SUMMER – 2022 EXAMINATION

Subject Name: Thermal Engineering **Model Answer Subject Code:** 22337

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 judgment 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.
8) As per the policy decision of Maharashtra State Government, teaching in English/Marathi and Bilingual (English + Marathi) medium is introduced at first year of AICTE diploma Programme from academic year 2021-2022. Hence if the students in first year (first and second semesters) write answers in Marathi or bilingual language (English +Marathi), the Examiner shall consider the same and assess the answer based on matching of concepts with model answer.

Q. No.	Sub Q. N.	Answer	Marking Scheme
01	a	The factors that cause a process to be irreversible are called irreversibilities. They include friction, unrestrained expansion, heat transfer across a finite temperature difference, mixing of two fluids, electric resistance, inelastic deformation of solids, chemical reactions, and combustion process.	02 (1/2 mark for each factor)

Q. No.	Sub Q. N.	Answer	Marking Scheme
01	b	Assumptions for ideal gas are : (1) the collisions occurring between molecules are elastic and their motion is frictionless, meaning that the molecules do not lose energy; (2) the total volume of the individual molecules is magnitudes smaller than the volume that the gas occupies; (3) there are no intermolecular forces acting between the molecules or their surroundings; (4) the molecules are constantly in motion, and the distance between two molecules is significantly larger than the size of an individual molecule. As a result of all these assumptions, an ideal gas would not form a liquid at room temperature.	02 (1/2 mark for each assumption)

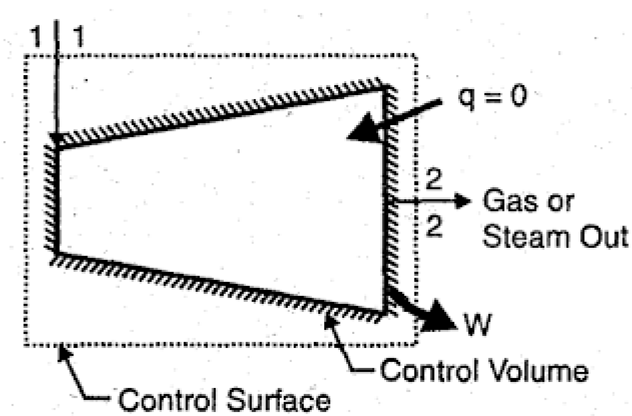
Q. No.	Sub Q. N.	Answer	Marking Scheme
01	c	The function of the superheater is to increase the temperature of steam above its saturation temperature as heat contained in unit mass of superheated steam is more than dry saturated or wet steam; it is extensively used in steam power plants. The function of blow-off cock is to discharge mud and other sediments deposited in the bottom most part of the water space in the boiler, while boiler is in operation. It can also be used to drain-off boiler water.	02 (1 mark for each function)

Q. No.	Sub Q. N.	Answer	Marking Scheme
01	d	The Mach Number is a dimensionless value useful for analyzing fluid flow dynamics problems where compressibility is a significant factor. It is ratio of velocity at a state in flowing fluid to the value of sonic velocity at the same state. The Mach Number can be expressed as M = v / c where M = Mach number ; v = fluid flow speed (m/s) ;c = speed of sound (m/s) significance:-. If the mach number is < 1, the flow speed is lower than the speed of sound - and the speed is subsonic. If the mach number is ~ 1, the flow speed is approximately like the speed of sound - and the speed is transonic. If the mach number is > 1, the flow speed is higher than the speed of sound - and the speed is supersonic. If the mach number is >> 1, the flow speed is much higher than the speed of sound - and the speed is hypersonic	02

Q. No.	Sub Q. N.	Answer	Marking Scheme
01	e	When the back pressure is decreased in case of a nozzle the mass flow rate through the nozzle increases proportionally. But after a fixed value of back pressure is reached , increase in mass flow rate is not observed . This value of back pressure is known as critical pressure. So we can define critical pressure as the back pressure for the maximum mass flow rate through the nozzle.	02

