S.Y. Diploma : Sem. III
[PG/PT/ME]

Thermal Engineering

Time: 3 Hrs. Prelim Question Paper Solution **[Marks : 70**

Q.1 Attempt any FIVE of the following. [10]

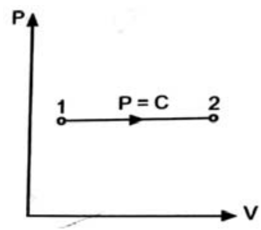
Q.1(a) Explain difference between Thermodynamic Heat & Work transfer. [2]

Ans.:

	Work	Heat
1.	Work is product of force and displacement in direction of force.	Heat is energy interaction due to temperature difference.
2.	Body or system never contains work.	Body or system possess heat.
3.	Work is high grade energy.	Heat is low grade energy.
4.	Entire work can be converted into heat.	Entire heat can not be converted into work.

Q.1(b) State Charle's law. [2]

Ans.:
- Charle's law states that 'If unit mass of gas is maintained at constant pressure, the volume of gas is directly proportional to the absolute temperature of the gas'.
- It can be shown on PV diagram as –
- Mathematically, $V \propto T$, if $P = C$



$\therefore \quad \dfrac{V}{T} = C$

$\therefore$ For process 1-2 $\quad P = C$

$\therefore \quad \dfrac{V}{T} = C$

$\therefore \quad \dfrac{V_1}{T_1} = \dfrac{V_2}{T_2}$

- Charle's law can also be states as, 'If unit mass of gas is maintained at constant volume.

Q.1(c) Define Dryness fraction and degree of superheat. [2]

Ans.: **Degree of Superheat:**

The degree of superheat is defined as 'the difference between superheated temperature of steam and its saturation temperature'.

$\therefore$ Degree of superheat = $T_{sup} - T_{satu}$

Thus, the superheated steam does not contain any moisture.

Q.1(d) List out the losses in steam turbines. **[2]**

Ans.: **(i) Nozzle Loss:** It is important loss in impulse turbine, which occurs when the steam flows through the nozzle. This loss takes place due to friction in the nozzle and the formation of eddies.

(ii) Blade Friction Loss: It is important loss in both the impulse and reaction turbines, which occurs when the steam glides over the blades. This loss takes place due to friction of the surface of blades. As a result of blade friction, the relative velocity of the steam is reduced while gliding over the blade.

Q.1(e) Explain the purpose of compounding of steam turbines. **[2]**

Ans.:

- Generally, in power plants the steam pressure and temperature are very high in order to increase thermal efficiency and to reduce size.
- If in turbine entire pressure drop from boiler pressure to condenser pressure is carried out in single stage, the velocity of steam entering the turbine becomes extremely high. This results in high rotational speed of the turbine, as speed is directly proportional to the steam velocity.
- Such a high rotational speed of turbine is not useful for any practical purpose and it becomes necessary to reduce the speed of turbine by gearing, as there is a danger of failure of blades due to the excessive centrifugal stresses when a single stage of blades is used. All these difficulties are overcome 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.

Q.1(f) Define Mach number and critical pressure. **[2]**

Ans.: **Concept of Mach Number:**

- Mach number is defined as 'the ratio of velocity (C) at a state in flowing fluid to the value of sonic velocity (a) at the same state'.

  Thus, Mach number, $M = \frac{C}{a}$

  when $M > 1$ Flow is called Supersonic.
  when $M = 1$ Flow is called Sonic.
  when $M < 1$ Flow is called Subsonic.
  when $M >> 1$ (M is much greater than 1) Flow is called Hypersonic.

Q.1(g) Define thermal Conductivity. State it's Unit. **[2]**

Ans.: Thermal Conductivity:

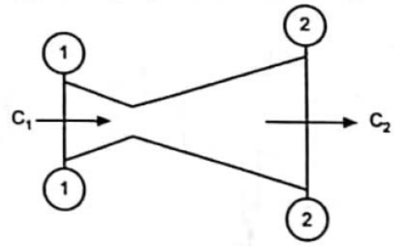
- Thermal conductivity of material is defined as 'amount of energy conducted through a body of unit area and unit thickness in unit time when the difference in temperature between the faces causing heat flow is 1°C'.
- Thermal conductivities of different bodies are different. Thermal conductivity of body mainly depends upon its molecular structure, specific gravity etc.
- Metals are good conductor of heat and insulator are poor conductor of heat.

