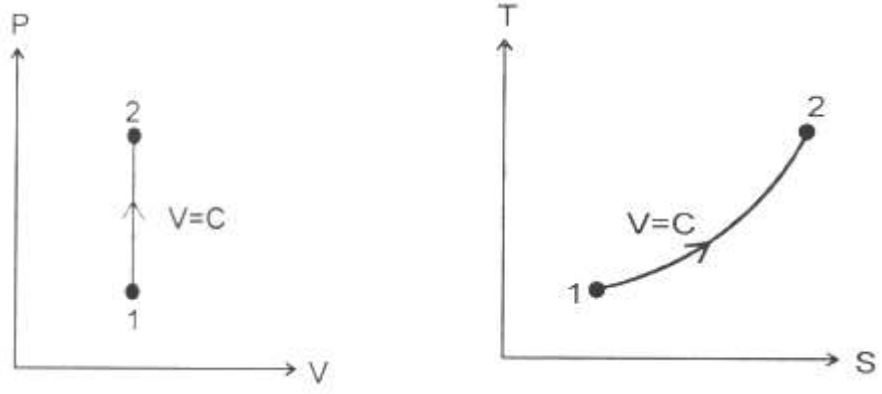
WINTER – 2022 EXAMINATION

Model Answer

Subject Name: Thermal Engineering **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 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.
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
1.		**Attempt any FIVE of the following:**	**10**
	a)	**Define Gray Body.**	
	Sol.	**Gray body :-** A grey body is defined as a body with constant emissivity over all wavelengths and temperatures. It absorbs a definite percentage of incident energy irrespective of their wavelengths.	**2 Marks for Def.**
	b)	**Represent Isochoric Process on P-V and T-S chart.**	
	Sol.		**1 Marks for each**

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1	c)	**State Function of :-** **i) Economizer** ii) **Fusible plug**	
	Sol.	(i) **Economizer :-** Function of economizers in steam power plants is to capture the waste heat from boiler flue gases and transfer it to the boiler feed water. This raises the temperature of the boiler feed water, lowering the needed energy input, in turn increase in boiler efficiency. (ii) **Fusible plug-**The function of the fusible plug is to put-off the fire in the furnace of the boiler when the water level falls below an unsafe level and thus avoids the explosion which may take place due to overhearing of the tubes and the shell.	**1 Marks** **1 Marks**
	d)	**List Four Applications of nozzle** 1) In flow measurement to measure discharge 2) Steam and gas turbine 3) Jet engines 4) Rocket motors 5) In flow measurement 6) In water sprinklers 7) In injectors for removing air from condensers.	**½ Marks for each (any four)**
	e) **Sol.**	**What is the necessity of compounding of steam turbine?** • The compounding of steam turbine means the methods to reduce the speed of rotor shaft. • To increase the thermal efficiency in power plants, high pressure and high temp. steam is used. • If the entire pressure drop (from boiler pressure to condenser pressure)is carried out one stage only. • Then the velocity of steam entering into the turbine will be extremely high. • This will make the rotor to run at a very high speed, which is not useful from practical point of view. • Hence it becomes necessary to reduce the rotor speed of turbine by gearing or no. of stages.	**Any 2 points** **01 mark each**

