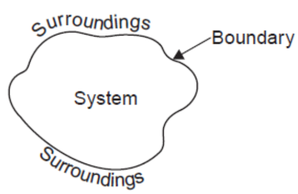
WINTER– 16 EXAMINATION

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. No.	Sub Q. N.	Answer	Marking Scheme
1a)	I	In thermodynamics the 'system' is defined as the quantity of matter or region in space upon which the attention is concentrated for the sake of analysis. These systems are also referred to as thermodynamic systems.  Clausius Statement	02
	ii	"It is impossible for a self acting machine working in a cyclic process unaided by any external agency, to convey heat from a body at a lower temperature to a body at a higher temperature". In other words, heat of, itself, cannot flow from a colder to a hotter body.	02
	iii	The equation of state is given as: PV = mRT Where, P = Pressure of the system in bar V = Volume of the system in m3 M = mass R = Characteristic gas constant T -= Temperature	01 for equation and 01 for terminology

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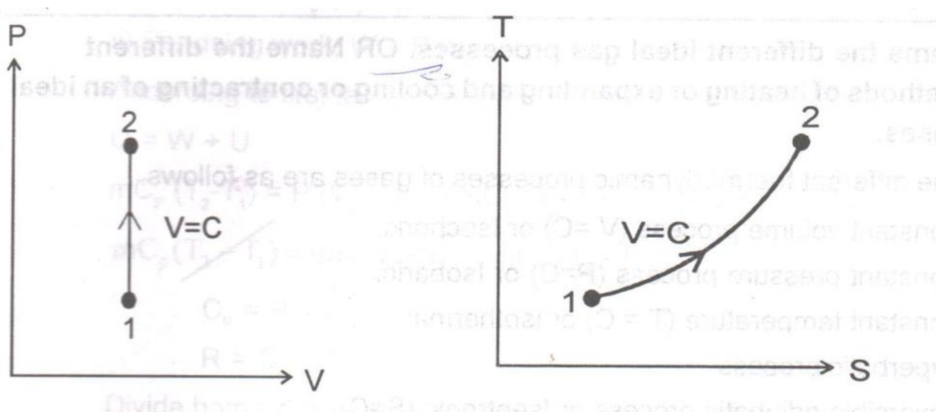
	iv	(i) Isobaric Process 	01 for PV and 01 for TS
	v	Boiler mountings are different fittings and devices which are necessary for the operation and safety of a boiler. Examples: i) Water level indicator (ii) Safety valves (iii) High steam and low water safety (iv) Fusible plug (v) Pressure gauge (vi) Stop valve (vii) Feed check valve (viii) Blow off cock (ix) Manhole and mud box	01 for defination and 01 for examples
	vi	continuity equation of steam nozzle For this system, $\Delta PE = 0$ $W = 0$ $Q = 0$ Applying the energy equation to the system, $h_1 + \frac{C_1^2}{2} = h_2 + \frac{C_2^2}{2}$ or $\frac{C_2^2}{2} - \frac{C_1^2}{2} = h_1 - h_2$ or $C_2^2 - C_1^2 = 2(h_1 - h_2)$ or $C_2^2 = C_1^2 + 2(h_1 - h_2)$ $\therefore$ $C_2 = \sqrt{C_1^2 + 2(h_1 - h_2)}$ where velocity C is in m/s and enthalpy h in joules.	02

vii Define

1. Mach number is defined as square root of the ratio of the inertia force of fluid to elastic force.

$$Mach\ number = \sqrt{\frac{inertia\ force}{elastic\ force}}$$

Mach number is also defined as velocity at point in a fluid to velocity of sound at that point at a given instant of time. 01+01

viii 'Condenser efficiency' is another condenser performance parameter. It is given by the ratio of actual rise in cooling water temperature to the maximum possible temperature rise.

$$\text{Condenser efficiency} = \frac{\text{Actual rise in cooling water temperature}}{\text{Maximum possible temperature rise}}$$

Here, the maximum possible temperature rise = {(Saturated temperature corresponding to condenser pressure) – (Cooling water inlet temperature)} 02

1b) i Differences between boiler mountings and accessories 04

Boiler mountings	Boiler accessories
Mountings are safety devices to control the steam generation process	Accessories are the auxiliary parts to increase overall efficiency o f the boiler
Mountings are compulsory to be fitted	Accessories are optional
Example : Water level indicator, stop valve, blow off cock etc.	Example : Economizer, air pre heater, superheater etc
They are mounted on boiler.	Accessories increase the boiler efficiency.

