SUMMER – 13 EXAMINATION

Subject Code: **12092** **Model Answer**

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.

SUMMER – 13 EXAMINATION

Subject Code: **12092** **Model Answer**

Q.No 1

a**)** **(01 Mark for definition and 01 mark for unit)**

i) **Coefficient of Performance (COP**) : For the refrigerator when the purpose is to achieve the maximum heat transfer from the cold reservoir, the measure of performance or success is called the co-efficient of performance (C.O.P.).

It is defined as the ratio of amount of heat removed from cold reservoir to the amount of work supplied

Co-efficient of performance, (C.O.P.)ref. = Q/W

where, Q = Heat transfer from cold reservoir, and

W = The net work transfer to the refrigerator.

The COP has no units.

Q.No 1 a) **(01 Mark for law and 01 mark for equation)**

ii) Charles law : It states that if any gas is heated at constant pressure, its volume changes directly as its absolute temperature.

In other words, $V \propto T$

or

V/T= Constant, so long as pressure is constant

Q.NO 1 a) iii) **(01 Mark for merits and 01 mark for demerits)**

Tidal Energy

Merits: (Any two)

1. Free from pollution
2. Renewable source
3. No fuel required

Demerits: (Any two)

1. Tidal plant disturbs marine life
2. Intermittent power generation
3. Turbines for variable head required
4. Site selection depends upon geographical position

Q.NO 1 a) iv) **(01 Mark for mountings and 01 mark for accessories)**

Boiler accessories: (Any two)

i) Air Preheater

ii) Economizer

iii) Super heater

List of boiler mountings : (Any two)

1. Water Gauge. 2. Pressure Gauge 3. Steam stop valve 4.Feed check valve 5. Blow down cock 6. Fusible plug 7. Spring loaded safety valve 8. Dead wt. safety valve 9. Lever safety valve. 10. High steam and low water safety valve.

Q.NO 1 a) v) Classification of steam condensers:

(01 Mark for each type)

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

SUMMER – 13 EXAMINATION

Subject Code: **12092** **Model Answer**

Q.NO 1 a) **(01 Mark for law and 01 mark for equation)**

vi) Fourier's law of heat transfer.

The rate of heat transfer per unit area is directly proportional to normal temperature gradient.

or

$Q \alpha A\, dt/dx$

Q.NO 1 a) **(02 Marks for definition)**

vii) Grey body. If the radiative properties of a body are assumed to be uniform over the entire wavelength spectrum, then such a body is called grey body.

A gray body is also defined as one whose absorptivity of a surface does not vary with temperature and wavelength of the incident radiation.

Q.NO 1 a) **(01 Mark for law and 01 mark for equation)**

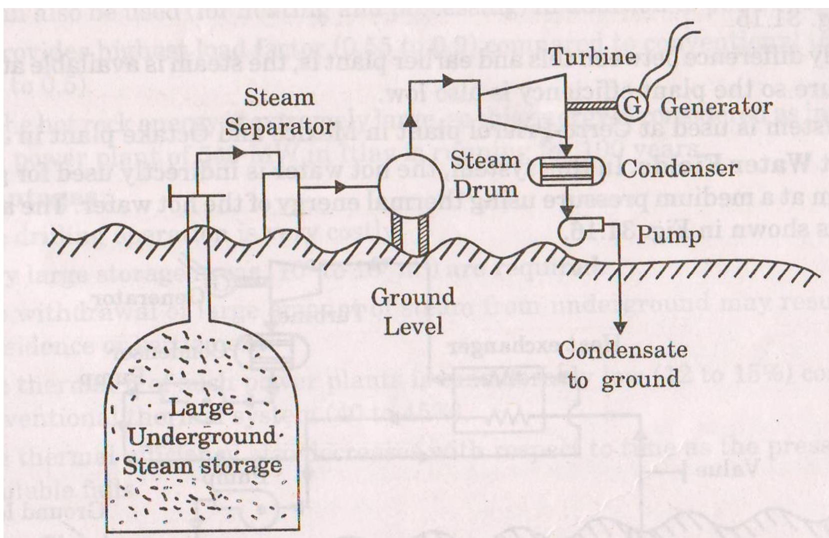
viii) **First Law of Thermodynamics:** - It states that if a system executes a cycle , transferring work and heat through its boundary, the net heat transfer is equivalent to the net work transfer.

or $$\oint dQ = \oint dW$$

where $\oint$ represents the sum for a complete cycle.

Q.NO 1 b) **(02 Mark for description and 02 marks for sketch)**

i) **Geothermal power Plant:** This is also known as one form of nonconventional energy source. The power plant sketch is as shown in figure. It consists of availability of large amount of steam in the crust of earth. Raw steam from underground is taken into steam separator and dry steam is stored into steam drum. The dry steam is then passed through the turbine. The condenser performs the function of condensation and the condensate from the condenser is reinjected into the ground. This condensate under the ground absorbs the heat from the rock and again steam is generated.



Geothermal power Plant

Q.NO 1 b) ii) **(04Marks)**

Sources of Air- leakage in condenser

1) Air leakage from the joints of parts
2) Air comes with steam from boiler
3) Air comes with cooling water.