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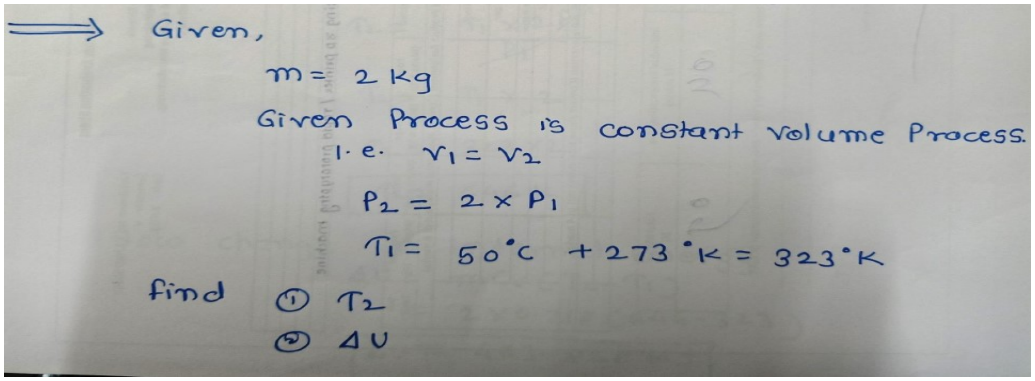
Q. No.	Sub Q. N.	Answer	Marking Scheme
1.	f)	**State Dalton's law of partial pressure.** It states that' "The pressure exerted by mixture of air and steam is equal to sum of partial pressures, which each constitute would exert, if it occupies the same volume". In condenser total pressure is the sum of partial pressure of steam and air. Mathematically, Pc= Pa + Ps Where; Pc = Pressure in condenser containing mixture of air and steam Pa = Partial pressure of air Ps = Partial pressure of steam	**1 Marks** **1 Marks**
	g) Sol.	**State Fourier's law of heat conduction** The law state that for homogeneous material the rate of heat transfer in steady state in any direction is directly proportional to temperature gradient in that direction. $Q/A \alpha dt/dx$ $Q/A = -k\, dt/dx$ Where, Q/A is rate of heat transfer dt/dx is temperature gradient k conductivity of medium	**1 Marks** **1 Marks**
2.		**Attempt any THREE of the following:**	**12**
	a) Sol.	**State Extensive property and Intensive property with two example of each .** **(i) Extensive Property:** It is defined as the property which depends upon the mass of the system. **Or** Extensive properties are those whose values are dependent of the mass possessed by the system, such as volume, enthalpy, and entropy. **Ex.** Total volume, Area, Enthalpy, Entropy etc. **(ii)Intensive Property:** It is defined as the property which is does not depend upon the mass of the system. **Or**	**2 Marks for Each Def.** **2 marks for Example of each**

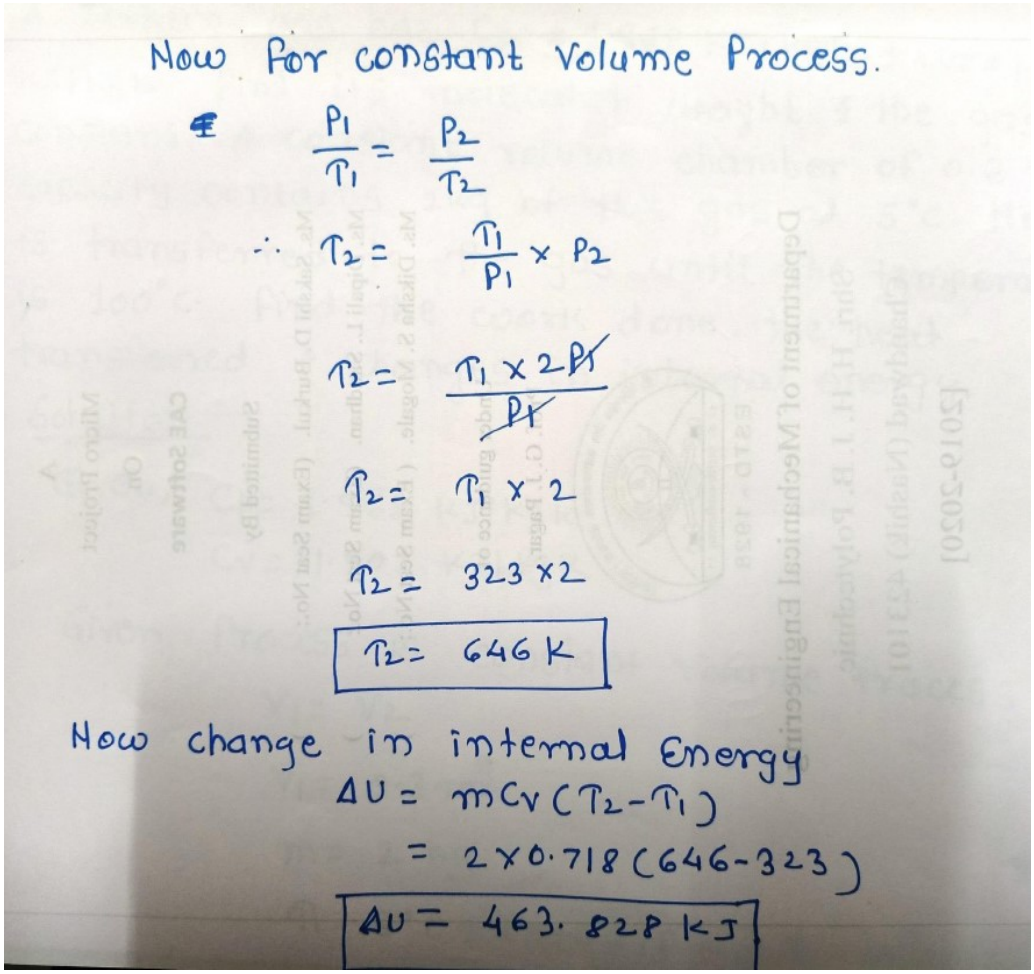
Intensive properties are those whose values are independent of the mass possessed by the system.

