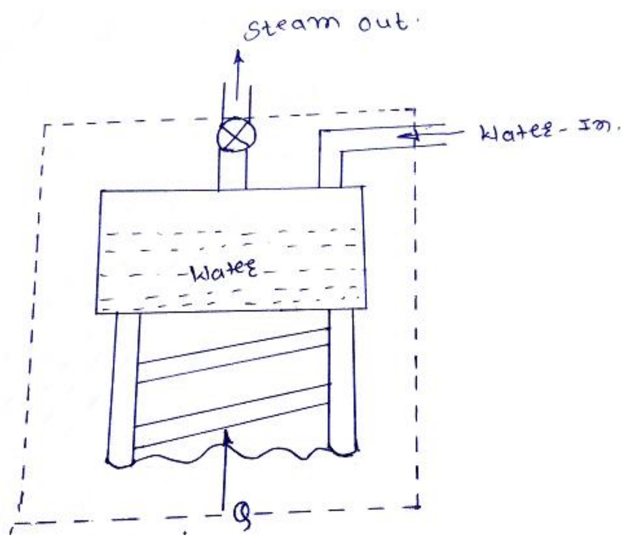
R=Gas constant.

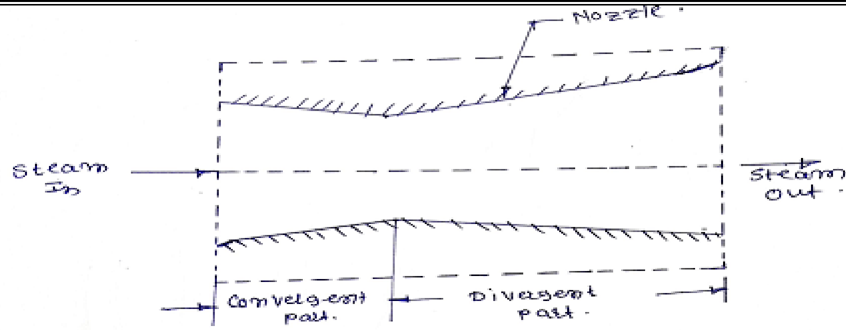
The value for universal gas constant(R_u) is same for all gases.in S.I. units the value of R_u is taken as 8314 J/Kg-mol K or 8.314 KJ/Kg-mol K

	c)	**Explain the concept of Generation of steam at constant pressure and represents on T-S diagram.**	
Sol.		 **Figure: Temperature (T)- Entropy(S) diagram** A T-S diagram is the type of diagram most frequently used to analyze energy transfer system cycles. This is because the work done by or on the system and the heat added to or removed from the system can be visualized on the T-S diagram. By the definition of entropy, the heat transferred to or from a system equals the area under the T-S curve of the process. Figure is the T-S diagram for pure water. A T-S diagram can be constructed for any pure substance. In the liquid-vapor region in figure, water and steam exits together.	**02 marks for figure** **02 marks for explanation**
	d)	**State the advantages and disadvantages of superheated steam.**	
Sol.		**Advantages of Superheated Steam:** 1] The efficiency of the boiler is increase with the use of superheated steam. 2] It eliminates the erosion of the turbine blades. 3] It reduces specific steam consumption of engine and turbine 4] It has a high thermal capacity per unit volume. **Dis-advantages of Superheated Steam:** 1] Special material such as stainless steel is required for stud, valve, blade etc. These metals retain their properties at high temperature and resistance to erosion. 2] Increased maintenance caused by the Superheater and erosive nature of superheated steam.	**02 marks for Advantages** **02 marks for dis-advantages**
	e)	**List the different types of heat exchangers? Write the application of heat exchangers.**	
Sol.		**Following are the types of heat exchanger:** 1] Shell and tube type heat exchanger 2] Plate type heat exchanger 3] Plate fin heat exchanger 4] Plate and shell heat exchanger	**Any 4 type ½ marks each**