	Ii	**Sources of air leakage** Generally, inside the condenser pressure less than atmospheric pressure is maintained, thereby increasing the chances of air leakage into condenser. Leakage of air occurs due to leaking joints, packings, glands etc. along with air in dissolved form coming with feed water. This leakage of air accounts up to 0.005% and 0.5% of steam condensed in case of jet type condenser and surface condensers respectively. Thus, leakage of air is practically always there in the condensers. **Effects:** Air leakage causes the reduction in work done per kg of steam as it increases the back pressure. Also the quantity of water required for condensation of steam is increased due to lowering of partial pressure of steam due to pressure of air. At low pressure the latent heat of steam to be released is more than at higher pressure. Air (having lower conductivity) when present between water and steam hampers the heat exchange and also takes away a portion of heat. Because of this reason also the more quantity of cooling water is required. Hence, leakage of air reduces the condenser efficiency and auxiliary devices such as reciprocating pump, rotary pump, steam ejector or air pumps etc. are required. Also the presence of air increases corrosive action as the corrosion depends largely upon the oxygen content.	02+02
	Iii	**Classification of heat exchanger and their applications** 1. Nature of heat exchange process Heat exchangers, on the basis of nature of heat exchange process, are classified as follows : *(a)* (i) Direct contact (or open) heat exchangers:- Examples : (i) Cooling towers ; (ii) Jet condensers ; (iii) Direct contact (ii) Indirect contact heat exchangers. *(a)* Regenerators:- Examples : (i) I.C. engines and gas turbines ; (ii) Open hearth and glass melting furnaces ; (iii) Air heaters of blast furnaces. (b) Recuperators Examples : (i) Automobile radiators, (ii) Oil coolers, intercoolers, air preheaters, economisers, superheaters, condensers and surface feed heaters of a steam power plant, (iii) Milk chiller of pasteurizing plant, (iv) Evaporator of an ice plant 2. Relative direction of fluid motion According to the relative directions of two fluid streams the heat exchangers are classified into the following three categories (i) Parallel-flow or unidirection flow :- : Examples : Oil coolers, oil heaters, water heaters etc. (ii) Counter-flow:- Examples : The cooling unit of refrigeration system etc. (iii) Cross-flow. Examples :- Automobile radiator etc. 3. Design and constructional features On the basis of design and constructional features, the heat exchangers are classified as	02+02

under :
(i) Concentric tubes.
(ii) Shell and tube
(iii) Multiple shell and tube passes.
(iv) Compact heat exchangers:- Example : Plate-fin, flattened fin tube exchangers etc.

4. Physical state of fluids
Depending upon the physical state of fluids the heat exchangers are classified as follows :
Condensers (ii) Evaporators

2 a

Difference between Heat and Work

01 for each

Heat	work
It is energy in transition across boundry of system due to temperature difference	It is energy in transition across boundry of system due to travel of force
Enthalpy, entropy are forms of it	Thermodynamic work, mechanical work, shaft work etc are form of work
Heat rejected by system is negative. Heat sypplied to system is positive by convention	Work supplied to system is negative. Workdone by the system is positive by convention
Unit is Joule	Unit is N-m

b

01 for each answer

Given: V_1= 0.26m^3, T_1=300^{0}C P_1= 0.4MPa= 0.4×10^3 KPa, V_2= 0.441m^3, P_2=0.26MPa= 0.26×10^3 KPa , m=1Kg

Solution : Cp - Cv = R

1-0.71=0.29=R

$P_2V_2= MRT_2$

$0.26\times10^3 \times 0.441 = 1\times0.29 \times T_2$

$T_2 = 114.66/ 0.29 = 395.37^0C$

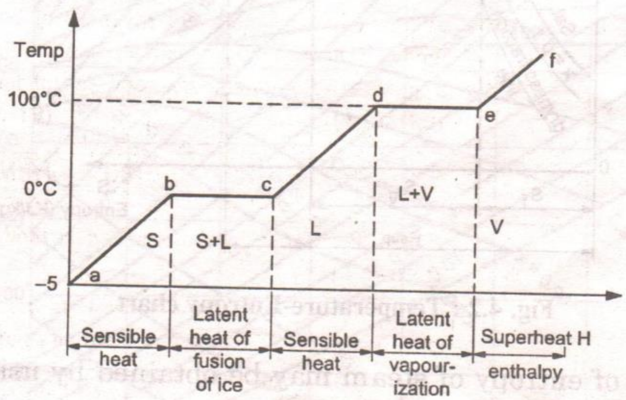
Change in internal energy per Kg of gas

$\Delta\mu = m \times Cv (T_2 - T_1) = 1 \times 0.71 \times(395.37-300) = 67.71$ KJ/Kg c

Generation of Steam at Constant Pressure :

- Water which is one of the pure substance exist in three phase i.e. solid (ice), liquid (water) and gas (steam).
- It is assume that the temperature of ice before start heating is below 0°C. (say - 5°C) and pressure is atmospheric.
- As heat is added, the temperature of ice increases upto 0°C. During the no change of phase takes place but only temperature change is sense by thermometer is known as sensible heat (a to b).