Q. No.	Sub Q. N.	Answer	Marking Scheme
01	f	The main functions of a steam condenser are listed below: 1. The condenser lowers the back pressure at the turbine exhaust. Thus, steam expands through a higher pressure ratio across the turbine. It results into (i) increased work done per cycle, (ii) improved thermal efficiency of the cycle, and (iii) reduced steam consumption. 2. The condenser enables the recovery and recirculation of pure feed water into the plant. Thus, (i) the cost of water softening plant is reduced, and (ii) it also saves the cost of fresh water to be supplied to the boiler. 3. The condenser enables the removal of air and non-condensable gases from steam. Thus the heat-transfer rate is improved and tube corrosion is reduced.	02 (1 mark for each function)

Q. No.	Sub Q. N.	Answer	Marking Scheme
01	g	Thermal conductivity can be defined as the rate at which heat passes through a specified material, expressed as the amount of heat that flows per unit time through a unit area with a temperature gradient of one degree per unit distance. The SI unit of this quantity is watts per meter-Kelvin or $Wm^{-1}K^{-1}$.	02

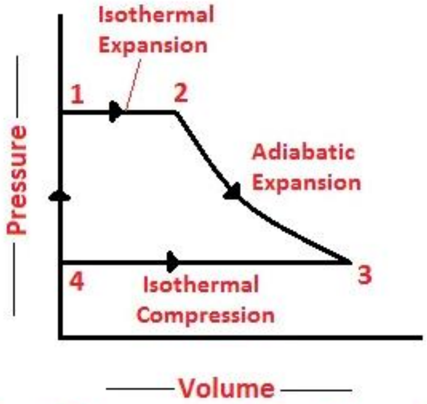
Q. No.	Sub Q. N.	Answer	Marking Scheme
02	a	For steady flow process, net quantity of energy contained within the system will never change with respect to time. Therefore according to the principle of conservation of energy, we will have following statement and energy equation for a steady flow process. Net quantity of energy entering to the control volume = Net quantity of energy leaving the control volume $H_1 + \frac{mV_1^2}{2} + mgZ_1 + Q - W = H_2 + \frac{mV_2^2}{2} + mgZ_2$ Steady flow energy equation for a turbine Turbine is basically defined as one prime mover where thermal energy of the high pressure fluid will be converted in to mechanical energy in terms of rotation of turbine shaft. Mechanical energy developed by turbine will be finally converted in to electrical energy. Turbine is also designated as mechanical device that will provide the work energy through the expansion of fluid. Let us see here the following figure, where high pressure fluid enters at inlet 1-1 and low pressure fluid leaves the turbine at its outlet section i.e. 2-2.  Let turbine is well insulated and hence there will no heat energy interaction between system and surrounding and therefore we can say that Q =0. When fluid flows through a turbine, change in kinetic energy could be assumed as zero as velocity of fluid flow will be small and we can neglect the small change in kinetic energy of the fluid. Therefore, we will have ΔKE =0 We have also assumed here that change in potential energy is zero or we can say that ΔPE =0 Let us implement above data that we have mentioned above in steady flow energy	02 01

		equation for a steady flow process and we will have following equation $H_1 - W = H_2$ We have taken work energy as positive because turbine is producing the work energy and this work is being done over the surrounding by the system. $W = H_1 – H_2$ We can also say that, work energy produced by the turbine during the process will be the result of drop in enthalpy. Steady flow energy equation for a condenser The condenser is used to condense the steam in case of steam power plant and condense the refrigerant vapour in the refrigeration system using water or air as cooling medium. For this system: ΔPE=0, ΔKE=0 (as their values are very small compared with enthalpies) W=0 (since neither any work developed nor absorbed) Using energy equation to steam flow h1−Q=h2 i.e. Q = h1 − h2 Where Q = Heat lost by 1 Kg of steam passing through the condenser.	01