Q.NO 1 b) iii) **(01 Mark for each)**

Following are the assumptions made for ideal gas

a) A finite volume of gas contains large number of molecules.
b) The collision of molecules with one another and with the walls of the container is perfectly elastic.
c) The molecules are separated by large distances compared to their own dimensions.
d) The molecules do not exert forces on one another except when they collide.

As long as the above assumptions are valid the behavior of a real gas approaches closely that of an ideal gas.

Q.NO 2 a**) (01 Mark for equation and 01 mark for each application 01 mark for sketch)**

Steady state energy equation.

$[m\,(K.E. + P.E.+I.E.)_1 + m(PV)_1 + \text{Heat transfer}]$ Energy entering

$= [m\,(K.E. + P.E.+I.E.)_2 + (PV)_2 + \text{work transfer}]$ Energy leaving

$$Z_1 g + V_1^2/2 + h_1 + q = Z_2 g + V_2^2/2 + h_2 + w$$

For Boiler,

$W = 0$, $V_1 = V_2$, $Z_1 = Z_2$

Therefore, $h_1 + q = h_2$

$q = h_2 - h_1$

$h_1 =$ Enthalpy of feed water entering the boiler

$h_2 =$ Enthalpy of steam going out of the boiler

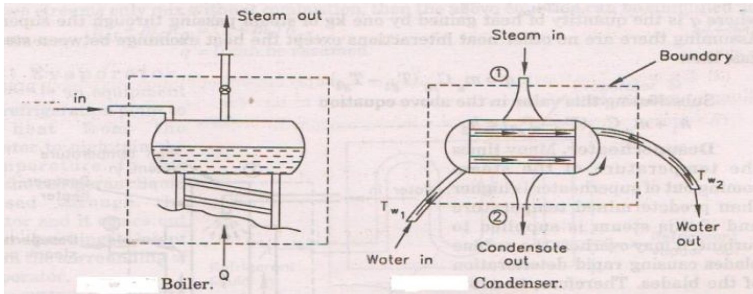
For Condenser,

$W = 0$, $V_1 = V_2$, $Z_1 = Z_2$

$q = h_1 - h_2$

$h_1 =$ Enthalpy of steam entering the condenser

$h_2 =$ Enthalpy of condensate going out of the condenser

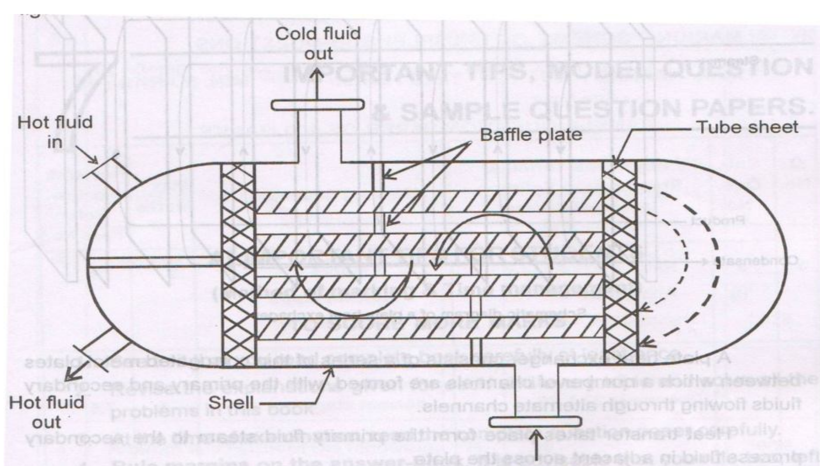


SFEE for Boiler and condenser

Q.NO 2) **(02 Mark for description and 02 marks for sketch)**

b) **Shell and tube heat exchanger:** Shell and tube heat exchanger consists of large number of tubes having parallel arrangement inside the shell. The ends of the tube on both sides are connected to a plate called as tube sheet. The whole assembly is called bundle of tubes. The shell should be a house of all the tubes and it should be leakage free. It is closed on both sides. The one fluid flow inside the tube it is called as tube side fluid and the other one which flows outside the tube known as shell side fluid.

The transfer of heat takes place between the two fluids through the medium of tube surfaces. Naturally heat flow takes place from hot fluid to the cold fluid. The arrangement of inlet and outlet for hot and cold fluid is shown in figure

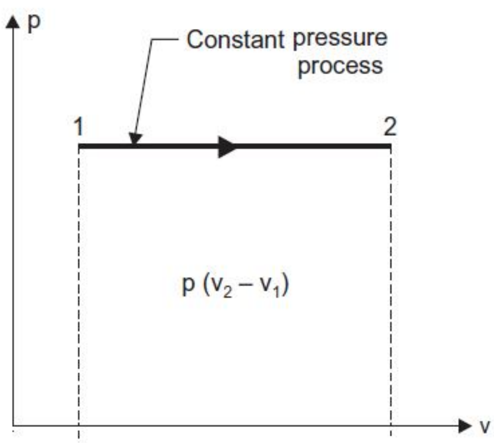


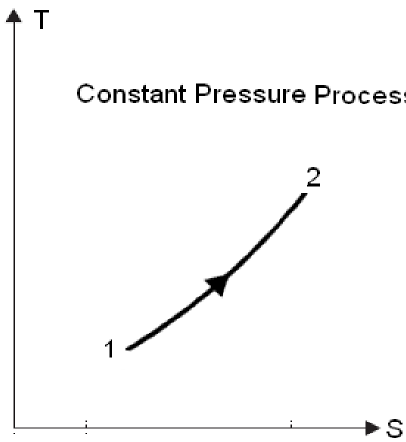
Shell and tube heat exchanger

Q.NO 2 c)) (01 Mark for each process)