02+ 02



S-solid, L-liquid, V-vapour

- From point b further addition of heat will not increase the temperature but ice start melting i.e. transformation of solid phase to liquid phase up to the point 'C' indicate ice convert into water. This is known as latent heat of fusion of ice defined as the amount of heat required to convert one kg of ice into water at constant temperature.
- From point c to d there in only increase in temperature of water but no change of phase hence it is sensible heat.
- From point d to e from temperature is saturation temperature 100°C of water, addition of heat, will not increase the temperature but transform water into vapour.
- So change of phase takes place. This is known as latent heat of vaporization defined as the amount of heat required to convert one kg of water into steam at constant temperature.
- From point e to f, addition of heat will increase the temperature of steam known as superheating defined as amount of heat added above saturation temperature.

d)

Impulse turbine		Reaction turbine	
1.	Steam completely expand in nozzle & pressure remain constant during flow through the blade passage	1.	Steam expand partially in nozzle and further epansion take in rotor blade passage.
2.	Relative velocity of steam passing over blades of impulse turbine is constant.	2.	Relative velocity increases as steam passing over the blade expands.
3.	Blade is symmetrical profile	3.	Blade is aerofoil section.
4.	Pressure is same at inlet and outlet	4.	Pressure is different at inlet and outlet.
5.	Steam velocity is very high	5.	Steam velocity is not very high
6.	Lesser no of stages require	6.	More no. of stages requires
7.	Occupies less space per unit power	7.	Occupies more space per unit power
8.	Suitable for small power.	8.	Suitable & higher power.
9.	At low load the efficiency is low	9.	At low load, the efficiency is high

01 for each Any four

e)

Compounding of steam turbine is required as in case of simple impulse turbine, the single stage may offer speed of the order of 30,000 rpm which can not be directly used for any engineering application and needs to be reduced. Also such a high speed shall induce large stresses in the blades. Compounding is a thermodynamic means for reducing the speed of turbine where speed reduction is realized without employing a gear box.

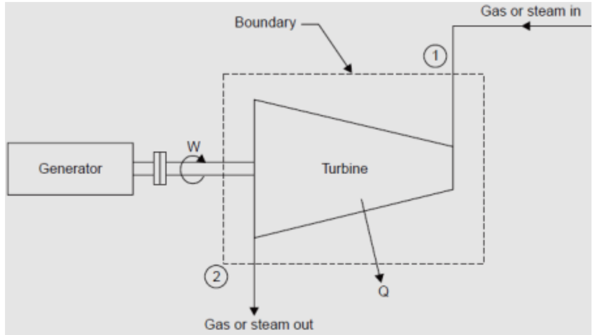
Compounding can be of following three types:

(i) Pressure compounded impulse turbine
(ii) Velocity compounded impulse turbine
(ii) Pressure-velocity compounded impulse turbine

02+02

f

steady flow energy equation for Turbine:



Steam or gas turbine.

02+02

Applying energy equation to the system.

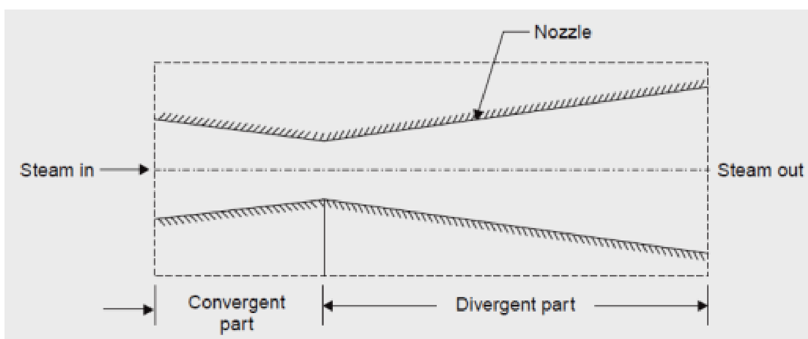
Here, $Z_1 = Z_2$ (*i.e.*, $\Delta Z = 0$)

$$h_1 + \frac{C_1^2}{2} - Q = h_2 + \frac{C_2^2}{2} + W$$

The sign of Q is *negative* because heat is *rejected* (or comes out of the boundary).

The sign of W is *positive* because work is done by the system (or work comes out of the boundary).

steady flow energy equation for Nozzle:



Steam nozzle.

Fig. shows a commonly used convergent-divergent nozzle.

For this system,

$$\Delta PE = 0$$
$$W = 0$$
$$Q = 0$$

Applying the energy equation to the system,

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

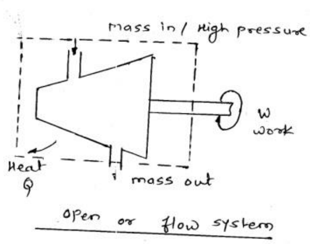
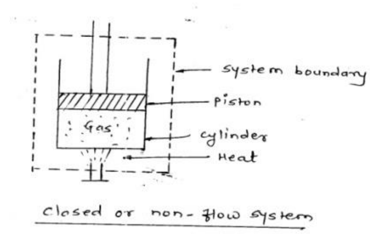
or $$\frac{C_2^2}{2} - \frac{C_1^2}{2} = h_1 - h_2 \quad \text{or} \quad C_2^2 - C_1^2 = 2(h_1 - h_2)$$

or $$C_2^2 = C_1^2 + 2(h_1 - h_2)$$

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

where velocity C is in m/s and enthalpy h in joules.