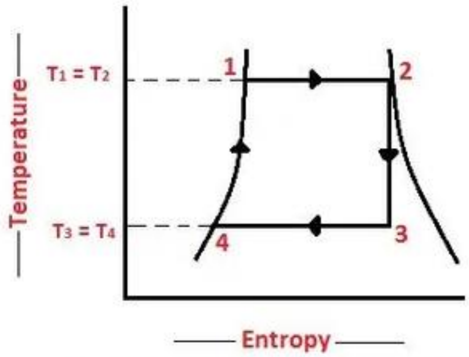
Q. No.	Sub Q. N.	Answer	Marking Scheme
02	b	<table><tr><th>Parameter</th><th>Isothermal</th><th>Adiabatic</th></tr><tr><td>Definition</td><td>It is defined as one of the thermodynamic processes which occur at a constant temperature.</td><td>It is defined as one of the thermodynamic processes which occur without any heat transfer between the system and the surrounding</td></tr></table>	04 (01 mark for each parameter)

Heat transfer	It contains the transfer of heat.	It does not contain the transfer of heat.
Pressure vs volume	The pressure is more in comparison to volume.	The pressure is less in comparison to volume.
Temperature	The temperature remains constant in such a process.	Temperature changes due to variations in the internal system in such a process.
Heat	To maintain the temperature, heat can be added or released to the system.	No need to add or release the heat, constant temperature maintenance is not required here.
Rate of transformation	The transformation is slow in such a process.	The transformation is fast in such a process.

<table>
<tr><td>No.</td><td>Q. N.</td><td></td><td>Scheme</td></tr>
<tr><td>02</td><td>c</td><td>



P-v Diagram of Rankine Cycle



T-s Diagram of Rankine Cycle

Process 4–1: The working fluid is pumped from low to high pressure. As the fluid is a liquid at this stage, the pump requires little input energy. Process 4-1 is isentropic compression.

Process 1–2: The high-pressure liquid enters a boiler, where it is heated at constant pressure by an external heat source to become a dry saturated vapour. The input energy required can be easily calculated graphically, using an enthalpy–entropy chart (h–s chart, or Mollier diagram), or numerically, using steam tables or software. Process 1-2 is constant pressure heat addition in boiler.

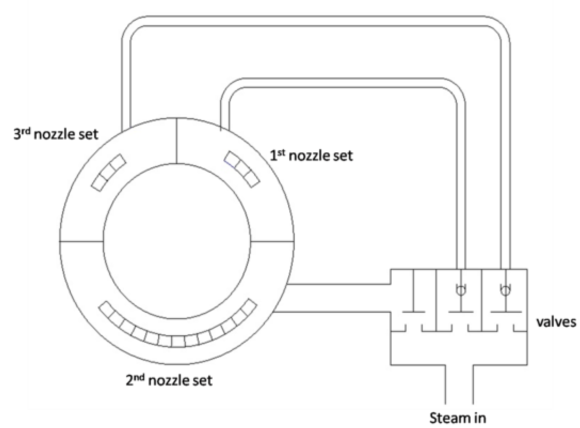
Process 2–3: The dry saturated vapour expands through a turbine, generating power. This decreases the temperature and pressure of the vapour, and some condensation may occur. The output in this process can be easily calculated using the chart or tables noted above. Process 2-3 is isentropic expansion.

Process 3–4: The wet vapour then enters a condenser, where it is condensed at a constant pressure to become a saturated liquid. Process 3-4 is constant pressure heat rejection in condenser.