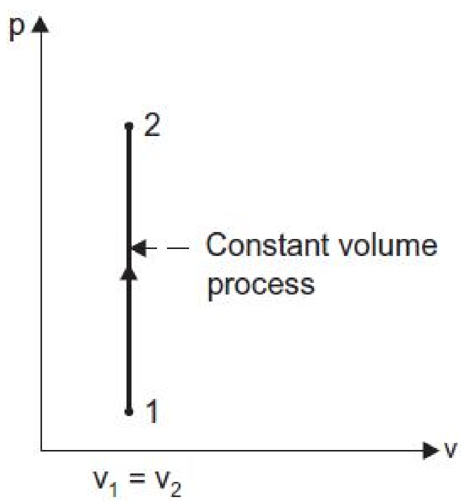
Gas processes on P-V and T-S diagram:

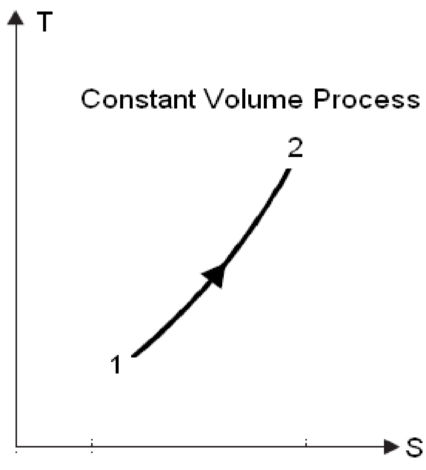
i) Isobaric Process



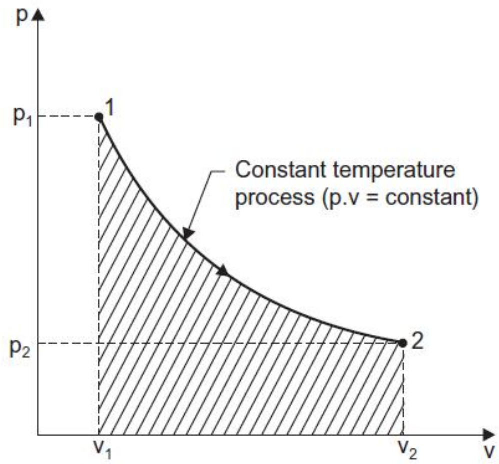


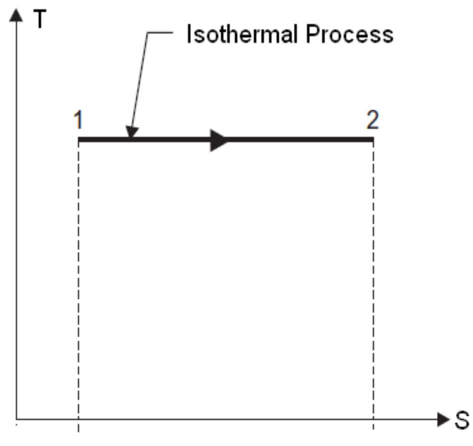
ii) Isochoric process



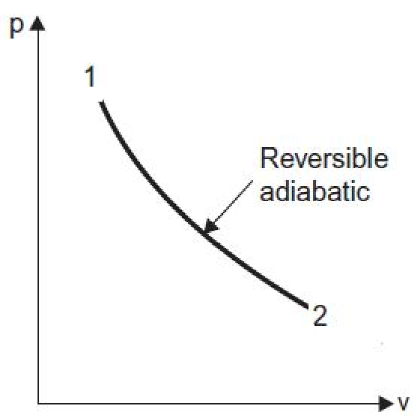


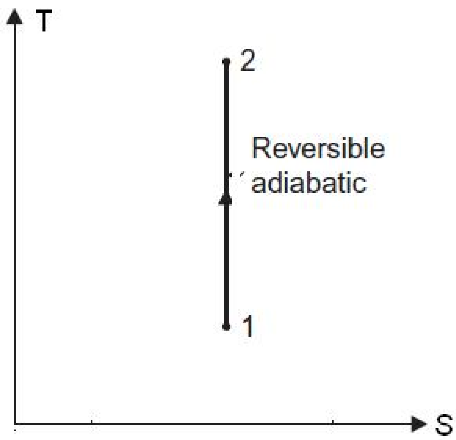
iii) Isothermal process





iv) Adiabatic process

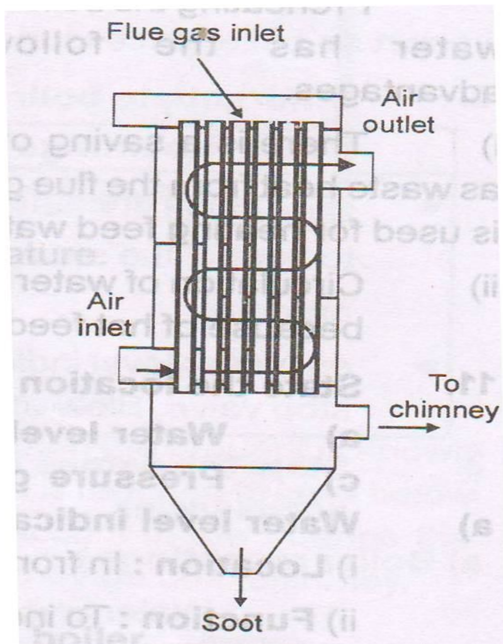




Q.NO 2 d)) (02 Mark for description and 02 marks for sketch)

Air Preheater: Air Preheater is an important accessory for steam boiler. It consists of plates or the tubes with hot gases on one sides and air on other side. For air Preheater the cold air required for burning of the fuel is passed from bottom, it comes out after circulation from the top as a hot air which is then passed further for combustion of fuel.