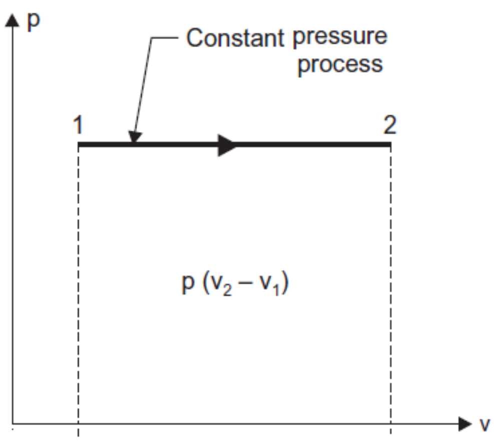
3 a Differentiation between open and closed system

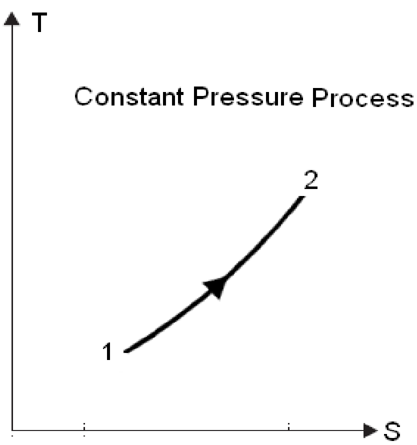
OPEN SYSTEM	CLOSED SYSTEM
In this system, both mass & energy may cross the boundary.	Only transfer of energy but no mass transfer across the boundary.
	
Ex. Nozzle , compressor, boiler	Ex. Piston cylinder arrangement without valve, refrigeration system.

04

b Gas processes on P-V and T-S diagram:

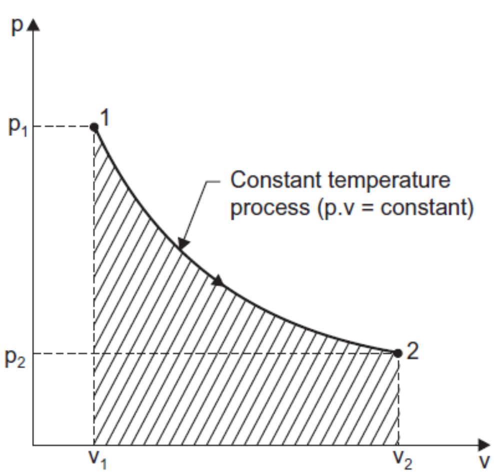
i) Isobaric Process

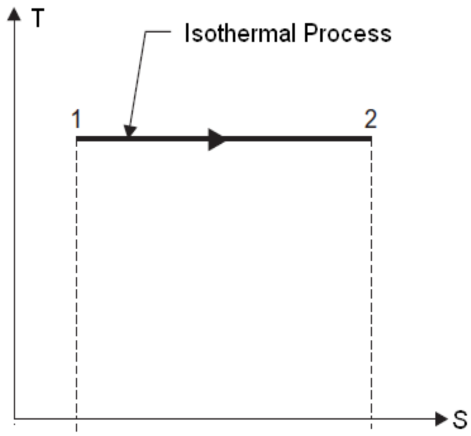




01+01

ii) Isothermal process



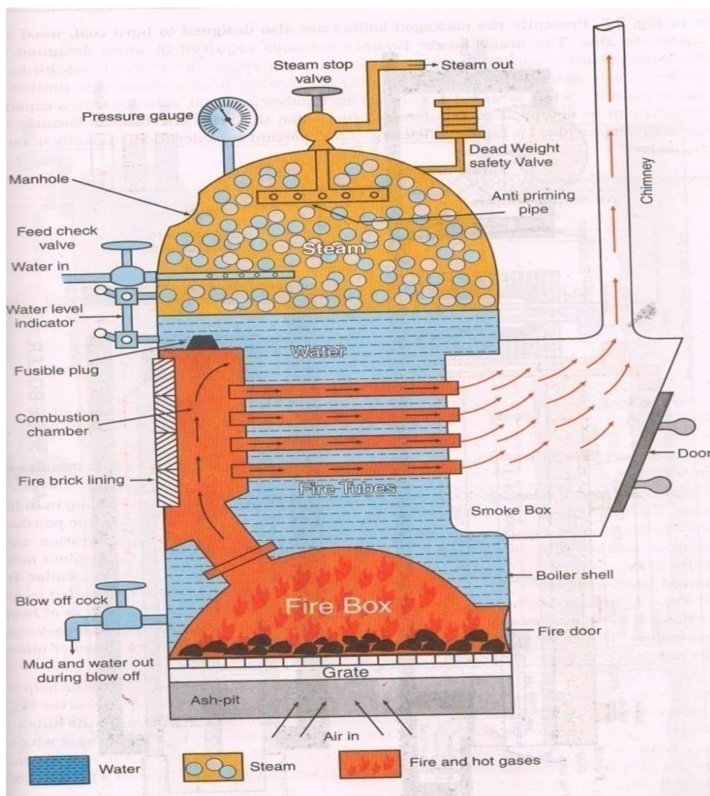


01+01

3 c) Cochran Boiler :

Cochran boiler is a vertical, multi tube boiler, commonly used for small capacity steam generation. Figure shows the arrangement of boiler. It consists of a cylindrical shell with the crown having hemispherical shape. The grate is placed at the bottom of the furnace and ash pit is below the grate. The furnace and the combustion chamber are connected through a pipe. The hot gases from the combustion chamber flow through the nest of horizontal fire tubes. The hemispherical crown of the boiler shell gives maximum strength. Coal or oil can be used as fuel. The smoke box is provided with doors for cleaning of the interior of the fire tubes. This boiler is very compact and requires minimum floor area. It gives 70% thermal efficiency. 02+02

b)