</td><td>02

02</td></tr>
</table>

Q. No.	Sub Q. N.	Answer	Marking Scheme
02	d	Q 2 d] Given :- $P = 8\ bar$ $v = 0.28\ m^3/kg$ From Steam Tables at $P = 8\ bar$ $T_{sat} = 170.4^\circ C$, $v_g = 0.2408\ m^3/kg$ $= 170.4 + 273$ $= 443.K$ $\therefore v_g < v$ (ie) $0.2408 < 0.28$ This means that given steam is in superheated region hence given steam is superheated steam.	02
		In superheated region, gas laws are applicable hence $\frac{v_1}{T_1} = \frac{v_2}{T_2}$ (i.e.) $\frac{v_g}{T_{sat}} = \frac{v_{sup}}{T_{sup}}$ $\therefore \frac{0.2408}{443.4} = \frac{0.28}{T_{sup}}$ $\therefore T_{sup} = 515.58\ K$	02

Q. No.	Sub Q. N.	Answer	Marking Scheme
03	a	In nozzle governing the flow rate of steam is regulated by opening and shutting of sets of nozzles rather than regulating its pressure. In this method groups of two, three or more nozzles form a set and each set is controlled by a separate valve. The actuation of individual valve closes the corresponding set of nozzle thereby controlling the flow rate. In actual turbine, nozzle governing is applied only to the first stage whereas the subsequent stages remain unaffected. Since no regulation to the pressure is applied. Figure shows the mechanism of nozzle governing applied to steam turbines. As shown in the figure the three sets of nozzles are controlled by means of three separate valves.  	02 02

Q. No.	Sub Q. N.	Answer	Marking Scheme
03	b	**Give classification of steam turbine.** Classification of steam turbines: a) With respect to action of steam: i. Impulse turbine ii. Reaction Turbine b) With respect to method of compounding i) Pressure compounding ii) Velocity compounding iii) Pressure-Velocity Compounding c) With respect to expansion stages i) Single stage ii) Multistage	04 Any four criteria

		d) With respect to direction of flow i) Axial flow ii) Radial flow iii) Tangential flow e) With respect to pressure of steam i) Low pressure ii) High pressure iii) Medium pressure f) With respect to shaft position i) Vertical shaft ii) Horizontal shaft g)According to The Nature Of Exhaust Steam. i) Condensing Type Steam Turbine. ii) Non Condensing Type Steam Turbine. h) According to No. Of Passes Of Steam Over Turbine Blades. i) Single Flow Turbine. ii) Double Flow Turbine. i)According to method of the governing. i) Turbine. ii) Turning With Nozzle Governing. With Throttle Governing iii)Turbine With By Pass Governing. j) According to their usage in industry. i) Stationary Turbine With Constant Rotation Speed ii) Stationary Turbine With Variable Speed iii) Non Stationary Turbine With Variation Speed.	

Q. No.	Sub Q. N.	Answer	Marking Scheme
3	c	Q3 (c) Given, $m = 1\,kg$ $P_1 = 1$ bar $T_1 = 156°C = 429°K$ $V_2 = 0.28\,m^3$ Isothermal Process By ideal gas eqn $P_1V_1 = mRT_1$ $1 \times 10^5 \times V_1 = 1 \times 287 \times 429$ $\therefore V_1 = 1.23123\,m^3$ $W = P_1V_1 \log_e (V_2/V_1)$ $= 1\times10^5 \times 1.23123 \log_e \left(\frac{0.28}{1.23}\right)$ $= -182342.6\,J$ $= -182.34\,KJ$ '(−)' signs is due to compression process In isothermal process change in internal energy $du = mC_v\Delta T = 0$	02 02

Q. No.	Sub Q. N.	Answer	Marking Scheme
03	d	Energy conservation in Boilers can be accomplished by applying following steps. 1. Stack Temperature 2. Feed Water Preheating using Economiser 3. Combustion Air Preheat 4. Incomplete Combustion 5. Excess Air Control 6. Radiation and Convection Heat Loss 7. Automatic Blowdown Control 8. Reduction of Scaling and Soot Losses 9. Proper Boiler Scheduling 10. Boiler Replacement	04 (01 mark for each step)