Due to arrangement of air Preheater the efficiency of boiler increases and also the smoke is reduced. Since it is comparatively high temperature air coming out from the Preheater, there is better combustion of fuel.



Air-Preheater (Tubular type)

Q.NO 2 (01 mark each) (Any four)

e) 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

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

Q.NO 2 f) Problem on Balloon (04 marks)

Q No 2 f

Volume of the balloon $= \frac{4}{3}\pi r^3 = \frac{4}{3} \times \pi \times (5)^3 = 523.6 \text{ m}^3$

$MR = 8.3143 \quad \therefore R = \frac{8.3143}{2} = 4.15715 \text{ kJ/kg K}$

Pressure of hydrogen in the balloon = Atmospheric pressure = 101.325 kN/m^2
Applying gas equation $PV = m\,R\,T$.

Mass of hydrogen in the balloon $= \frac{PV}{RT} = \frac{101.325 \times 523.6}{4.15715 \times (25+273)} = 42.825 \text{ kg}$

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

$= \frac{PV}{RT} = \frac{101.325 \times 523.6}{0.287 \times (20+273)} = 630.9 \text{ kg}$

$\therefore$ The load which can be lifted by the balloon = 630.9 – 42. 825 = 588.075 kg.

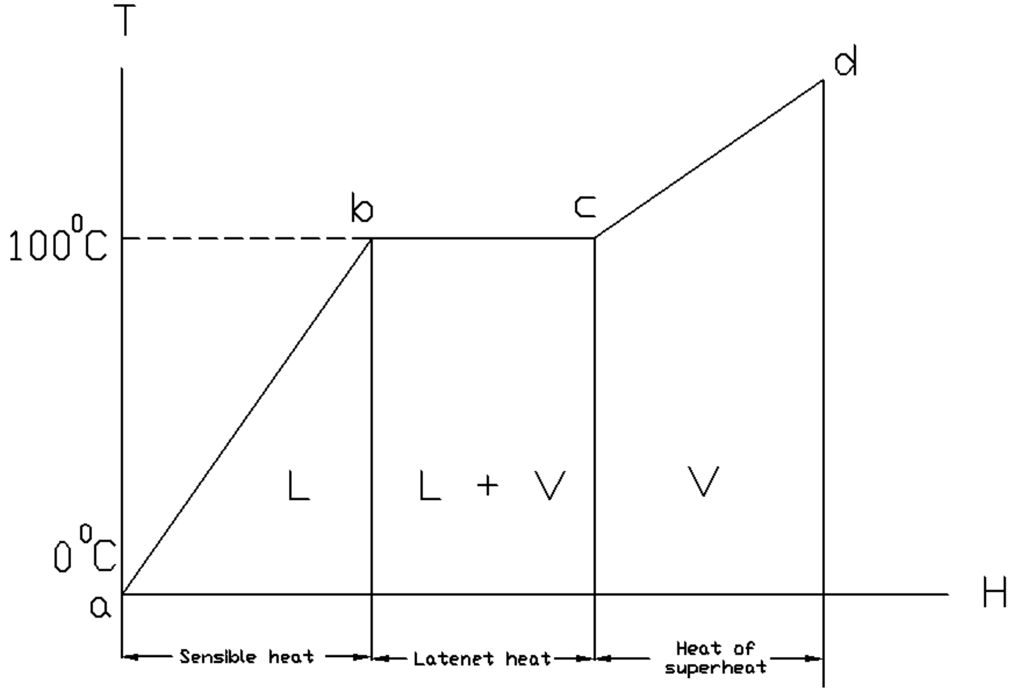
Q.NO 3) (02 Mark for description and 02 marks for sketch)

a) Steam generation at constant pressure

Figure shows steam generation from one kg of water at 0^o C under constant pressure processes. The steam formation process starting point is a. From a to b it is sensible heating process where water temperature is raised to saturated temperature . From b to c saturated water is converted into saturated steam. From c to d, the steam is superheated. In this case amount of heat required is known as heat of superheat or superheat enthalpy.

SUMMER – 13 EXAMINATION

Subject (



Q. 3 b : 02 marks for correct formula, 02 marks for correct answer

SUMMER – 13 EXAMINATION

Subject Code: **12092** **Model Answer**

Q 3 b) Data:- $T_1 = 42^0C$, $T_2 = 22^0C$,

Area $A = 3 \times 6 = 18\ m^2$

$K = 0.55\ W/m^0K$ $l = 250\ mm = 0.25\ m$.