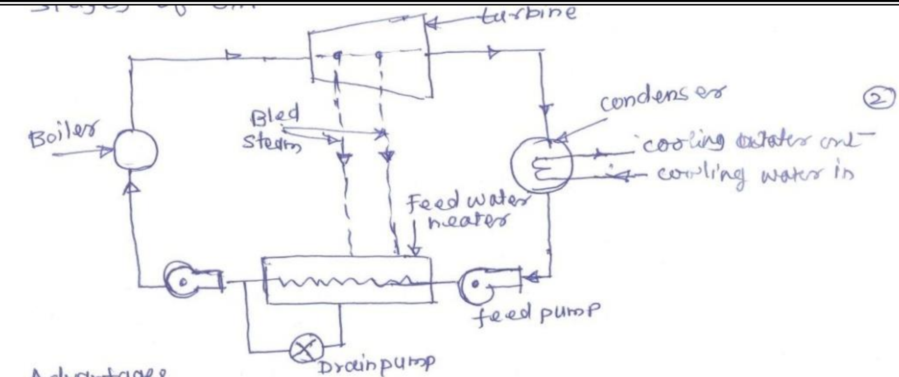
d)

Regeneration feed heating: Heating of feed water of boiler by bleeding steam during expansion in turbine at certain (1) stages of expansion is known as Regeneration feed heating

Advantages

1. It increases the thermal efficiency of the plant
2. the temperature stresses in boiler are reduced due to decreases range of working temperature.

02+02



Advantages

1) It increases the thermal efficiency of the plant (1)

2) The temperature stresses in boiler are reduced due to decreased range of working temperature.

e) Difference between jet condenser and surface condenser (any four)

Sr. No	Jet condenser	Surface condenser
01	Cooling water and the exhaust steam from turbine come in direct contact with each other.	Cooling water and the exhaust steam do not come in direct contact
02	Simple in design and low running cost. Economical and simple	Costly and complicated. Capital and running cost is high
03	Less suitable for high capacity plants	More suitable for high capacity plants
04	Condensate from jet condenser cannot be used as feed water to boiler	Condensate can be used as feed water to boiler
05	Power requirement of air extraction pump are high	Power requirement of air extraction pump is low
06	Vacuum obtained is low	Vaccum obtained is very high
07	Require less space	Require more space

04

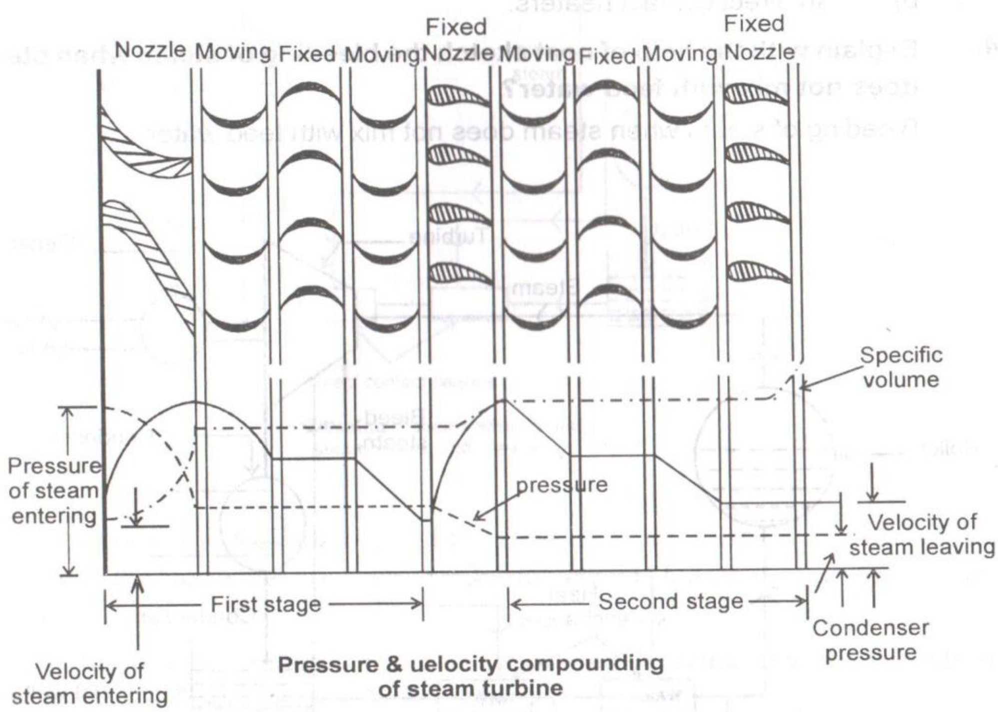
f) Free convection: Free convection occurs where the fluid circulates by virtue of the natural differences in densities of hot and cold fluids

Ex : Heating of water in container.

Forced convection : When the work is done to blow or pump the fluid , it is said to be forced convection.

Or external force such as fans,blower,pumps etc,giving rise to forced convection.