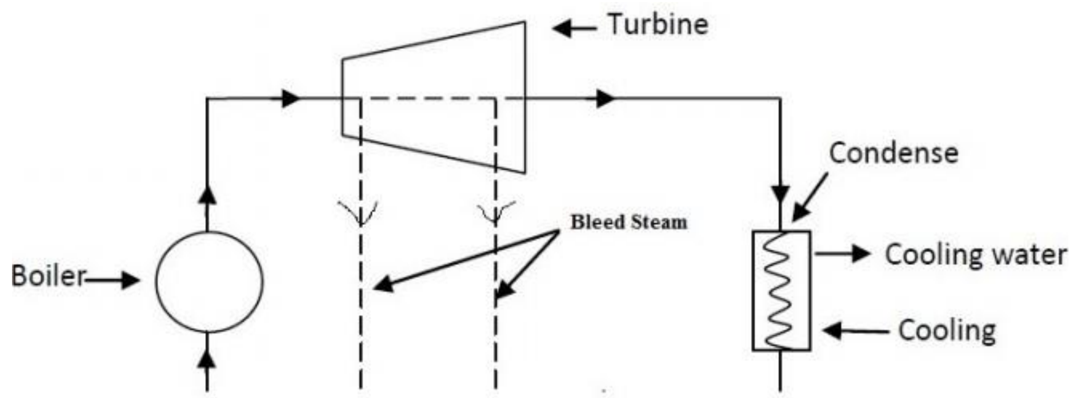
Q. No.	Sub Q. N.	Answer	Marking Scheme
04	a	Q4 (a) Given, The absolute pressure in the Condenser (P_t) = 11.56 KPa = 0.1156 bar Barometer Reading = (P_b) = 1 bar Condenser temp. = 40°C Partial pressure of air (P_a) = ? Vaccum efficiency = ? Vaccum efficiency = $\frac{P_b - P_t}{P_b - P_s}$ where $P_t = P_a + P_s$ P_s = Saturation pressure of steam at 40°c from steam table = 0.074 bar. Now, $P_t = P_a + P_s$ $0.1156 = P_a + 0.074$ $P_a = 0.0416$ bar	02
		Vaccum efficiency = $\frac{(1-0.1156)}{(1-0.074)}$ = 0.9550 = 95.50%	02

Q. No.	Sub Q. N.	Answer	Marking Scheme
04	b	Q4 (b) $m = 0.44\,kg$ $V_1 = 0.28\,m^3$ $P_1 = 1.4\,bar$ $P_2 = 14\,bar$ $PV^{1.3} = C$ By ideal gas equation $P_1V_1 = mRT_1$ $T_1 = \frac{1.4 \times 10^5 \times 0.28}{0.44 \times 0.298 \times 10^3}$ $R = C_p - C_v = 1.041 - 0.743 = \underline{0.298\ kJ/kg}$ $= \underline{299^\circ K}$ $T_2 = T_1 \times \left(\frac{P_2}{P_1}\right)^{n-1/n}$ $= 299 \times \left(\frac{14}{1.4}\right)^{0.3/1.3}$ $= \underline{509^\circ K}$ $\Delta U = mC_v(T_2 - T_1) = 0.44 \times 0.743\,(509 - 299)$ $= \underline{68.65\,kJ}$	01 01 02