Ex. Pressure, Temperature, Density, Specific volume, specific Enthalpy, etc.

2. **b)** **2 kg of gas at 50°c is heated at constant volume until the pressure is doubled. Determine i) Final Temp. ii) Change in internal energy. Take C_v = 0.718 KJ/Kgk.**

An

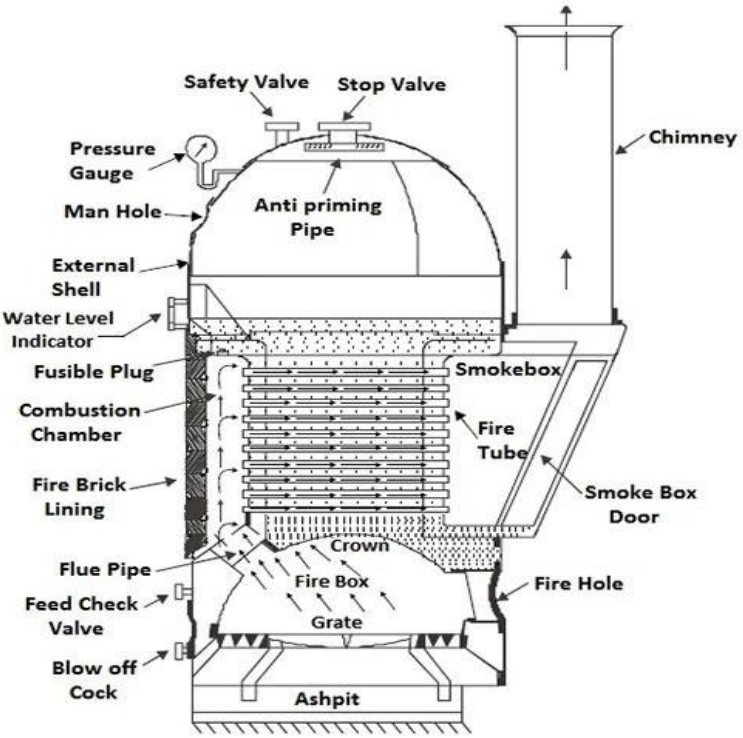




2 Marks for Final Temp.

2 Marks for Change in Internal Energy

2.	**c)** **Sol.**	**State the Main Features of Indian Boiler Regulation (IBR)** 1. A boiler cannot be put to use unless it has been registered with the Chief Inspector of Boilers. 2. The maximum working pressure of the boiler has to be determined by Boiler Inspector who will issue certificate for this. Owner cannot exceed this pressure limit in any case. 3. In case of accident, it should be reported by owner within 24 hours with full details. 4. The rules, regulations and bye-laws governing the upkeep and maintenance of boilers, procedure of registration, inspection and certification of maximum pressure, safety conditions etc. are subject to a revision by a Central Board under control of Govt. of India. 5. The boiler house plan, chimney design (Max height 30.48 m from floor) should be approved by boiler inspector. 6. Owner should apply for registration in prescribed format, inspector should fix date of inspection within 30 days, conduct inspection/examination of boiler, Issue the certificate of registration not exceeding 12 months period. 7. Following inspections are carried out by Boiler Inspector at various stages/ levels /need- Inspection for registration, Hydraulic test, steam test, annual inspection, Inspection under steam, Internal inspection, Accident inspection, Casual inspection 8. Violation of law is liable to prosecution and punishment with fine.	**Any Four Features** **1 Mark for each**
	d) **Sol.**	**Explain the working of Cochran boiler with neat sketch** The Cochran boiler is vertical, multi-tube boiler generally used for small capacity steam generation. Cochran boilers are made in different sizes of evaporative capacities ranging starting from 150 to 3000 kg/hr. and working pressure up to 15 bar.	