Q.2 Attempt any THREE of the following. **[12]**

Q.2(a) Apply steady state energy equation with a block diagram to nozzle & turbine. **[4]**

Ans.: Applications of steady Flow Energy Equation to Nozzle

- Nozzle is a passage of varying cross-section by means of which pressure energy of flowing fluid is converted into kinetic energy. Main purpose of nozzle is to produce a jet of high velocity.



∴ Steady flow energy equation

$$\therefore\ m\times\left[\frac{C_1^2}{2}+g z_1+h_1\right]+Q = m\times\left[\frac{C_2^2}{2}+g z_2+h_2\right]+W$$

- For Nozzle; Work done, w = 0, No heat transfer ∴ Q = 0 and $z_1 = z_2$.

$$\therefore\quad h_1+\frac{C_1^2}{2} = h_2+\frac{C_2^2}{2}$$

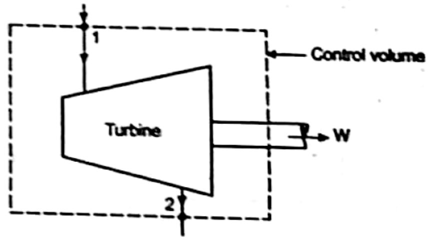
$$\therefore\quad C_2 = \sqrt{2(h_1-h_2)+C_1^2}$$

- Inlet velocity is very small as compared to exit velocity. Therefore, neglecting inlet velocity,

$$C_2 = \sqrt{2(h_1-h_2)}$$

Application of Steady Flow Energy Equation to Turbine

- Turbine converts the heat energy of fluid into useful work.



- For turbine, Change in K.E. and P.E. is negligible, Turbine is insulated.

∴ $Q = 0$

∴ Steady flow energy equaion is,

$$m\times\left[\frac{C_1^2}{2}+g\,z_1+h_1\right]+Q = m\times\left[\frac{C_2^2}{2}+g\,z_2+h_2\right]+W$$

∴ $mh_1 = mh_2 + W$

∴ $W = m(h_1 - h_2) = H_1 - H_2$

- Thus, enthalpy drop is converted into useful work.

Q.2(b) Define adiabatic process and plot it on Pv & Ts diagrams. **[4]**

Ans.: **Isentropic/Adiabatic Process**

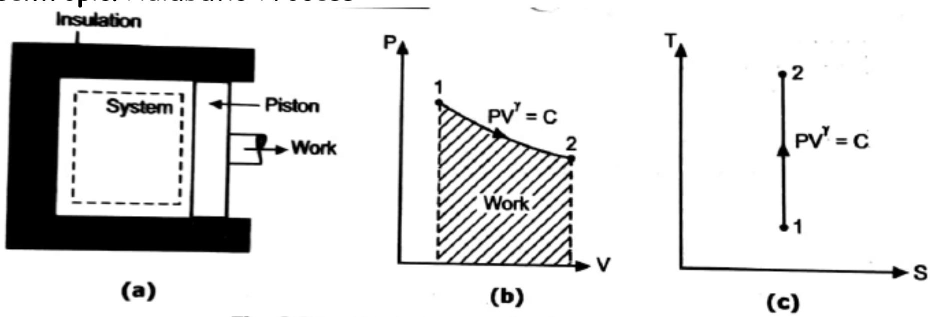


Fig.: Isentropic/Adiabatic process

- A simple definition of isentropic is "No change in entropy". For isentropic process entropy remains constant.
- An adiabatic process is transfer of energy as work, occuring without transfer of heat between system and surrounding. Thus, for adiabatic process "No transfer of heat take place" (i.e. $dQ = 0$).

d – e (Latent heat of vapourization of water):

At point 'd' water is at its saturation state. Further addition of heat will not increase the temperature but heat is transferred at constant temperature to chagne liquid phase (water) into vapour phase (steam) is known as 'latent heat of vapourization of water'.

Thus, latent heat of vapourization of water is defined as 'the amount of heat added at constant temperature to convert 1 kg of water into steam'. It is denoted as h_{fg}. From steam table we get the value of latent heat as,

$$h_{fg} = 2256.9 \text{ kJ/kg at } 1.0325 \text{ bar}$$

In this region, conversion of water into steam starts a point 'd' and completes at point 'e'. Thus, both liquid as well as vapour phase exists in this region.

e – f (Superheating of steam):

At point 'e' steam is present in its dry saturated state. It does not contain any moisture, as all liquid is converted into steam.

Further heating of steam will increase the temperature of steam, which is known as superheating. Thus, superheating is defined as 'heating of steam above its saturation temperature'.

Thus, steam is heated from its saturation temperature (T_{satu}) to superheated temperature (T_{sup}).