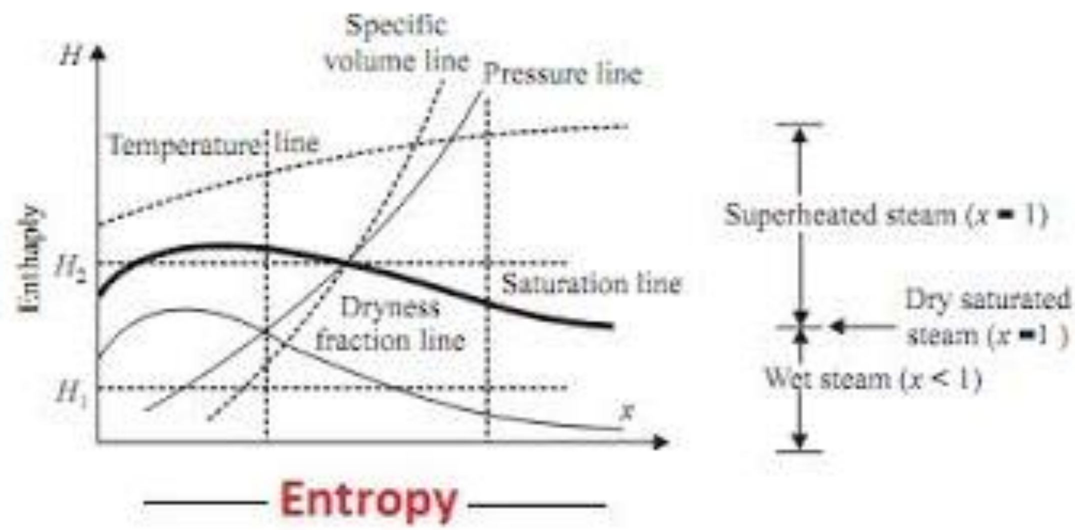
Q. No.	Sub Q. N.	Answer	Marking Scheme
04	c	Q4 (c) Given, $v_1 = 0.14\ m^3$ $\quad P_1 = 1400\ kPa = 14\ bar$ $T_1 = 300^\circ C = 573^\circ K$ $\quad P_2 = 280\ kPa = 2.8\ bar$ Take $\gamma = 1.4$ $T_2 = T_1 \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}}$ $= 573 \left(\frac{2.8}{14}\right)^{\frac{0.4}{1.4}} = 361^\circ K$ $\frac{P_1 v_1}{T_1} = \frac{P_2 v_2}{T_2}$ $\quad v_2 = \frac{P_1 v_1 T_2}{P_2 T_1}$ $v_2 = \frac{14 \times 10^5 \times 0.14 \times 361}{2.8 \times 10^5 \times 573} = 0.44\ m^3$ $W = \frac{P_1 v_1 - P_2 v_2}{\gamma - 1} = \frac{14 \times 10^5 \times 0.14 - 2.8 \times 10^5 \times 0.44}{1.4 - 1}$ $= 1,82,000\ J = 182\ kJ$	 02 02