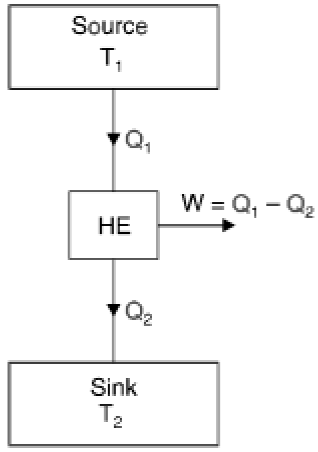
Ex: by providing the circulating fan in container.

4	a)	Point function : The properties of the system whose change depends on only initial and final state of the system and not on the path followed by the system then such properties are called point function Ex : pressure, volume , temperature etc Path function : The quantities of a system which are depend on path followed by the system and not depend on point or state of the system are called path function. Ex: Heat, work etc	01 for each
	b)	Boiler Draught: -Force necessary to draw is called as draught. This force may be due to small pressure difference the steam or current of gas or air which causes the flow to take place. In boiler support combustion by means of draught. So draught is a small pressure difference which causes flov gases. The draught may be classified as below. Necessity: - Draught is necessary to continuously remove the products of combustion,	02+02
	C)	Impulse steam turbine : it works on the principal of impulse . It consists of nozzle or set of nozzles, a rotor moujnted on shaft, one set of moving blades attached to rotor.  Pressure & uelocity compounding of steam turbine Pressure velocity compounding of impulse turbine : . the total pressure drop of the steam from boiler to condenser pressure is divided into a number of stages as done in pressure compounding and the velocity obtained in each stage is also absorbed in several stages. The velocity, pressure and specific volume variation of steam along the axos of the turbine are shown in figure. The blade height in the second stage must be greater than the first stage as	02+02

	a	specific volume of steam is higher in the second stage.	
		Q 4 d) Given Thickness of wall = $b_1 = 3\,cm = 3\times10^{-2}\,m$ Thickness of insulation = $b_2 = 0.5\,cm = 0.5\times10^{-2}\,cm$. Inside temp = 300^0C Outside temp = 50^0C $K_1 = 60\,W/mK$ $K_2 = 0.12\,W/mK$ Rate of heat flow; $\frac{q}{A} = \frac{(T_1 - T_2)}{\left(\frac{b_1}{K_1} + \frac{b_2}{K_2}\right)}$ $= \frac{300 - 50}{\frac{3\times10^{-2}}{60} + \frac{0.5\times10^{-2}}{0.12}}$ $= 5929.79\,W/m^2$	04
		Q 4 (e) $t_{w1} = 30^0c$, $t_{w2} = 37.5^0c$ Absolute pressure in the condenser $= 760 - 705 = 55$ mm of Hg $= 55\times0.001333 = 0.073$ bar from steam tables corresponding to 0.073 bar $t_s = 40^0c$ ∴ Condenser efficiency $= \frac{\text{Rise in temp. of cooling water}}{(\text{Temp. corresponding to vaccum in condenser} - \text{Inlet temp. of cooling water})}$ $= \frac{(t_{w2} - t_{w1})}{(t_s - t_{w1})} = \frac{37.5 - 30}{40 - 30} = \frac{7.5}{10}$ $= 0.75$ or 75%	04

	e	Q4f :- 1) $P_1 = 10$ bar $v_s = 0.185\ m^3/kg$ From steam tables, at P_1, $v_f = 0.0011274$ $v_g = 0.19429$ Hence the steam is in wet condition ii) $P_1 = 12$ bar $T_1 = 200^\circ C$ From steam tables at P_1, $T_{sup} = 187.96^\circ C$ Hence the steam is in superheated condition.	02+02
	f	(02 marks for statement) i**) Kelvin-Plank Statement of second law of thermodynamics**: " It is impossible to construct a heat engine to work in a cyclic process whose sole effect is to convert all the heat supplied to into an equivalent amount of work Or It is impossible to construct 100 % heat engine **ii)** (02 marks for statement) **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.	08
5	a)	**Application of Second Law of Thermodynamics to Heat Engine:** Kelvin-Planck Statement of Second Law of Thermodynamics "It is impossible to construct an engine, which while operating in a cycle produces no othereffect except to extract heat from a single reservoir and do equivalent amount of work". There are three important applications of Statement of Second Law of Thermodynamics namely: a) Heat Engine b) Heat Pump and	

c) Refrigerator



Heat engine is shown in the figure below having source of temperature (T_1) and Sink at temperature (T_2). The amount of heat taken from source is Q_1. 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 Q_1.
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 (Q_2).

An efficiency of the heat engine can be calculated as:

$$\text{Efficiency} = \text{Workdone (W)} / \text{Input Heat } (Q_1)$$

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 workdone. 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.

From the above discussion it is clear that Heat Engine is an important application of Second Law of Thermodynamics.