Cochran Boiler

Working:

- First, the coal is fed to grate via a fire hole for a burn.
- The ash formed in burning is collected in ash-pit below the grate and it removes manually.
- The hot gases from the grate pass through the combustion chamber to horizontal fire tubes and transfer the heat to water by convection.
- Exhaust gases out from fire tubes pass through smokebox and exhaust to the atmosphere via a chimney.
- There is a door in the smokebox for cleaning the fire tunes and smokebox. The Cochran boiler has a working pressure of 6.5 bar and a steam capacity of 3500 kg/hr.

2 Marks for fig.

2 Marks for working

3		**Attempt Any <u>THREE</u> of the following.**	**12**
	a	**Define and state significance of Mach number.**	
	Sol	• It is the ratio of velocity of fluid to the sonic velocity of compressible fluid M=V/a Where, M= Mach number	**Define 02 Marks**

V=Velocity of fluid

a=Sonic velocity

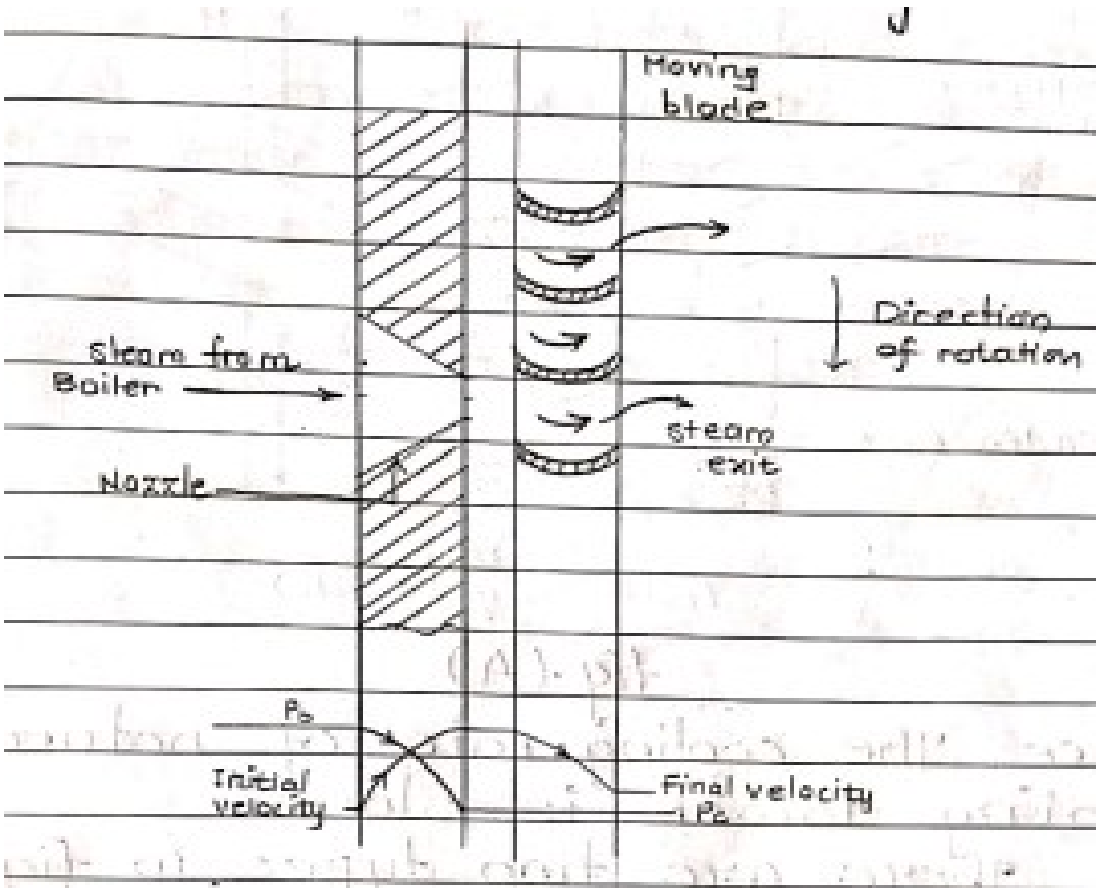
Significance of Mach number:

If

- M<1 subsonic nozzle
- M>1 supersonic nozzle
- M=1 subsonic and supersonic nozzle

02

b **Working of Impulse Turbine:**



02

Pressure velocity variation in Impulse turbine

Working of Impulse Turbine:

02

- The impulse turbine consists of one set of Nozzle followed by one set of moving blades as shown in above figure.
- In Impulse turbine power is developed by impulsive force of high velocity steam jet on moving blade