Degree of superheat is the difference of $T_{sup} - T_{satu}$

Heat supplied i.e. Enthalpy = $mC_p (T_{sup} - T_{satu})$

If steam is heated upto 150°C at 1.01325 bar then,

$$\begin{aligned}\text{Degree of superheat} &= T_{sup} - T_{satu} \\ &= 150 - 100 \\ &= 50°C\end{aligned}$$

and

$$\begin{aligned}\text{Heat supplied} &= mC_p (T_{sup} - T_{satu}) \\ &= 1 \times 2.1 (150 - 100) \\ &= 105 \text{ kJ/kg}\end{aligned}$$

Thus, superheating of steam may be shown as e-f in Fig. 3.1.

Q.2(c) Describe generation of steam at constant pressure with temperature enthalpy diagram [4]

Ans.: Formation of Steam of Constant Pressure

- Consider formation of steam from Ice at -10°C, when atmospheric pressure is 1.01325 bar. This conversion of Ice into steam can be explained with the figure.
- The stages of heat addition for 1 kg can be explained as:

a – b (Heat of ice from -10°C to melting temperature of ice):

Heat is added to ice at -10°C to 0°C, which is melting point of ice. During this addition of heat, temperature of ice will increase and we can sense the temperature in thermometer. Therefore, it is called 'sensible heat'. During this heat addition, only solid phase (i.e. ice) will exist. This sensible heat can be denoted as 'h_1'.

b – c (Latent heat of fusion of ice):

At point 'b' ice is at its saturation state. Further addition of heat will not increase the temperature but ice will start to convert into water i.e. transformation of phase will take place and at point 'c' all ice will convert into water.

Thus, in this region solid as well as liquid phase exists and heat supplied is called as 'latent heat' as it can not be sensed by thermometer (Latent means hidden). It can be denoted as h_f.

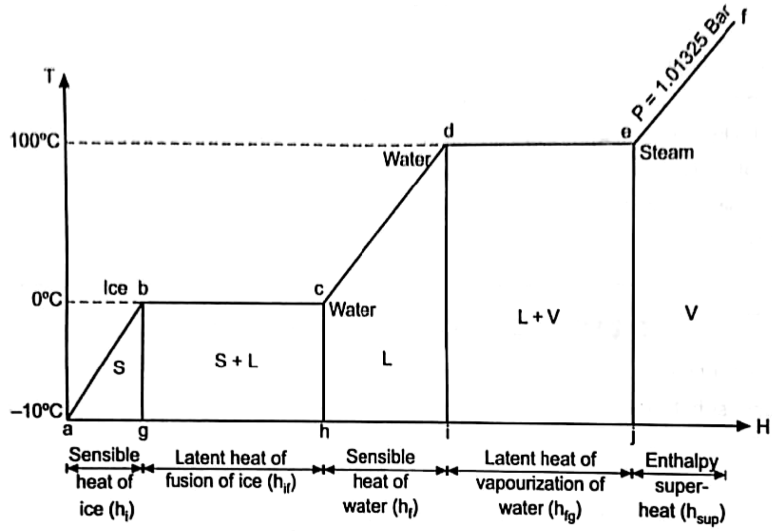


Fig.: Formation of steam

c – d (Sensible heating of water grom 0°C to saturation temperature):
In this region, water at 0°C is heated to 100°C (Boiling point of water or saturation temperature is 1.0325 bar), the change in temperature can be seen in thermometer therefore it is called as 'Sensible heat of water'. It can be denoted by h_f. Here no change of phase takes place. In this region c-d, only liquid phase will exist.

$\therefore$ Heat supplied = $h_f = mC_p\,(T_d - T_c)$

$= 1 \times 4.18 \times (100 - 0) = 418$ kJ/kg

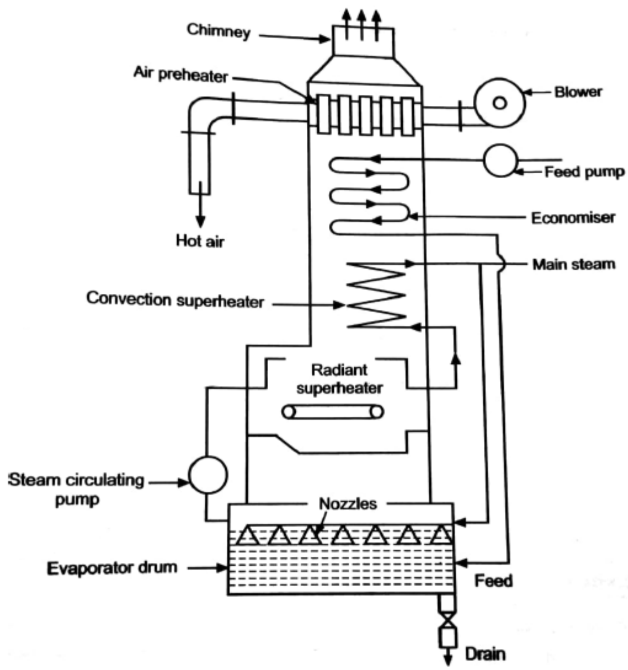
Q.2(d) Draw a neat sketch of Loeffler boiler and explain its working. [4]