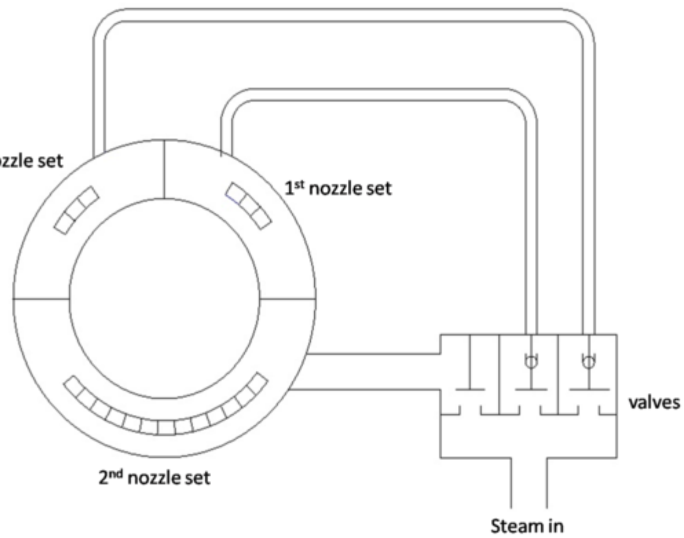
Governing:

Steam turbine governing is the procedure of controlling the flow rate of steam to a steam turbine so as to maintain its speed of rotation as constant. The variation in load during the operation of a steam turbine can have a significant impact on its performance. In a practical situation the load frequently varies from the designed or economic load and thus there is always exists a considerable deviation from the desired performance of the turbine. The primary objective in the steam turbine operation is to maintain a constant speed of rotation irrespective of the varying load. This can be achieved by means of governing in a steam turbine.

Nozzle control governing: 02+03+03

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, the advantage of this method lies in the exploitation of full boiler pressure and temperature. 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.

5 b)



Given data: Initial pressure = P_1 = 14 Bar = 14 x 10^5 N/m^2

Final pressure = P_2 = 1.4 Bar = 1.4 x 10^5 N/m^2 , Initial volume = V_1 = 0.6 m^3

C_p = 1.005 kJ/kgK, C_v = 0.718 kJ/kgK and Process is $PV^{1.25} = C$ Air mass m = 1 kg

R = C_p-C_v = 0.287 kJ/kgK

For Polytropic process, we have

$[V_1/ V_2]^n = [P_2/ P_1]$ or $[V_1/ V_2] = [P_2/ P_1]^{1/n}$

$[0.6/ V_2] = [1.4/ 14]^{1/1.25}$

$[0.6/ V_2] = [0.1]^{0.8}$

$V_2 = 0.158\ m^3$ 04+04

Also from following two general gas equations for initial & final conditions

$T_1 = P_1 V_1 / m R = 1400 \times 0.6/0.287 = 2926$ K

$T_2 = P_2 V_2 / m R = 140 \times 0.158 /0.287 = 77$K

C)

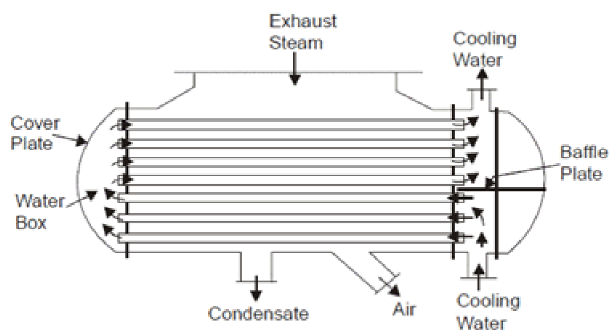
Now change in internal energy

$dU = m\,C_v[T_2 - T_1] = 1\times0.718\ [\ 2926.8 - 77] = 2045$ KJ

Workdone = 1400 × 0.6 – 140 × 0.58 / 1.25-1= 327152 kJ

Surface condenser

A surface condenser is a commonly used term for a water-cooled shell and tube heat exchanger installed on the exhaust steam from a steam turbine in thermal power stations. These condensers are heat exchangers which convert steam from its gaseous to its liquid state at a pressure below atmospheric pressure. Surface condensers are also used in applications and industries other than the condensing of steam turbine exhaust in power plants. One such surface condenser is shown below:



6 a

Shell: The shell is the condenser's outermost body and contains the heat exchanger tubes. The shell is fabricated from carbon steel plates and is stiffened as needed to provide rigidity for the shell. 04+04

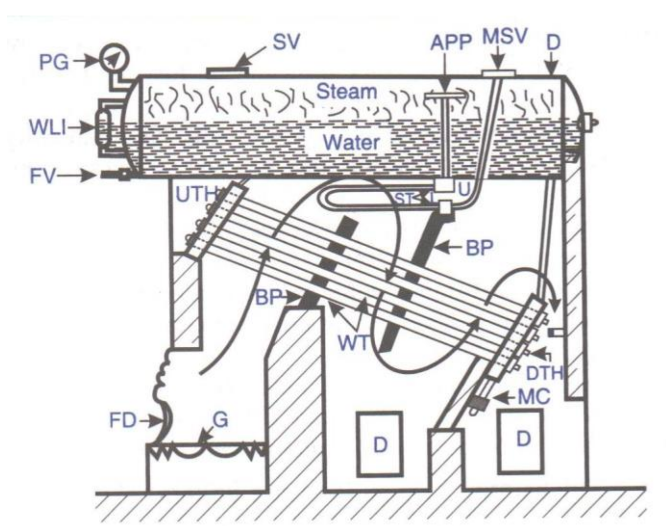
Vacuum system: For water-cooled surface condensers, the shell's internal vacuum is most commonly supplied by and maintained by an external steam jet ejectorsystem. Such an ejector system uses steam as the motive fluid to remove any non-condensible gases that may be present in the surface condenser.