- Steam from boiler enters in nozzle ring of impulse turbine where, high velocity jet is obtained by expansion of steam in nozzle ring.
- Moving blades changes direction of steam jet thus the momentum of jet which rotates the shaft.
- High velocity steam jet then passed through moving blade ring with no pressure drop but gradual reduction in velocity.

c

Given Data : Pressure $= P_1 = 7$ bar

Final Pressure $= P_2 = 1.5$ bar

Temprature $= T_1 = 400°K$

Volume $= V_1 = 0.2\ m^3$

$\therefore \quad PV^{1.5} = C$

$n = 1.5$

To Find : Work Transfer

Solution : $P_1 V_1^{\,n} = P_2 V_2^{\,n}$

$$\frac{V_2}{V_1} = \left(\frac{P_1}{P_2}\right)^{1/n}$$

$$V_2 = V_1 \times \left(\frac{P_1}{P_2}\right)^{1/n}$$

$$= 0.2 \times \left(\frac{7}{1.5}\right)^{1/1.5}$$

$$= 0.2 \times 2.792$$

$$\boxed{V_2 = 0.558\ m^3}$$

02

Work Transfer $= W = \dfrac{P_1 V_1 - P_2 V_2}{n-1}$

$$W = \frac{(7 \times 10^5 \times 0.2) - (1.5 \times 10^5 \times 0.558)}{1.5 - 1}$$

$$= \frac{56300}{0.5}$$

$$= 112600 \text{ Joules}$$

$$\boxed{W = 112.600 \text{ KJ}}$$

02

d

Q.3.d.

Given Data : Pressure (P) = 10 bar

Total Volume (V) = $0.125\ m^3$

Total Enthalpy (h) = 1800 KJ

To Find : Mass and Dryness fraction of Steam

Solution : From steam table, At 10 bar,

$V_g = 0.194\ m^3/kg$

$h_f = 762.5\ KJ/kg$

$h_{fg} = 2013.6\ KJ/kg$

Mass of Steam, $m = \frac{V}{V_g} = \frac{0.125}{0.194} = 0.6443\ kg$ **02**

Hence for m kg, $h_f = 0.6443 \times 762.5 = 491.27875 KJ$

For m kg, $h_{fg} = 0.6443 \times 2013.6 = 1297.36248 KJ$

Total enthalpy $h = h_f + h_{fg}\, x$

$1800 = 491.27875 + (x \times 1297.362)$

$\boxed{x = 1.008}$

As the dryness fraction is greater than one hence the steam is in superheat condition. **02**

4		Attempt Any THREE of the following.	12
	a	**Differentiate between natural draught and forced draught cooling tower.**	**Any four point 01 mark each**

Natural Draught cooling tower	Forced draught cooling tower
1. Circulation of air is provided by pressure difference of air inside cooling tower	1.for circulation of air forced draught fan provided.
2.cooling capacity is less	2.cooling capacity is more
3.Operating cost is less	3. Operating cost is more
4. Maintenance Cost is less	4.Maintenance cost is more
5.Space Requirement is more	5.Space requirement is less
6. It is generally hyperbolic in shape	6.It is rectangular in shape.

4 b

Q.4.b.

Given Data : $V_1 = 0.14\ m^3$

$P_1 = 1400\ kPa$

$T_1 = 300°C$

$= 300 + 273 = 573°K$

Gas expanded isentropically to 280 kPa

$\therefore P_2 = 280\ kPa.$

To find : 1) Final temprature $= T_2 = ?$

2) Work transfer $= dw = ?$

Solution : For isentropic Process :

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} \quad \text{Assume } \boxed{\gamma = 1.4}$$

$$\frac{T_2}{573} = \left(\frac{280}{1400}\right)^{\frac{1.4-1}{1.4}}$$

$$T_2 = (0.2)^{0.286} \times 573$$

$$T_2 = 0.631 \times 573 = 361.62°K$$

$$\boxed{T_2 = 361.62 - 273 = 88.62°C}$$ **02**

We know that, $P_1 V_1^{\gamma} = P_2 V_2^{\gamma}$

$$\frac{P_1}{P_2} = \left(\frac{V_2}{V_1}\right)^{\gamma}$$

$$\frac{1400}{280} = \left(\frac{V_2}{0.14}\right)^{\gamma}$$

$$(5)^{1/1.4} = V_2/0.14 \; ; \; V_2 = 0.14 \times 3.16$$

$$\boxed{V_2 = 0.44\ m^3}$$

$$dw = \frac{P_1V_1 - P_2V_2}{\gamma - 1} = \frac{(1400 \times 0.14) - (280 \times 0.44)}{1.4 - 1}$$

$$= \frac{196 - 123.2}{0.4} = 182\ KJ \quad \boxed{dw = 182\ KJ}$$ **02**

c

Q.4.C.