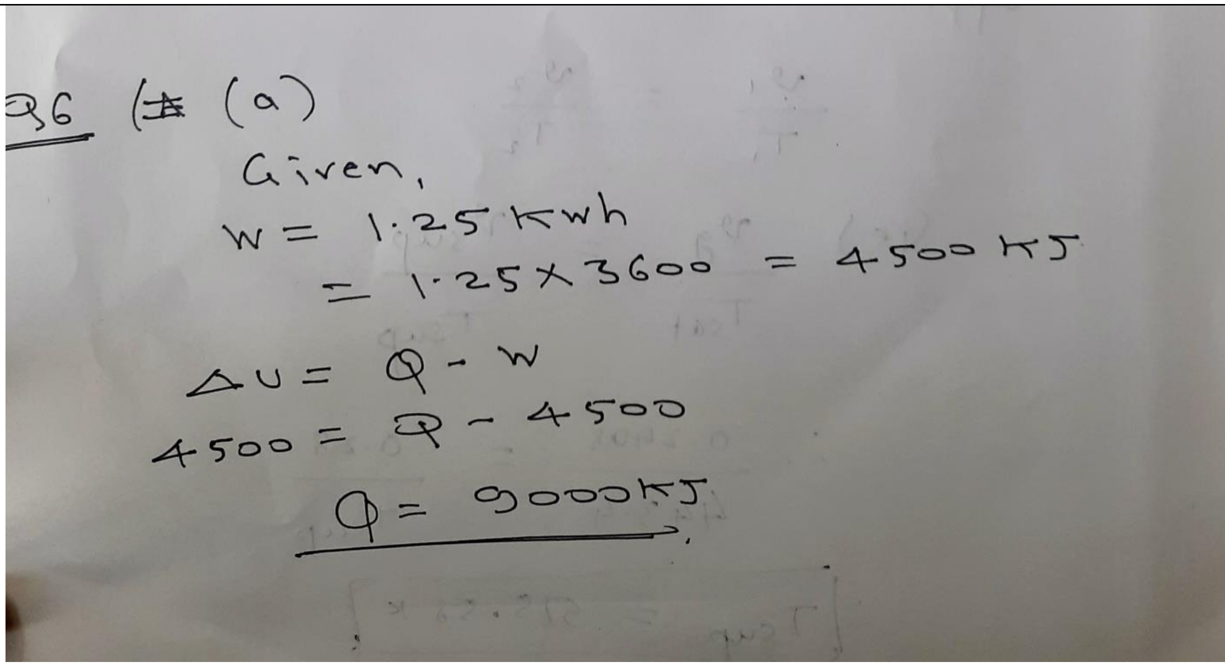
Q. No.	Sub Q. N.	Answer	Marking Scheme
04	d	Natural convection is a method of heat transfer in which natural means influence the motion of the fluid. There is no influence from external facts. This movement of molecules in the fluid is due to the differences between densities of different regions of the same fluid. The density of a fluid decreases when it heats and vice versa. That is because of the thermal expansion of the fluid (the speed of molecules increase with the temperature increase, which results in the increase of the volume of the fluid. Although the volume increases, the mass remains constant. Therefore the density decreases). Examples of natural convection include cooling down a boiled egg when kept in the normal air, loss of cool of a cool drink can, etc. Forced convection is a method of heat transfer in which external means influence the motion of the fluid. There, external sources such as pumping, fans, suction devices, etc. are useful in generating the fluid motion. This method is very valuable because it can efficiently transfer heat from a heated object. Some common examples of this mechanism include air conditioning, steam turbines, etc.	02 02

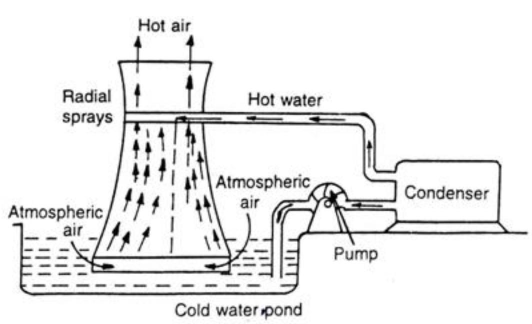
Q. No.	Sub Q. N.	Answer	Marking Scheme
04	e	Classification of steam condensers: A) Jet condenser/contact type condenser a) Parallel flow condenser b) Counter flow condenser c) High level condenser d) Ejector condenser B) Surface condenser/non contact type a) Down flow surface condenser b) Central flow surface condenser c) Regenerative surface condenser d) Evaporative surface condenser e) Double pass surface condenser or shell and tube type	02 02

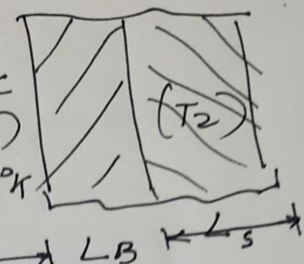
Q. No.	Sub Q. N.	Answer	Marking Scheme
05	a	 **Figure: Bleeding of steam** The process of draining steam from the turbine, at certain points during its expansion, and using this steam for heating the feed water supplied to the boiler, is known as bleeding and this process of feed heating is known as regenerative feed heating. At. certain sections of the turbine, a small quantity of wet steam is drained out from the turbine, as shown in fig. This bled steam is then circulated around the feed water pipe leading from the hot-well to the boiler. The relative cold feed water causes this bled steam to condense, the heat thus lost by steam being transferred to the feed water. The condensed steam then drains into the hot-well. The result of this process is to supply the boiler with hotter feed water whilst a small amount of work is lost by the turbine. This definitely increases efficiency of plant, but there is also a decrease in the work done per kilogram of steam; Advantages – 1. Thermal efficiency of boiler increases. 2. Specific fuel consumption decreases.	02 02 02