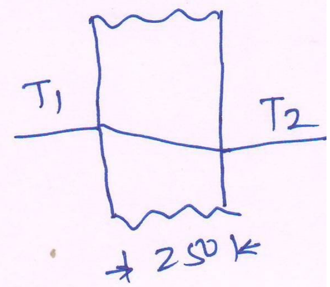
$q = ?$

We have,

$$\frac{q}{A} = \frac{(T_1 - T_2)}{(l/K)}$$

$$= \frac{20}{0.25} \times 0.55$$

$$= 44\ W/m^2$$



$$q = 44 \times 18$$

$$\boxed{q = 792\ W}$$

Q 3 c) Data:- $T_1 = 27^0C = 300^0K$

$T_2 = -3^0C = 270^0K$

Ref. effect $N = 6.3$

We have,

$$COP = \frac{Q_2}{W} = \frac{T_2}{T_1 - T_W}$$

$$= \frac{270}{300 - 270} = 9$$

$$COP = \frac{N}{W} = \frac{Q_2}{W} = 6.3$$

$$\text{Compressor work} = \frac{6.3}{9}$$

$$= 0.7\ KJ/sec$$

Powe required $= 0.7\ KW$.

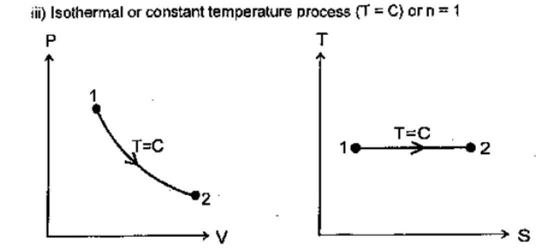
So, power required= 0.7 kW

(02 marks for COP and 02 marks for Power)

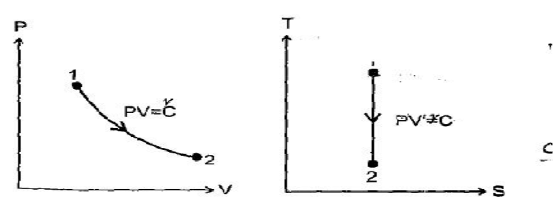
Q.No.3) **(Any four, 01 Mark for each**)
d) Difference between Isothermal process and adiabatic process

Sr. No	**Isothermal process**	**Adiabatic process**
01	Temperature remains constant during the process (T=C)	Entropy remains constant during the process (S=C)
02	PV=C (n=1)	$PV^{\gamma}=C$
03	Change in internal energy is zero ($\Delta U=o$)	Change in internal energy is not zero
04	Heat transfer $Q=P_1V_1\log(V_2/V_1)$	Heat transfer Q=0
05	Work done $W= Q=P_1V_1\log(V_2/V_1)$ as $\Delta U=o$	Work done $W= \Delta U$
06	Isothermal process is very slow	Adiabatic process is very fast

iii) Isothermal or constant temperature process (T = C) or n = 1



Q.2 (c)



Adiabatic process

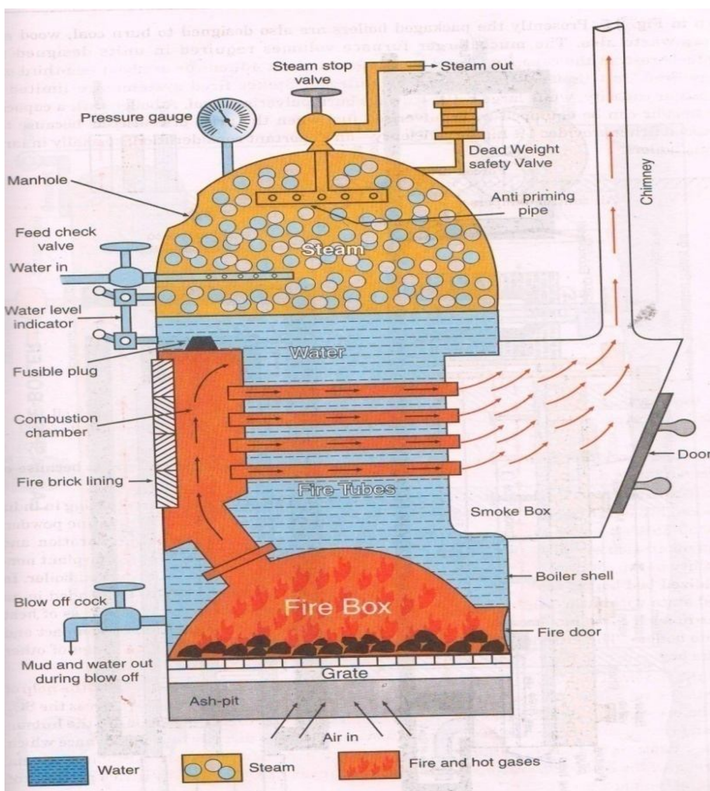
SUMMER – 13 EXAMINATION

Subject Code: **12092** **Model Answer**

Q.No.3 **) (02 Marks for description and 02 marks for sketch)**

e) 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.



COCHRAN BOILER

Q.No.3) **(02 Mark for bleeding and 02 marks for regeneration)**

f) Bleeding of steam turbines: It is the process of abstracting steam at a certain section of turbines and then using it for heating feed water supplied to the boiler.

The principle of regeneration can be practically utilized by extracting steam from the turbine at several locations and supplying it to the regenerative heaters. The resulting cycle is known as regenerative or bleeding cycle.