		5] Spiral heat exchanger 6] Shell and coil heat exchanger 7] Radiator or automotive heat exchanger **Application of Heat Exchanger:** 1] They are used in food industries. 2] They are used in dairy product industry. 3] They are used in refrigeration application in close loop system. 4] In gasket and brazing technology made this heat exchanger in HVAC application.	**Any 4 applications ½ marks each**
	f)	**Describe the construction of impulse turbine with neat sketch.**	**04 Marks**
	Sol.	 **Figure: Impulse Turbine** **Construction:** Impulse turbine is simpler, less expensive and does not need to be pressure proof. It can operate with any pressure stream but is considerably less efficient. Impulse turbine consist of one fixed set of nozzle mounted on a stationary diaphragm that orient the steam flow into high speed jets, which is followed by one set of moving blade ring as shown in Fig. for a single stage impulse turbine.	**02 marks for Figure** **02 marks for Construction**
Q.5.		**Attempt any <u>TWO</u> of the following:**	**16 Marks**
	a)	**What is compounding of steam turbines? List different methods of compounding? Explain any one method.**	
	Sol.	**Compounding:** The arrangement to reduce pressure from boiler pressure to condenser pressure by use of multiple system of rotors in series, keyed to common shaft or by increasing number of stages and the steam pressure or steam velocity is absorbed in stages as it flows over moving blades. This is known as compounding. **Three types of compounding (**a) velocity compounding and (b) pressure compounding. (c) Pressure- Velocity compounding. **The Velocity - Compounding of the Impulse Turbine:** The velocity-compounded impulse turbine was first proposed by C.G. Curtis to solve the problems of a single-stage impulse turbine for use with high pressure and temperature steam. The *Curtis stage* turbine, as it came to be called, is composed of one stage of nozzles as the single-stage turbine, followed by two rows of moving blades instead of one. These two rows are	**02 marks** **03 marks**

		separated by one row of fixed blades attached to the turbine stator, which has the function of redirecting the steam leaving the first row of moving blades to the second row of moving blades. A Curtis stage impulse turbine is shown in Fig a. with schematic pressure and velocity changes through the stage. In the Curtis stage, the total enthalpy drop and hence pressure drop occur in the nozzles so that the pressure remains constant in all three rows of blades.  **Vi= Inlet Velocity** **Ve=Exit Velocity** **N= Nozzle** **M= Moving Blade** **Fig: Velocity Compounding**	**03 marks**
	b)	**State steady state energy equation. Give the meaning of all parameter contained in it. Apply this equation to boiler and nozzle.**	
	Sol.	**The steady flow energy equation** [m (K.E. + P.E.+I.E.)1+ m (PV)1 + Heat transfer] Energy entering = [m (K.E. + P.E.+I.E.)2 +m (PV)2 + work transfer] Energy leaving Therefore, $H_1+C_1^2/2+Z_1g +Q = H_2+C_2^2/2+Z_2g +W$	**02 mark**

		Where, H1& H2 = Enthalpy at inlet and outlet in----J/Kg C1& C2 = velocity at inlet and out of fluid----m/sec Z1 and Z2 = height of inlet & outlet above datum…. m Q = heat supplied ---------------Joule W = work done by 1 kg of fluid----Joule PV = Flow work---------N-m or Joule **Boiler** Boiler is a steel closed vessel, which converts the water into steam. Applying energy equation,  **For Boiler**, W = 0 , C1 =C2 , Z1 = Z2 Therefore, H1 + Q = H2 Q = H2 - H1 H1 = Enthalpy of feed water entering the boiler H2 = Enthalpy of steam going out of the boiler **Nozzle** It is the passage of varying cross sectional area in which heat energy of fluid is converted into kinetic energy.	**02 mark** **02 marks**



Applying S. F. E. E ,

For Nozzle,

$H_1+C_1^2/2+Z_1g +Q = H_2+C_2^2/2+Z_2g +W$

Since Q= 0, Z1, Z2= 0, W = 0 where,

$H1 - H2 = (C2^2/2) – (C1^2/2)$

$2(H1 - H2) = C_2^2– C_1^2$

$C2 = \sqrt{2(H2 - H1) + C1^2}$

02 mark

c) **Refer the question paper…**

Sol. Given Data:

Mass (m) = 1 Kg.

Pressure (P) = 7 bar = 7 X 10^5 N/mm2.

Dryness fraction (x) = 85 % = 0.85

Super heated by 100^0 C.