Q. No.	Sub Q. N.	Answer	Marking Scheme
05	b	 Most automotive heat exchangers are similar to shell and tube cross flow design, with multiple tube passes. But instead of having a defined shell around the tubes, with another controlled fluid forced across the tubes by means of a pump, there is no limited control volume for the shell. The tubes are open to the air and are dependant upon outside conditions. $Q = h A \Delta T$ Some types of Automotive Heat Exchangers include but are not limited to radiators, oil coolers and intercoolers. It is possible to use heat exchangers for almost any of the fluids in a vehicle. Air conditioners and heaters are also examples, however they are not restricted to vehicles. A radiator is a cooling device used in the engine in which hot liquid flows through exposed pipes and transfers heat to the air by fans. Fins are used to conduct the heat from the tubes and transfer it to the air. The fluid used is typically a mixture of ethylene glycol, water and a small amount of corrosion reducer. Oil coolers are used mainly in transmissions to keep the oil temperatures within safe limits. Finally intercoolers are air-to-air or air-to-liquid heat exchangers. They are used on turbocharged internal combustion engines to cool down the hot compressed air coming from the turbocharger.	03 03

Q. No.	Sub Q. N.	Answer	Marking Scheme
05	c	Features of Mollier Chart are : Constant Pressure lines Constant Temperature lines Constant Volume lines Constant Enthalpy lines Constant Entropy lines	02
			04

Q. No.	Sub Q. N.	Answer	Marking Scheme
06	a	 Q6 (a) Given, $W = 1.25\ Kwh$ $= 1.25 \times 3600 = 4500\ KJ$ $\Delta U = Q - W$ $4500 = Q - 4500$ $Q = 9000\ KJ$	02 04

Q. No.	Sub Q. N.	Answer	Marking Scheme
06	b	The purpose of cooling tower is to remove heat from a building or facility by spraying water down through the tower to exchange heat into the inside of the building. Air comes in from the sides of the tower and passes through the falling water. As the air passes through the water, heat is exchanged and some of the water evaporates. This heat and evaporated water flow out the top of the tower in the form of a fine cloud-like mist. The cooled water is collected at the bottom of the tower and pumped back into the plant or building for reuse. Cooling towers provide large scale air-conditioning where land and (or) water are expensive, or regulations prohibit the return of once-through cooling waters In natural draft cooling tower, hot water is pumped to ring trough's. 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).  Natural draught cooling tower.	02 02 02

Q. No.	Sub Q. N.	Answer	Marking Scheme
06	c	Q6 (c) $L_B = L_s = 10\ mm$ $K_B : K_s = 2:1$ 100°C (T_1) 373°K  (T_2) 0°C (T_3) 273°K $\frac{Q}{A} = \frac{(T_1 - T_2)}{\frac{L_B}{K_B}} = \frac{(T_2 - T_3)}{\frac{L_s}{K_s}}$	02
		$\frac{(T_1 - T_2)}{\left(\frac{0.01}{2K_s}\right)} = \frac{(T_2 - T_3)}{\left(\frac{0.01}{K_s}\right)}$ $(T_1 - T_2) \times \frac{0.01}{K_s} = (T_2 - T_3) \times \left(\frac{0.01}{2K_s}\right)$	02
		$2(T_1 - T_2) = (T_2 - T_3)$ $2T_1 - 2T_2 = T_2 - T_3$ $2T_1 + T_3 = T_2 + 2T_2$ $3T_2 = 2T_1 + T_3$ $3T_2 = (2 \times 373) + 273$ $T_2 = 1019/3 = 339.67\ °K$	02