The mean temperature of heat addition can also be increased by decreasing the amount of heat added at low temperatures. The unique feature of ideal regenerative cycle is that the condensate after leaving pump circulates around the turbine casing, counter flow to the direction of vapor flow in the turbine

Q.No.4) **(02 Marks for advantages and 02 marks for limitations)**

a) Conventional sources of energy

Advantages:

i. High output in terms of power and efficiency
ii. Do not depend on nature
iii. Storage is easy
iv. Conveyance from one place to other is easy

Limitations :

i. Availability is limited
ii. High operation cost
iii. Pollute the atmosphere
iv. High maintenance cost

Q.No.4) **(01 Mark for definition and 01 marks for each value)**

b) Quality of steam: The wet steam is a mixture of steam and saturated water and relative amounts of each that are present in such a two phase mixture determines the quality of the mixture.

The quality of steam is designated by the term ‘dryness fraction of steam” which is defined as the ratio of the mass of dry vapor to the total mass of the mixture and is designated by “x”.

i) dryness fraction for wet steam is less than one

ii) Dryness fraction of Dry saturated steam is one

iii) Dryness fraction of superheated steam is one

Q.No.4 c) 04 Mark for differences)

Difference between jet condenser and surface condenser

Sr. No	**On the basis of**	**Jet condenser**	**Surface condenser**
01	Construction	Cooling water and the steam to be condensed come in direct contact	Cooling water and the steam to be condensed do not come in direct contact
02	Performance	Simple in design and low running cost. Economical and simple	Costly and complicated. Capital and running cost is high
03	Application	Less suitable for high capacity plants	More suitable for high capacity plants

Q.No.4 d)) (02 Mark for each)

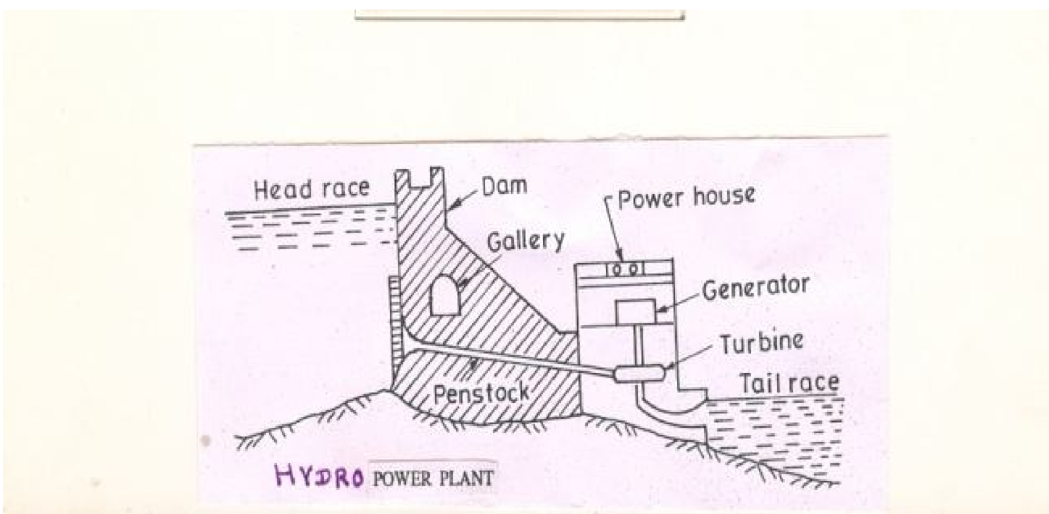
i) Pure Substance: Pure substance is a substance of constant chemical composition throughout its mass. It is one component system. It may exist in one or more phases. Water, Air, Hydrogen, Nitrogen, Helium, mixture of water and steam and mixture of ice and water are the examples of pure substance

ii) Working substance: The working substance is most work producing and absorbing devices is gas and vapor, or vapor and liquid. It is a substance which is capable of absorbing and rejecting heat during the process. Freon, Ammonia is the examples of working substance

Q.No.4 e) **(02 Mark for description and 02 marks for sketch)**

Construction and working of Hydal power plant

Working of Hydal power plant: Figure shows the construction of Hydal plant. It consists of head race, penstock, turbine, electric generator and a power house. When the water flows through the head race to tail race, kinetic energy gets converted into mechanical energy and finally to the electrical energy.



Hydro electric Power Plant

Q.No.4 f) (Any four, 01 Mark for each)

Differentiate between fire tube boilers and water tube boilers (Any four)

Sr. No	Fire tube boilers	Water tube boilers
01	Hot flue gases flow in the tubes surrounded outside by the water	Water flows in the tubes surrounded outside hot gases
02	Slower in operation and have low evaporation rates	faster in operation and have high evaporation rates
03	Failure due to Temperature stress causing failure of feed water arrangement is minimum	Failure due to Temperature stress causing failure of feed water arrangement is more
04	It can work upto 20 bar pressure only	It can work upto 200 bar pressure
05	Simple and rigid construction	Complex construction
06	More maintenance and operation cost	less maintenance and operation cost
07	Smaller sizes and hence not suitable for large power houses	Bigger sizes and hence suitable for large power houses
08	Installation is difficult	Installation is easy
09	Requires less floor area	Requires more floor area
10	Cochran boiler, Lancashire boiler are the examples	Babcock and Wilcx boiler are the examples