Ans.: Loeffler Boiler

- Loeffler boiler is a forced circulation, indirect heating type of boiler. In this boiler, water is heated mainly by means of superheated steam. The steam will act as heat carrying and heat absorbing medium. Thus, boiler uses the circulation of steam instead of water and difficulty of deposition of salt and sediment in boiler tubes is completely eliminated.
- Loeffler boiler consists of evaporator drum, which may be placed at any convenient point outside the furnace setting. The feed water pump feeds

the water to economiser, which is placed in the path of flue gases. The economiser extracts sensible heat from flue gases and hot water at temperature close to saturation temperature is passed to evaporator drum.

- From superheater big portion of steam (About $\frac{3}{4}$) is trapped off for external use and remainder portion (About $\frac{1}{4}$) is passed to evaporator drum which is used to evaporate the water by giving sensible as well as latent heat. The evaporator drum is provided with set of nozzle through which steam enters in evaporator drum. Nozzles are made of special design to avoid priming and noise.
- The steam from evaporator drum is passed to superheater through circulating pump. The air preheater may be placed in path of flue gases to supply the hot air in combustion chamber.
- Loeffler boiler has steam-generating capacity of 100 tons/hr at 140-bar pressure.



Q.3 Attempt any THREE of the following. [12]

Q.3(a) Classify steam turbines in detail. [4]

Ans.:
- Steam turbines may be classified in following ways:
  1. According to working principle or Action of steam over blade:
     (a) Impulse turbine (b) Reaction turbine
     (c) Impulse-reaction turbine
  2. According to the stages of expansion of steam:
     (a) Single stage turbine (b) Multistage turbine

3. According to the position of shaft:
   (a) Horizontal turbine (b) Vertical turbine
4. According to pressure of steam supplied:
   (a) High pressure turbine (b) Low pressure turbine
5. According to direction of steam flow:
   (a) Axial flow turbine (b) Radial flow turbine
   (c) Tangential flow turbine
6. According to exhaust steam pressure:
   (a) Condensing type steam turbine
   (b) Non-condensing type steam turbine.

Q.3(b) Explain the working of impulse steam turbine with a sketch. Also show pressure 7 velocity variation for the same. [4]

Ans.:
- The impulse turbine consists of one set of nozzle, which is followed by one set of moving blades as shown in Fig. 4.3. In impulse turbine, power is developed by the impulsive force of high velocity steam jet or jets.
- The high velocity steam jets are obtained by expansion of steam in the stationary nozzles only, and steam then passes at high velocity through moving blade with no drop in pressure but a gradual reduction in velocity.
- Thus, in pure impulse turbine the high velocity jet having nozzle strikes on the blades mounted on the wheel attached to the shaft. These blades changes the direction of steam and hence momentum of the jet of steam, which rotates the shaft.
- The nozzle axis is inclined to an angle to the tangent of the rotor; figure shows the variation of pressure and velocity.

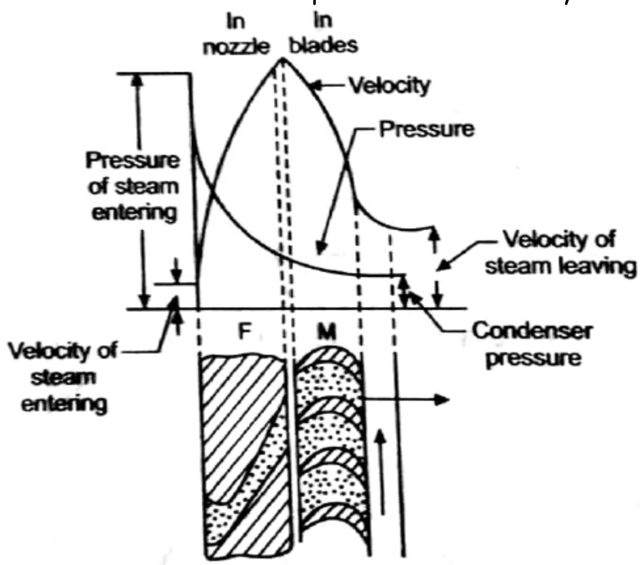


Fig.: Variation of pressure and velocity of steam in impulse turbine

Q.3(c) A gas at 7 bar, 400 K occupies a volume of 0.2 m^3. The gas expands according to the law $PV^{1.5} = C$ upto pressure of 1.5 bar. Determine work transfer. **[4]**