Sp. Heat at constant pressure Cp = 2.1 KJ/Kg K

What to Find out: -

i) Enthalpy (h)

ii) Entropy (S)

iii) Sp. Volume (v)

iv) Internal Energy (dU)

From Steam Table:

Absolute pressure in bar	**Saturated Temp.**	**Sp. Volume in m3/Kg**		**Sp. Enthalpy in KJ/Kg**			**Sp. Entropy in KJ/Kg K**		
P	**Tsatu**	**V_f**	**Vg**	**h_f**	**h_{fg}**	**h_g**	**s_f**	**s_{fg}**	**s_g**
7.0	**165.0**	**0.001108**	**0.27268**	**697.1**	**2064.9**	**2762.0**	**1.992**	**4.173**	**6.705**

		First Condition Steam with dryness fraction 85 % 1) hwet = hf + x hfg = 165 + 0.85 * 2064.9 **hwet = 2452.265 KJ/Kg**	**01 mark**
		2) Swet = Sf + x Sfg = 1.992 + 0.85 * 4.173 **Swet = 5.99805 KJ/ Kg K**	**01 mark**
		3) vwet = x vg = 0.85 * 0.27268 **vwet = 0.231778 m^3/Kg**	**01 mark**
		4) hwet = dU + P vwet 2452 * 103 = dU + 7 * 10^5 * 0.231778 dU = 2452 * 103 – 7 * 10^5 * 0.231778 dU = 2289.755 * 10^3J/Kg **dU = 2289.755 KJ/Kg**	**01 mark**
		Second Condition Steam is superheated by 100^0 C, It means that Tsup = Tsatu + 100 Tsup = 165 + 100 = 265^0C Tsup = 265 + 273 = 538^0 K Tsatu = 165 + 273 = 438^0 K 1) $h_{sup} = h_g + C_p (T_{sup} – h_{satu})$ = 2762 + 2.1 (538 – 438) **h_{sup} = 2972 KJ/Kg**	**01 mark**
		2) $S_{sup} = S_g + C_p * \log_e (T_{sup}/T_{satu})$ S_{sup} = 6.705 + 2.1 $\log_e$ (538/438)	**01 mark**
		S_{sup} = 7.1368 KJ/Kg 3) $V_{sup} = V_g *(T_{sup}/T_{satu})$ V_{sup} =0.27268 *(538/438)	**01 mark**

V_{sup} = 0.334936 m^3/Kg

4) hsup = dU + P vsup
2972 * 103 = dU + 7 * 105 * 0.334936
dU = 2972 * 103 – 7 * 105 * 0.334936
dU = 2737.5448 * 103 J/Kg
dU = 2737.5448 KJ/K

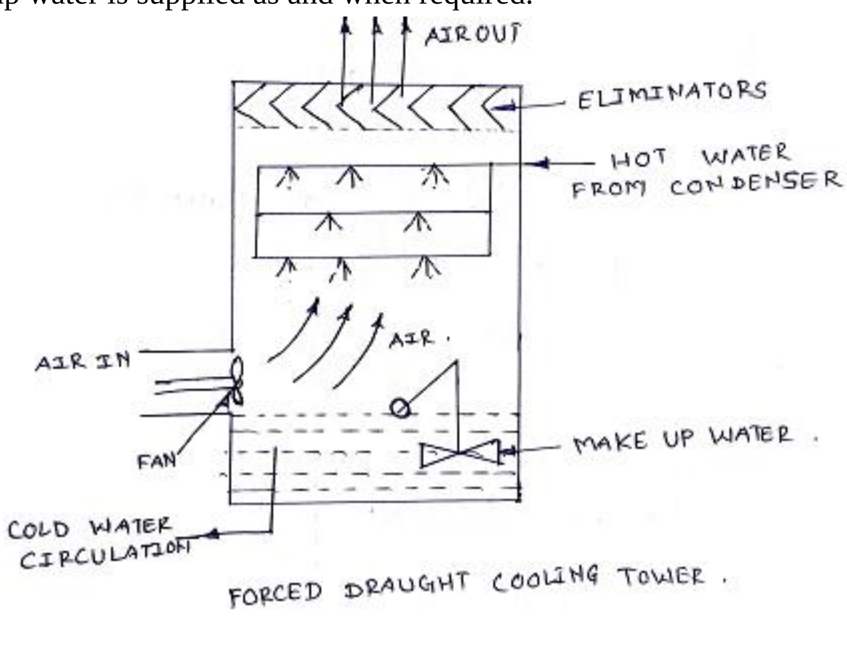
01 mark

Q.6.		**Attempt any <u>TWO</u> of the following:**	**16 Marks**
	a)	**Explain the construction and working of forced draught and natural draught cooling tower with neat sketch.**	

Sol.