Tube and Tube sheets: At each end of the shell, a sheet of sufficient thickness usually made of stainless steel is provided, with holes for the tubes to be inserted and rolled. The inlet end of each tube is also bell-mouthed for streamlined entry of water. Generally the tubes are made of stainless steel, copper alloys such as brass or bronze, nickel, or titaniumdepending on several selection criteria.

Waterboxes: The tube sheet at each end with tube ends rolled, for each end of the condenser is closed by a fabricated box cover known as a waterbox

Babcock and Wilcox Boiler

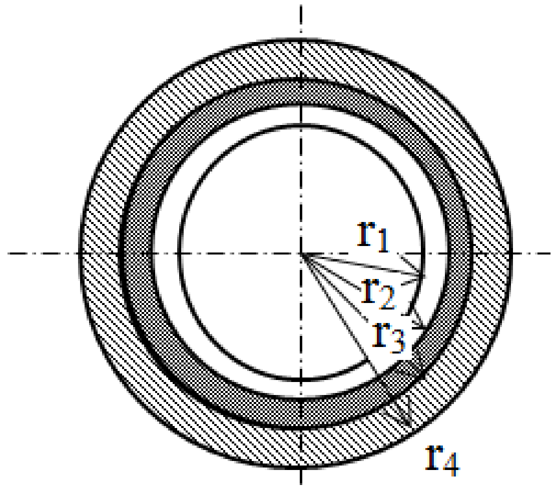
This type of boiler consists of following parts:

	b	Water tubes:Water tubes are placed between the drum and furnace in an inclined position (at an angle of 10 to 15 degree) to promote water circulation. These tubes are connected to the uptake-header and the down-comer as shown.Uptake-header and down-corner (or down-take-header).The drum is connected at one end to the uptake-header by short tubes and at the other end to the down-corner by long tubes.Grate: Coal is fed to the grate through the fire door.Furnace : Furnace is kept below the uptake-header.Baffles: The fire-brick baffles, two in number, are provided to deflect the hot flue gases.Superheater: The boiler is fitted with a superheater tube which is placed just under the drum and above the water tubesMud box: Mud box is provided at the bottom end of the down comer. The mud or sediments in the water are collected in the mud box and it is blown-off time to time by means of a blow –off cock.Inspection doors: Inspection doors are provided for cleaning and inspection of the boiler. Working of Babcock and Wilcox Boiler: Coal is fed to the grate through the fire door and is burnt. Flow of flue gases: The hot flue gases rise upward and pass across the left-side portion of the water tubes. The baffles deflect the flue gases and hence the flue gases travel in the zig-zag manner (i.e., the hot gases are deflected by the baffles to move in the upward direction, then downward and again in the upward direction) over the water tubes and along the superheater. The flue gases finally escape to atmosphere through chimney. Water circulation: That portion of water tubes which is just above the furnace is heated comparatively at a higher temperature than the rest of it. Water, its density being decreased, rises into the drum through the uptake-header. Here the steam and water are separated in the drum. Steam being lighter is collected in the upper part of the drum. The water from the drum comes down through the down –comer into the water tubes.A continuous circulation of water from the drum to the water tubes and water tubes to the drum is thus maintained. The circulation of water is maintained by convective currents and is known as “natural circulation”.A damper is fitted as shown to regulate the flue gas outlet and hence the draught.  	04+04

c

Given data

Inner radius of pipe = r_1 = 8 cm = 0.08 m
Outer radius of pipe = r_2 = 8.5 cm = 0.085 m
Radius r_3 = 0.085 + 0.03 = 0.115 m
Radius r_4 = 0.115 + 0.05 = 0.165 m
K_1 = 58 W/mK for steam pipe
K_2 = 0.17 W/mK for first layer of 3 cm
K_3 = 0.093 W/mK for second layer of 5 cm
hi = 30 W/m^2K and ho = 5.8 W/m^2K
Inside Temperature T_1= 300^0C and outside Temperature T_2= 30^0C



Steam pipe covered with two insulating layers

The rate of heat loss(Q) per meter length from inside of pipe to outside is given by the equation

$$Q = \frac{2\pi L(T_1 - T_2)}{\left[\frac{1}{h_i r_1} + \frac{\ln(r_2/r_1)}{K_1} + \frac{\ln(r_3/r_2)}{K_2} + \frac{\ln(r_4/r_3)}{K_3} + \frac{1}{h_o r_4}\right]}$$

02+03+03

Now $2\pi L(T_1 - T_2) = 1696.46$

$1 / h_i r_1 = 0.417$

$1 / h_o r_4 = 1.045$

$\ln(r_2/r_1) / K_1 = 0.0010$

$\ln(r_3/r_2) / K_2 = 1.7776$

$\ln(r_4/r_3) / K_3 = 3.8817$

so, **Q = 238.19 kW** per m length of pipe