Ans.: Initial pressure of a gas = P_1 = 7 bar
Initial temperature of gas = T_1 = 400 K
Initial volume of gas = V_1 = 0.2 m^3
Final pressure of gas = P_2 = 1.5 bar
Law of expansion is $PV^{1.5}$ = C
∴ Index of expansion, n = 1.5

For polytropic expansion process,

$$P_1V_1^n = P_2V_2^n$$

$$\therefore\ 7 \times (0.2)^{1.5} = 1.5 \times (V_2)^{1.5}$$

$$V_2 = 0.5585\ m^3$$

Work transfer,

$$dW = \frac{P_1V_1 - P_2V_2}{n-1}$$

$$= \frac{7 \times 10^5 \times 0.2 - 1.5 \times 10^5 \times 0.5585}{1.5 - 1}$$

$$= 112450\ J$$

$$= 112.45\ kJ$$

Q.3(d) Determine the state of steam if **[4]**
(i) Pressure is 10 bar and specific volume is 0.185 m^3/kg
(ii) Pressure is 12 bar and temperature is 200°C.

Ans.: (i) From steam table, At P = 10 bar,
Specific volume = 0.199444 m^3/kg
∴ Specific volume of sample < Specific volume of saturated steam
i.e. 0.185 < 0.199444
∴ Sample of steam is in wet condition.

(ii) From steam table, at P = 12 bar
T_{satu}= 187.99°C
∴ Temperature of sample steam > Saturation of temperature of steam at 12 bar
i.e. 200°C > 187.99°C
∴ Sample steam is in superheated condition.

Q.4 Attempt any THREE of the following. [12]

Q.4(a) State the sources of air leakage and its effects in steam condenser. [4]

Ans.: **Sources of Air Leakage**

The sources of air leakage in the condenser are,

(i) The air leaks through joints and packing into condenser, as the pressure inside is below atmospheric pressure. The quantity of air leakage through these sources depends upon quality of workmanship.

(ii) Air also comes in condenser with the steam. The feed water supplied to the boiler contains certain amount of air dissolved in it. The dissolved air gets liberated when steam is formed and is carried with the steam into the condenser. The amount of air entering through this source is relatively small and depends upon the treatment given to the feed water before it enters the boiler.

(iii) In jet condensers, dissolved air in the cooling water enters the condenser and it gets separated at low pressure in the condenser.

Effects of Air Leakage in Condenser:

The presence of air in condenser affects its performance in the following ways:

(i) The increased amount of air reduces the vacuum in condenser i.e. it increases the absolute pressure or back pressure of the prime mover, hence reduces the work done per kg of steam.

(ii) The heat transfer rates are greatly reduced due to the presence of air because air is a bad conductor of heat. Due to this, more quantity of cooling water is required to maintain heat transfer rates. Otherwise, it reduces condensation rates and increases the backpressure of the prime mover.

(iii) The presence of air reduces the partial pressure of steam and its temperature. The latent heat of steam increases at lower pressure; therefore more quantity of cooling water is required to steam as more latent heat is to be measured.

Q.4(b) Wet steam at 10 bar pressure having total volume of 0.125 m^3 and enthalpy content is 1800 kJ. Calculate mass and dryness fraction of steam. [4]

Ans.: From steam table at pressure P = 10 bar

$V_g = 0.19429\ m^3/kg$, $h_f = 762.79\ \frac{kJ}{kg}$, $h_{fg} = 2015.3\ \frac{kJ}{kg}$

Volume of wet steam $(V_{wet}) = 0.125\ m^3$

For wet steam, $V_{wet} = x \times v_g$

$$\therefore \quad \frac{0.125}{m}\ \frac{m^3}{kg} = x \times 0.19429\ \frac{m^3}{kg}$$

where, x = Dryness fraction of steam

m = Mass of steam

$$\therefore \quad x = \frac{0.6434}{m} \quad \ldots (1)$$

Enthalpy of wet steam (h_{wet}) = 1800 kJ

$$h_{wet} = h_f + x\, h_{fg}$$

$$\frac{800 \text{ kJ}}{m \text{ kg}} = 762.29 \frac{\text{kJ}}{\text{kg}} + x \times 2015.3 \frac{\text{kJ}}{\text{kg}} \quad \ldots (2)$$