Q.No.5 a) (02 Mark for each)

Second law of thermodynamics:

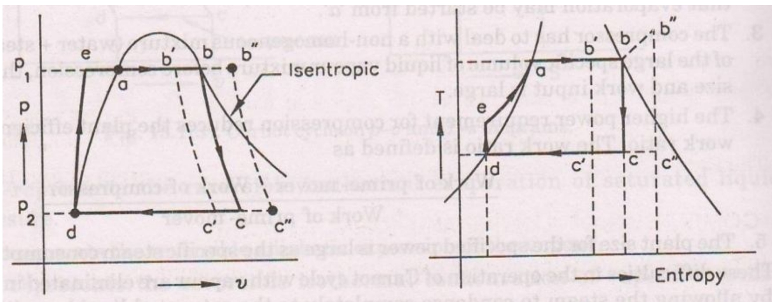
i) Kelvin-Plank Statement of second law of thermodynamics: “It is impossible to construct a heat engine to work in a cyclic process whose sole effect is to convert all the heat supplied to into an equivalent amount of work”

ii) 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 from body at a lower temperature to a body at a higher temperature without the aid of external work.

Q.No.5 b) (02 Mark for description and 02 marks for sketch)
Rankine cycle:



Rankine cycle on p–v diagram.
Rankine cycle on T–s diagram.

Figure shows the Rankine cycle on P-V and T-S charts. It consists of mainly four processes as follows

i) Heat addition (e-a-b)
ii) Isentropic expansion (b-c)
iii) Heat rejection (c-d)
iv) Isentropic Compression (d-e)

Q.No.5 c)) (02 Marks each for 02 correct parameters)

To condense the steam, its latent heat is to be abstracted .

The latent heat at 12KN/m² from steam table is 2384.1kJ/kg

∴ Heat to be removed per Kg = 0.88 x 2384.1

= 2098 kJ/Kg

The specific volume of dry saturated steam at a pressure of 12KN/m² from steam table = 12.36m³.

∴ Specific valume of steam at 0.88 dryness fraction

= 0.88 x 12.361

=10.8776 m³/Kg

∴ Heat to be exttracted per m³ of steam

$$= \frac{2098}{10.8776} = 192.87 \text{KJ}/m^3$$

Q.No.5 d) (02 Mark for each)

i) Thermal conductivity: it is a physical property of a substance and characterizes the ability of substance to transfer heat. It is denoted by “K”.

Its unit is W/m ^{0} K

ii) Thermal resistance: The process of conduction is analogous with the process of flow of current. Electric resistance (R) is analogous with the thermal resistance (dx/KA) .

The term dx/KA is called thermal resistance and is denoted as R_{th}

Its unit is ^{0}K/W

Q.No.5 e) (02 Mark for each)

i) Condenser efficiency: it is defined as the ratio of difference between the outlet and inlet temperature of cooling water to the difference between saturation temperature corresponding to condenser pressure and inlet temperature of cooling water

Condenser efficiency= Actual rise in cooling water temperature/ Maximum rise in cooling water temperature

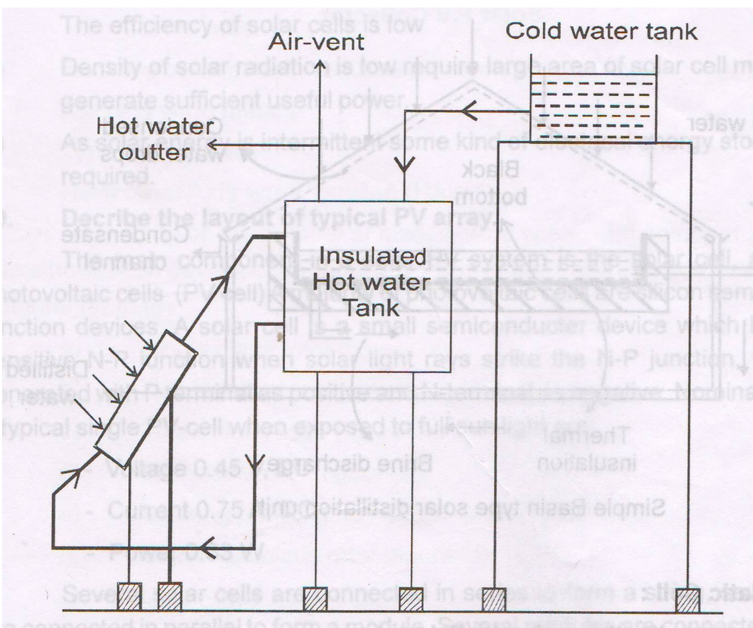
Max rise = (saturation temperature corresponding to condenser pressure) – (inlet temp.)

ii) Vacuum efficiency: It is defined as the ratio of actual vacuum to the ideal vacuum.

Ideal vacuum = (Atmospheric pressure) - (Saturation pressure corresponding to condensation temp)

Q.No.5 f) (02 Mark for description and 02 marks for sketch)

Solar water heater: A tilted flat plate solar collector with water as heat transfer fluid is used in solar water heater system. A thermally insulated hot water storage tank is mounted above the collector. The heated water of the collector raises up to the hot water tank and equal quantity of cold water enters the collector. The cycle repeats, resulting in all the water of the hot water tank getting heated up. When water is taken out from hot water outlet, the same is replaced by cold water from cold water tank, fixed above the hot water tank.