Given Data : Sphere Dia (d) = 10m

Hydrogen Temprature = 25°C

Surrounding Air Temprature = 20°C

To find : Load lifted by the Balloon

Solution : Volume of balloon $= \frac{4}{3}\pi r^3$

$V = \frac{4}{3}\pi(5)^3 = 523.6\ m^3$

$MR = 8.3143$

$R = \frac{8.3143}{2} = 4.15715\ kJ/kg°K$

Pressure of hydrogen in the balloon = atmospheric pressure

$= 101.325\ kN/m^2$

Applying gas equation, $PV = mRT$ **01**

Mass of hydrogen in balloon $= \frac{PV}{RT} = \frac{101.325 \times 523.6}{4.15715 \times (25+273)}$

$m_h = 42.825\ kg$

The volume of air displaced by the balloon = Volume of the balloon $= 523.6\ m^3$

The mass of air displaced by the balloon **01**

$m_a = \frac{PV}{RT} = \frac{101.325 \times 523.6}{0.287 \times (20+273)}$

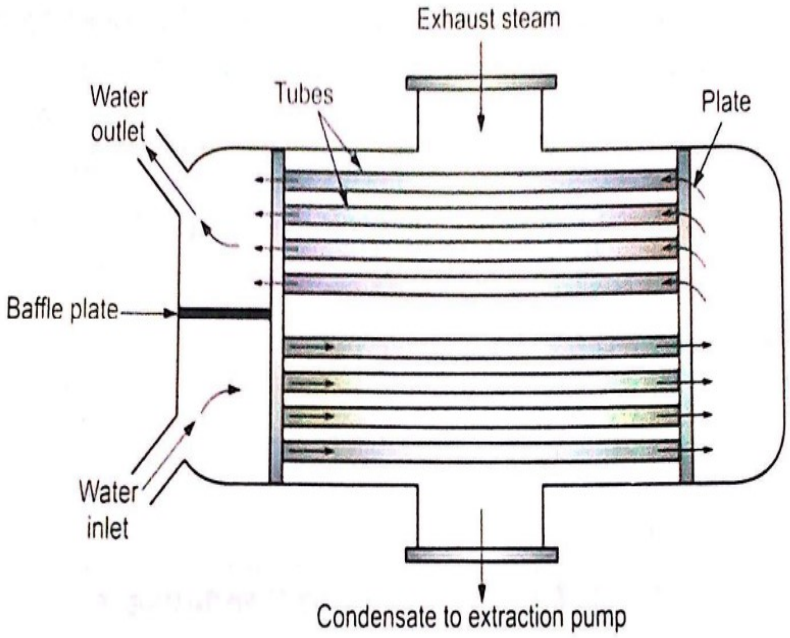
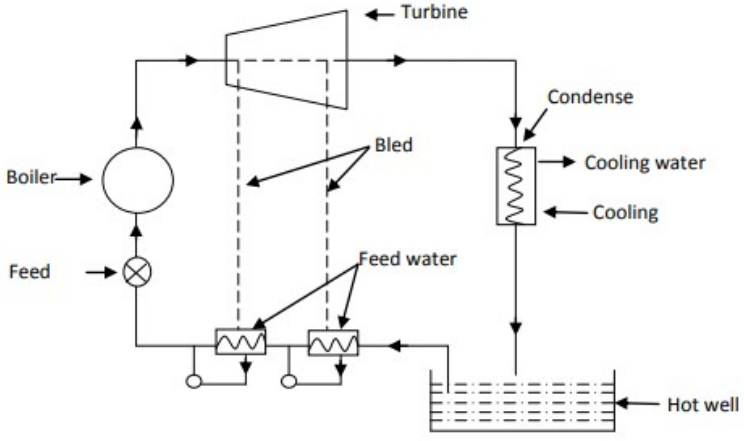
$m_a = 630.9\ kg$