Put $x = \frac{0.6434}{m}$ in equation (2)

$$\therefore \quad \frac{1800}{m} = 762.79 + \frac{0.6434}{m} \times 2015.3$$

$$\therefore \quad \frac{1}{m}(1800 - 0.6434 \times 2015.3) = 762.79$$

$$\therefore \quad m = \frac{1800 - 1296.84}{762.79} = 0.6598 \text{ kg}$$

$$\therefore \quad x = \frac{0.6437}{m} = \frac{0.6434}{0.6598} = 0.97$$

$\therefore$ Mass of steam = 0.6598 kg

Dryness fraction of steam = 0.97

Q.4(c) A CO_2, gas expands adiabatically from a pressure and volume of 7 bar and 0.03 m^3 respectively to pressure 1.4 bar. Determine : **[4]**
(i) Final volume (ii) Work done (iii) Change in internal energy
Assume C_p = 1.046 kJ/kg K and C_v = 0.752 kJ/kg K

Ans.: Initial pressure = P_1 = 7 bar

Initial volume = V_1 = 0.03 m^3

Final pressure = P_2 = 1.4 bar

To find gas constant, $R = C_p - C_v = 1.046 - 0.75 = 0.294$ kJ/kg K

Expansion is adiabatic,

$$\therefore \quad P_1V_1^{\gamma} = P_2V_2^{\gamma}$$

$$\therefore \quad V_2 = V_1 \times \left(\frac{P_1}{P_2}\right)^{\frac{1}{\gamma}} = 0.03 \times \left(\frac{7}{1.4}\right)^{\frac{1}{1.4}} = 0.0947 \text{ m}^3$$

Work done is given by, $W = \dfrac{P_1V_1 - P_1V_2}{\gamma - 1}$

$$= \frac{7 \times 10^5 \times 0.03 - 1.4 \times 10^3 \times 0.0947}{1.4 - 1}$$

$$= 19355 \text{ J} = 19.355 \text{ kJ}$$

$\therefore \quad P_1V_1 = mRT_1$

$7 \times 10^5 \times 0.03 = 1 \times 294 \times T_1$

$\therefore \quad T_1 = 71.43$ K

$\therefore \quad P_2V_2 = mRT_2$

$1.4 \times 10^5 \times 0.0947 = 1 \times 294 \times T_2$

$\therefore \quad T_2 = 45.09$ K

Change in internal energy,

$\Delta U = mC_V (T_2 - T_1)$

$= 1 \times 0.752 \times (45.09 - 71.43)$

$= - 19.80$ kJ

Q.4(d) Draw a labelled sketch of plate heat exchanger. (6) **[4]**

Ans.:

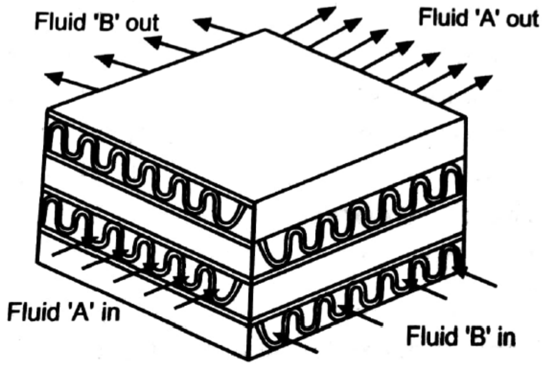


Fig.: Plate f_{in} type heat exchanger

Q.4(e) Draw neat sketch of any one type of surface condenser with neat sketch. **[4]**

Ans.:

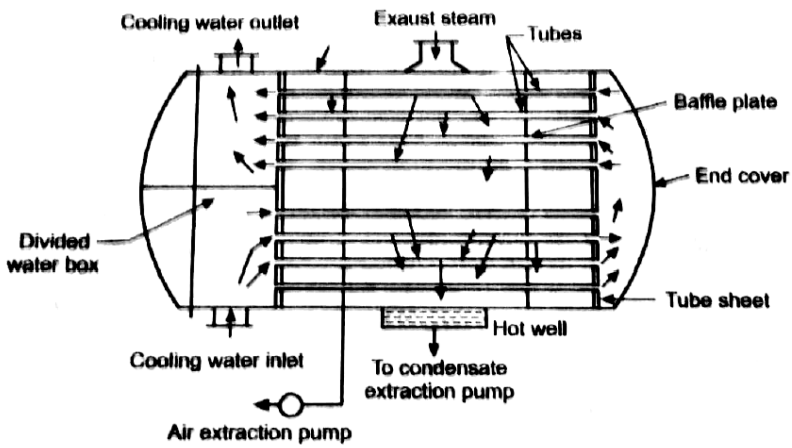


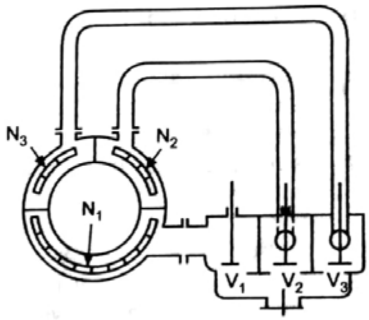
Fig.: Surface condenser

Q.5 Attempt any TWO of the following. [12]