Forced draught cooling tower: — **02 marks explanation**

Forced draft cooling tower consist of spray nozzles, circulating pipe lines, water tank, nozzles fan, pump and valves.
Basically water is sprayed from topside by using spray nozzle. Air is taken inside by using fan.
They flow in opposite direction. Fan is provided at bottom of tower as shown in figure. As fan is located at the base & air is blown by the fan up through the descending water. The water particles are removed at the top of tower by eliminator.
Make up water is supplied as and when required.



02 marks diagram

Fig: Forced draught cooling tower

ii) Natural draught cooling tower: — **02 marks explanation**

In natural draught cooling tower, the circulation of air is produced by the pressure difference of air inside the tower and outside atmospheric air Hot cooling water falls down in a form of sprays and atmospheric air enters from bottom of the tower. The falling water gives up its heat to the rising column of air and temperature of circulating water reduces

In natural draught cooling tower, hot water is pumped to ring troughs. Trough sprays water in the
form of droplets, which is placed at bottom of towers. Most advantage is of no use of fan, for air
circulation. An air circulation takes place by the pressure difference of air inside and outside of
cooling tower (natural flow).

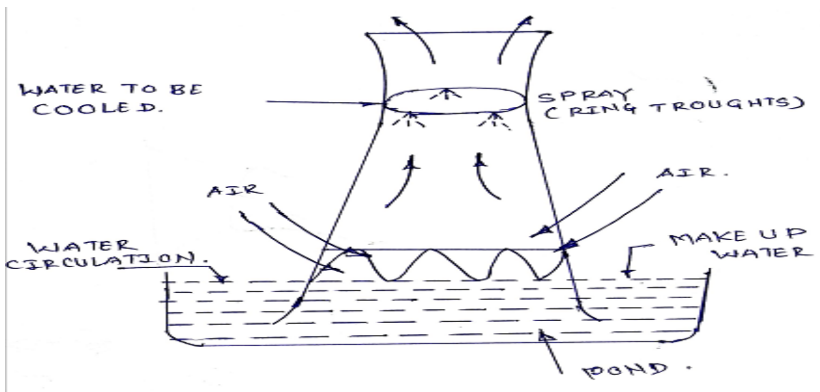


Fig- Natural Draught Cooling Tower

02 marks diagram

	b)	**Discuss the application of second law of thermodynamics on heat engine and refrigerator.**	

Sol. **Second Law of Thermodynamics Contains Two Statements:**

Kelvin-Plank Statement of second law of thermodynamics: Kelvin-Planck Statement of Second Law of Thermodynamics
“It is impossible to construct an engine, which while operating in a cycle produces no other effect except to extract heat from a single reservoir and do equivalent amount of work”.

Clausius statement of second law of Thermodynamics:- It states that it is impossible to construct a device working in a cyclic process whose sole effect is the transfer of energy in the form of heat from a body at a lower temperature (sink) to a body at a higher temperature (source).

Or

It is impossible for energy in the form of heat to flow a body at a lower temperature to a body at a higher temperature without the aid of external work.

Application of Second Law of Thermodynamics to Heat Engine:
There are three important applications of Statement of Second Law of Thermodynamics namely:

a) Heat Engine

		b) Heat Pump c) Refrigerator. • **Heat Engine**	

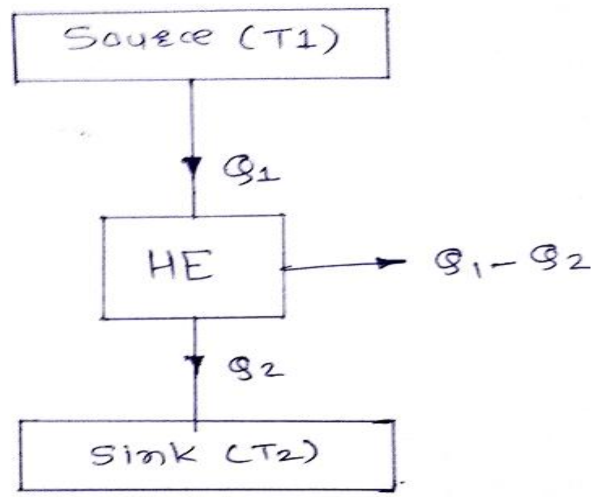


Fig - Heat Engine.