Solar water heater

Q.No.6 a) (02 marks for taking correct values from steam table, 02 marks each for calculation of initial entropy, X_2 and X_3)

At pressure 9.2 bar

$\phi_w = 2.1038$ kJ/kg K, $\phi_s = 6.6151$ kJ/kg K

At pressure 3.55 bar

$\phi_w = 1.7327$ kJ/kg K, $\phi_s = 6.9358$ kJ/kg K, $V_s = 0.5173$ m^3/kg.

At pressure 0.36 bar, $V_s = 4.408$ m^3/kg

$$\phi_1 = \phi_{w_1} + x_1(\phi s_1 - \phi_{w_1}) = 2.1038 + 0.96(6.6151 - 2.1038) = 6.4346 \text{ kJ/kg K}$$

$$\phi_1 = \phi_2 \text{ or } 6.4346 = 1.7327 + x_2(6.9358 - 1.7327) \text{ or } x_2 = 0.9036$$

$$\therefore \quad V_2 = x_2 V s_2 = 0.9036 \times 0.5173 = 0.46747 \text{ m}^3.$$

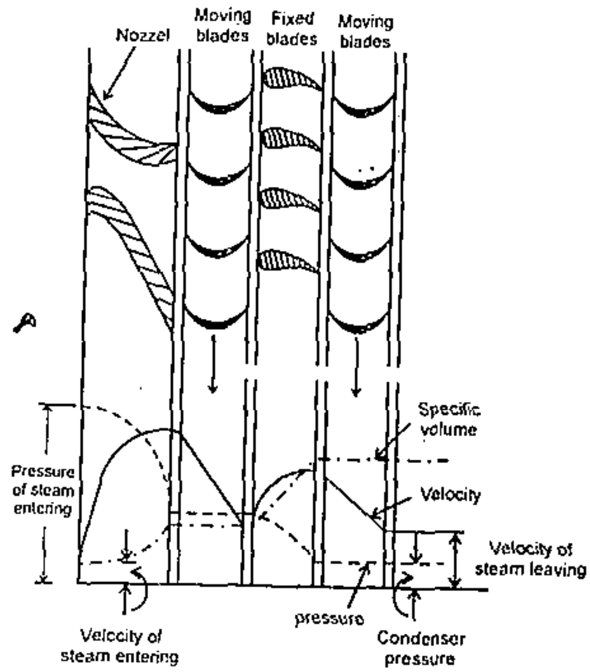
As the volume remains constant, the quality is given by

$$0.46747 = x_3 \times 4.408, \quad \therefore \; x_3 = 0.106$$

Q.No.6 b) (04 marks for compounding, 02 Mark for description of any one method and 02 marks for sketch)

Compounding of steam turbines:- If entire pressure drop from boiler pressure to condenser pressure is carried out in a single stage of nozzle then the velocity of steam entering the turbine blades will be very high. The turbine speed has to be also very high as it is directly proportional to steam velocity. Such high rpm of turbine rotor are not useful for practical purposes & there is a danger of structural failure of blades due to excessive centrifugal stresses. Hence compounding is carried out.

Pressure compounding of steam turbines. A number of simple impulse turbine stages are arranged in series as shown in fig.



Pressure compounding of stea n turbine

The turbine is provided with one row of fixed blade (nozzle) at the entry of each row of moving blades. The total pressure down of stream does not take place in a single nozzle but is divided among all the rows of fixed blades which work as nozzles.

SUMMER – 13 EXAMINATION

Subject Code: **12092** **Model Answer**

Q.No.6c) (04 marks for n, 02 marks for W and 02 marks for heat rejected)

NOTE : ASSUME THAT THE FINAL VOLUME IS 1/5 OF THE INITIAL VOLUME

(Any other suitable assumption made by the student should be considered & be given full marks.)

$$P_1 = 100 \text{ kN/m}^2, \quad V_1 = 750 \text{ cm}^3 = 750 \times 10^{-6} \text{ m}^3$$

$$P_2 = 780 \text{ kN/m}^2 \quad V_2 = \frac{1}{5} \times 750 = 150 \text{ cm}^3 = 150 \times 10^{-6} \text{ m}^3$$

We have $P_1 V_1^n = P_2 V_2^n$

Taking logarithm of both sides, we get

$$\log P_1 + n \log V_1 = \log P_2 + n \log V_2$$

or $\quad n \log V_1 - n \log V_2 = \log P_2 - \log P_1$

$$n \log \frac{V_1}{V_2} = \log \frac{P_2}{P_1}$$

or $\quad n = \dfrac{\log \frac{P_2}{P_1}}{\log \frac{V_1}{V_2}} = \dfrac{\log \frac{780}{100}}{\log \frac{750}{150}} = 1.277$

Work done during compression is given by,

$$W = \frac{P_1 V_1 - P_2 V_2}{n-1} = \frac{100 \times 750 \times 10^{-6} - 780 \times 150 \times 10^{-6}}{1.277 - 1} = -0.15 \text{ kJ.}$$

Negative sign indicates that work is done on the gas.

Heat rejected $= \dfrac{\gamma - n}{\gamma - 1} \times$ Work done $= \dfrac{1.4 - 1.277}{1.4 - 1} \times 0.15 = 0.046 \text{ kJ} = 46$ J