Total load which can be lifted by the balloon **02**

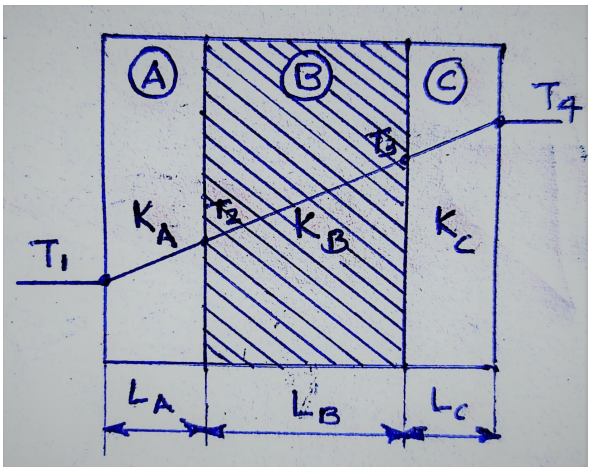
$= 630.9 - 42.825$

$= 588.073\ kg.$

4	**d**	i)**Fourier's law:** " Heat Transfer Rate per unit area is proportional to normal temperature gradient." $\therefore Q = -K.A.\frac{dt}{dx} \therefore Q = -K.A.\frac{dt}{dx}$ $\therefore\therefore\quad K = \frac{Q}{A.dx}\frac{dt}{dx} K = \frac{Q}{A.dx}\frac{dt}{dx}$ K=Thermal conductivity. **ii)Thermal Conductivity**: Thermal conductivity of material is define as, "the amount of energy conduct through a body of unit area and unit thickness in unit time when the difference in temperature between the face causing heat flow is unit temperature difference." K=Thermal conductivity. $\therefore Q = -K.A.\frac{dt}{dx} \therefore Q = -K.A.\frac{dt}{dx}$ $\therefore\therefore\quad K = \frac{Q}{A.dx}\frac{dt}{dx} K = \frac{Q}{A.dx}\frac{dt}{dx}$ K=Thermal conductivity. State **i) Newton's Law of cooling:** "The rate of cooling of a body is directly proportional to the difference in temperature of the body (T) and surrounding (To), provided difference in temperature should not be exceed by 30 ^{0}c." **ii) Radiation** : "It is process of heat transfer between two bodies without any carrying medium through different kind of electro-magnetic wave."	**01** **01** **01** **01**

	e	**Draw Neat sketch of surface condenser and label it.**  **Figure: Surface Condenser**	**03 marks for sketch and 01 mark for labelling**
5		**Attempt ant TWO of the following:**	**12**
	a	**Regenerative feed heating** The process of draining steam from turbine at certain points during its expansion and using this steam for heating feed water supplied to boiler is known as regenerative feed heating.  **Fig. Regenerative feed heating** **Advantages:** 1. It increases the thermal efficiency of plant. 2. The temperature stresses in the boiler are reduced due to decreased range of working temperature.	**02 Marks** **02 Marks For Fig.** **02 Marks**

b **Given data:**



02 Marks Figure

L_A= 2 mm = 0.002 m
L_B= 5 cm =0.05 m
L_C=2 mm =0.002 m
$K_A = K_C$ = 50 W/m^{0}k
K_B = 0.1 W/m^{0}k
T_1= -10 ^{0}C = -10 +273 = 263 ^{0}k
T_4= 40 ^{0}C = 40 + 273 = 313 ^{0}k

01 Mark for data

$$\frac{Q}{A} = \frac{(T_1 - T_4)}{\frac{L_A}{K_A} + \frac{L_B}{K_B} + \frac{L_C}{K_C}}$$

$$\frac{Q}{A} = \frac{(263 - 313)}{\frac{0.002}{0.1} + \frac{0.05}{50} + \frac{0.002}{0.1}}$$