01 mark diagram

03 marks explanation

Heat engine is shown in the figure above having source of temperature (T1) and Sink at temperature (T2). The amount of heat taken from source is Q1. Out of this amount of heat work done by the engine is W and remaining part of heat rejected to the sink.

As per the statement of Statement of Second Law of Thermodynamics, it is observed that heat engine operates between the two reservoirs in a cyclic manner. It also extracts the heat from source only (single reservoir) and does the equivalent amount of work as shown.

In a full cycle of a heat engine, three things happen:

1. Heat is added. This is at a relatively high temperature, so the heat can be called Q1.
2. Some of the energy from that input heat is used to perform work (W).
3. The rest of the heat is removed at a relatively cold temperature (Q2).

An efficiency of the heat engine can be calculated as:

Efficiency = Work done (W) / Input Heat (Q1)

Kelvin–Plank statement is directly related with heat engines. As the heat engine takes some amount of heat from high temperature source and coverts partly into work done. Remaining part of heat is rejected to the low temperature sink. It is also clear that heat engine cannot work with one heat reservoir and there is always a rejection of heat.

• **Refrigerator**

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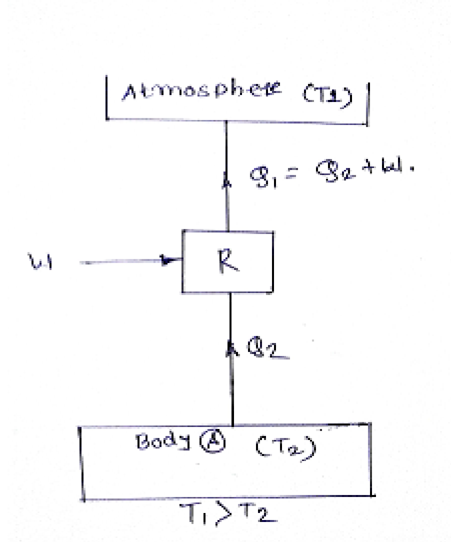

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Refrigerator: It is a device which working in Cycle and maintains the temperature lower than the temperature of surroundings. As shown in diagram body **A** is maintained at temperature T2 which is lower than atmospheric temperature T1.The heat leakage Q2 into the body **A** from the surroundings is to be removed from it by doing work W by the refrigerator R. The performance of refrigerator is given as
COP = Heat Absorbed/Work supplied
= Q2/ W
= Q2/ Q1-Q2 ……………………………… As W= Q1-Q2

Refrigerator obeys and follows Clausius statement of second law of Thermodynamics.

From the above discussion it is clear that Heat Engine and Refrigerator is are important applications of Second Law of Thermodynamics.
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<td>**01 mark diagram**

03 mark explanation</td>
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<td>**c)**</td>
<td>**Describe various mode of heat transfer. Give one example of each mode. Also define transmissivity and emissivity.**</td>
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<td>**Sol.**</td>
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Modes of heat transfer:
1. Conduction, 2. Convection, 3. Radiation

1. Conduction – It is transmission of heat energy between two bodies or two parts of same body through molecules which are more or less stationery

e.g. heating of solid- fins provided on engine, motor

2. Convection – It is process of heat transfer from higher temperature to lower temperature due to movement of matter or fluid molecules (density differences) is called convection.

e.g. heating of water.

3. Radiation – It is process of heat transfer between two bodies without any carrying
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01 mark for example</td>
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		medium through different kind of electro-magnetic wave. e.g. heating of earth surface by sun **Transmissivity:** The fraction of radiation transmitted to incident radiation is called the Transmissivity and it is denoted by τ. **Emissivity:** it is defined as total emissive power to total emissive power of a black surface, at the same temperature.	 **01 mark** **01 mark**