Q.5(a) What is governing of steam turbine? Explain with neat sketch nozzle control governing. [6]

Ans.: Nozzle Control Governing:

- The arrangement of nozzle control governing is as shown in figure. In nozzle control governing, the nozzles are made in groups and the supply of steam to each group is controlled by a regulating valve.
- The nozzles are divided into three groups N_1, N_2 and N_3 and respective control valves provided are V_1, V_2 and V_3 that controls the supply of steam to nozzles. The number of nozzles in a group may be three, five or ten.
- Under full load condition all the regulating valves are open, when the load on turbine is reduced, the suitable valve is closed to reduce the supply of steam.



Q.5(b) In a cold storage, the wall measures 3 m × 4 m constructed of bricks, 10 cm thick cork slab, insulation of 7.5 cm from outside and additional pine wood covering of 2.5 cm thick protecting cork. If the internal temperature is −5°C and outside temperature is 20 °C. Find out heat leakage per unit time. Thermal conductivity is 0.25 per brick, 0.036 for cork and 0.092 W/mK for pine wood. What would be interface temperature? [6]

Ans.:

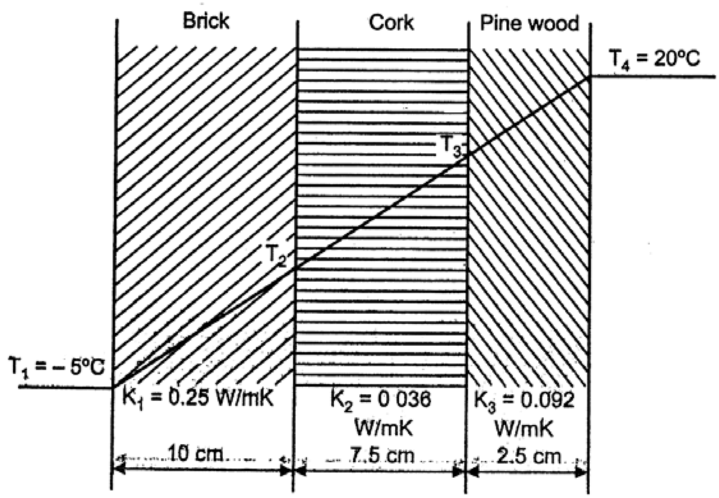


Fig. : Heat transfer through composite wall

Area of wall = A = 3 × 4 = 12 m^2
Thickness of brick = L_1= 10 cm
Thickness of cork = L_2 = 7.5 cm
Thickness of pine wood = L_3 = 2.5 cm
Temperature on inner face of wall = T_1 = –5°C
Temperature on outer face of wall = T_4 = 20°C
K for brick = K_1 = 0.25 W/mK
K for cork = K_2 = 0.036 W/mK
K for pine wood = K_3 = 0.092 W/mK

∴ Heat leaked inside the composite wall is given as,

$$Q = \frac{A\left(T_1 - T_4\right)}{\frac{L_1}{K_1} + \frac{L_2}{K_2} + \frac{L_3}{K_3}}$$

$$\therefore \quad Q = \frac{12 \times \left(-5 - 20\right) K}{\frac{0.1\,m}{0.25\,W/mK} + \frac{0.075\,m}{0.036\,w/mK} + \frac{0.025\,m}{0.092\,W/mK}}$$

= – 108.89 watts.

–Ve sign indicates that heat is flowing into refrigeration from outside.