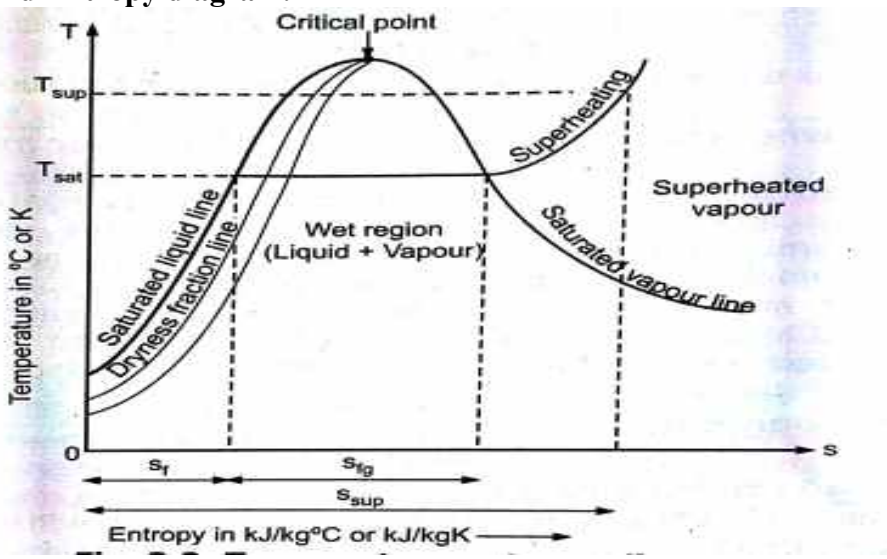
$$\frac{Q}{A} = \frac{-50}{0.02 + 0.001 + 0.02}$$

$$\frac{Q}{A} = \frac{-50}{0.041}$$

$$\frac{Q}{A} = -1219.51\ W/m^2$$

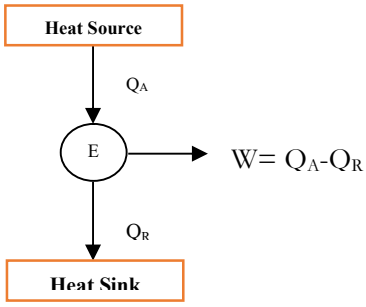
03 Marks For cal.

c **Temperature and Entropy diagram:**



04 Mark for dia.

02

		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.	**Marks For expl.**
6		**Attempt any TWO of the following:**	**12**
	a i	**Heat Engine:**  **Fig. Heat Engine** In heat engine, heat is extract from the high thermal reservoir or heat source same part of heat is converted into work and remaining heat rejected to thermal reservoir or heat sink. **The performance of heat engine is measured in terms of efficiency.** So, $n_{th} = Q_A - \frac{Q_R}{Q_A}$ $n_{th} = 1 - \frac{Q_R}{Q_A}$ The efficiency of heat engine is always less than 1. It means that heat engine is not 100% efficient.	**1.5** **1.5**
	a ii	--- **Prove that, (C.O.P.) Heat pump = 1 + (C.O.P.) refrigeration.** $(C.O.P.)_{\text{Heat pump}} = \frac{Q_R}{Q_A - Q_R}$ $(C.O.P.)_{\text{Refrigeration}} = \frac{Q_A}{Q_A - Q_R}$ $(C.O.P.)_{\text{Heat pump}} + 1 = \frac{Q_R}{Q_A - Q_R} + 1$ $= \frac{Q_R + Q_A - Q_R}{Q_A - Q_R}$ $= \frac{Q_R + Q_A - Q_R}{Q_A - Q_R}$	**03**

$$= \frac{Q_A}{Q_A - Q_R}$$

$$(C.O.P.)_{\text{Heat pump}} + 1 = (C.O.P.)_{\text{Refrigeration}}$$

b i

The main **sources of air leakage** in condenser are given below:

1) There is leakage of air from atmosphere at the joint of the parts which are internally under a pressure less than atmospheric pressure.
2) Air is also accompanied with steam from the boiler into which it enters dissolved in feed water.
3) In jet condensers, a little quantity of air accompanies the injection water.

03

b ii

$$\text{Absolute pressure in condenser} = P_{atm} - P_{gauge}$$

$$= 759 - 700$$

$$= 59\ mm\ of\ Hg$$

$$Corrected\ Vacuum = 760 - Absolute\ pressure\ in\ condenser$$

$$= 760 - 59$$

$$= 701\ mm\ of\ Hg$$

$$= \frac{701}{760} X\ 1.01325\ bar$$

$$= 0.92345\ bar$$

03

C i

Type of Heat Exchanger for following applications:

i. **<u>Dairy Plant (Milk Chilling Plant):</u> Plate Type Heat Exchanger**
Because,
1. It is made up of aluminum alloy which provides higher rate of heat transfer.
2. Due to larger surface area, it has more heat transfer as compare to other heat exchanger which is useful for dairy plant.
3. It is lighter in weight.

03

C ii

ii. **<u>Condenser of Refrigeration System (Household system):</u> Counter Flow tube type heat Exchanger**
Because,
1. High performance due to large surface area.
2. Compact and light in weight.
3. In tubes generally turbulent flow is develop which reduces scale deposition.

Less installation and maintenance cost.

03

END