Q.5(c) Calculate enthalpy of 1 kg of steam at a pressure of 7 bar and dryness fraction 0.8. How much heat would be required to raise 2 kg of this steam from water at 30°C? C_{pw} = 4.187 kJ/kg°C. **[6]**

Ans.: From steam table, at p = 7 bar.
H_f = 697.06kJ/jg, h_{fg} = 2762 kJ/kg
Dryness fraction = x = 0.8
∴ Enthalpy of 1 kg of wet steam at 7 bar,

Hwet = $h_f + x\,h_{fg}$
= 697.06 + 0.8 × 2762
= 2906.66 kJ/kg

Enthalpy of water at 30°C is calculated as

h_1 = m C_p T
= 1 × 4.187 × (30 + 273)
= 1268.66 kJ/kg

∴ Heat required to convert water into steam,
= $h_{wet} - h_1$
= 2906.66 – 1268.66
= 1638 kJ/kg

∴ Heat required to raise 2 kg of steam
= 2 × 1638 = 3276kJ

Q.6 Attempt any TWO of the following. [12]

Q.6(a) A steam of gases at 7.5 bar, 750°C and 140 m/s is passed through a turbine of a jet engine. The steam comes out of the turbine at 20 bar, 550°C and 280 m/s. The process is assumed to be adiabatic. The enthalpy of gas at the entry and exit of the turbine are 950 kJ/kg and 650 kJ/kg of gas respectively. Find the capacity of turbine. [6]

Ans.: At inlet of turbine,

Pressure = P_1 = 7.5 bar

Temperature = T_1 = 750°C

Velocity of stream = C_1 = 140 m/s

At exit of turbine,

Pressure = P_2 = 20 bar

Temperature = T_2 = 550°C

Velocity of stream = C_2 = 280 m/s

Enthalpy of stream at inlet = h1 = 950 kJ/kg

Enthalpy of stream at exit = h2 = 650 kJ/kg

Steady flow energy equation for turbine can be written as,

$$H_1 + \frac{C_1^2}{2} + gz_1 + dQ = h_2 + \frac{C_2^2}{2} + gz_2 + dw$$

For turbine, dQ and $z_1 = z_2$

$$\therefore \quad 950 \times 1000 + \frac{(140)^2}{2} = 650 \times 1000 + \frac{(280)^2}{2} + dw$$

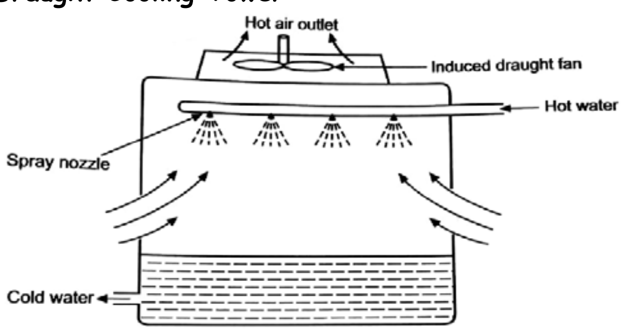
$\therefore$ dw = 270600 j/kg

$\therefore$ Capacity of turbine = 270.60 kJ/kg

Q.6(b) What is the function of cooling tower? Explain with neat sketch, the working of induced draught cooling tower. [6]

Ans.:
- Cooling tower is an artificial device used to cool the hot cooling water coming out of condenser. Cooling towers are used when positive control on temperature of cooling water is required. The space occupied by cooling system is an important factor.

Induced Draught Cooling Tower:



In induced draught cooling tower, induced draught fan is provided at top of condenser to provide circulation of air as shown in Fig. 5.6.

Merits of Cooling Tower:

(i) It cools the condenser water.

(ii) It allows condenser water to be used again and again.

Demerits of Cooling Tower:

(i) It requires water pump for circulation of water which consumes power.

Q.6(c) A metal pipe having diameter of 150 mm carries steam at 250°C. The pipe is covered externally by a 25 mm thick of an insulting material whose thermal conductivity is 0.152 W/mK. If outside temperature is 38°C. Find out amount of heat lost per metre length per minute. **[6]**

Ans.:

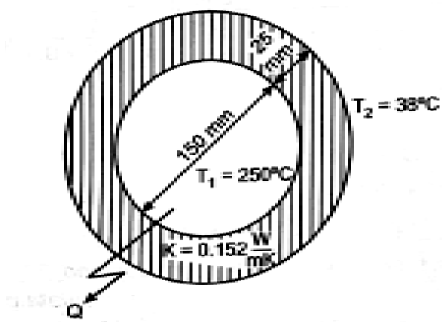


Fig.

$\therefore \quad r_1 = \frac{150}{2}$ mm = 75 mm = 0.075 m

r_2 = 75 + 25 = 100 mm = 0.1 m

Heat lost from pipe $= \dfrac{T_1 - T_2}{\dfrac{1}{2\pi LK}\log_e\left(\dfrac{r_2}{r_1}\right)}$

$= \dfrac{250 - 38}{\dfrac{1}{2\pi \times 1 \times 0.112}\log_e\left(\dfrac{0.1}{0.075}\right)}$

= 518.58 Watt

❑ ❑ ❑ ❑ ❑