
WINTER – 14 EXAMINATION Subject Code: **17410** **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.

Q.1- a)

i) Intensive Property:- The properties which are independent on mass of system are known as intensive property. 01

Example : pressure ,temperature , density etc. 01

ii) Steady flow energy eqn.

1) Nozzle

$$q + h_1 + 9z_1 + \frac{1}{2}c_1^2 = w + h_2 + 9z_2 + \frac{1}{2}c_2^2$$

$$q = 0, z_1 = z_2, c_1 \& c_2 = velo. of\ at\ inlet\ \&\ outlet$$

$$0 + h_1 + 0 + \frac{c_1^2}{2} = 0 + h_2 + 0 + \frac{c_2^2}{2}$$

$$h_1 - h_2 = \frac{c_2^2}{2} - \frac{c_1^2}{2}$$

Velocity at outlet of nozzle $\therefore c_2 = \sqrt{2(h_1 - h_2) + c_1^2}$ **01**

2) Boiler – it is closed vessel to produce steam by combustion of fuel & heating or wale

$$q = h_2 - h_1$$

Avogadro's law:- that equal volumes of all gasses at same temperature and pressure contain the same number of molecules.

iii) Ideal gas – A gas is a phase of substance whose evaporation from it liquid phase is complete and obeys all gas laws under all condition of pressure & temperature.

Assumption – it applies for same gases within range of pressure and temperature (i.e. air, nitrogen, O_2 and H_2 called ideal gas)

An ideal gas obeys all the gas laws under all conditions of pressure and temperature. 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.

iv)

Boiler mounting (any two)	Boiler accessories (any two)	
Safety valve	Feed water pump	
Water level indicator	Economizer	01
Flexible plug	Air-pre heater	
Steam pressure gauge	Super hater	01
Feed check valve	Injector	
Blow off clock		

v) Application of steam nozzle 02
1. In steam turbine
2. Spray painting
3. Steam jet refrigeration system
4. In injector

vi) Losses in steam turbine 02
1. Residual velocity loss
2. Loss due to friction
3. Leakage loss
4. Loss due mechanical friction
5. Radiation loss
6. Loss due to moisture

vii) Dalton's law of partial pressure- 02
it state that the total pressure exerted by a mixture of gases or mixture of gas vapour is equal to the sum of individual partial pressure of constituents of mixture, it individual alone occupies total volume occupied by mixture having same temperature of mixture.

Q.1- b) **Each 01 M**

i) 1. Dryness fraction :- It is defined as a fraction of steam that is in vapour form in liquid vapour is called dryness fraction.

$$X = \frac{mv}{mv+mL}$$

Where x – Dryness fraction

Mv – mass of vapour (dry steam) contain in steam

ML = mass of water in suspension in steam

Dryness fraction is ratio of the mass of actual dry steam to the mass of wet steam.

2. Enthalpy of dry saturated steam:-

It is defined as the quality of heat required to raise the temperature of one kilogram of water from freezing point to temperature of evaporation tsR there convert it into dry saturated steam at that temperature & pressure.

$$H_s = hf + hfg$$

Where H_s enthalpy of dry saturated steam

Hf = sensible heat

Hfg = latent heat of evaporation

The quantity of heat required to convert 1 kg of water at 0 ^{0}c into dry saturated steam at constant pressure is known as enthalpy of dry saturated steam.

3. Enthalpy a superheated steam

An amount of heat required to one kg of water from freezing temperature into super heated steam is called enthalpy of super heated steam

$$Hsnp = hf + hg + cpsnp(Tsup - T_s)$$

Where Hsnp = enthalpy of superheated steam

Hf = sensible heat

hfg = latent heat

cpsnp = specific heat of superheated vapour

Tsat – saturated temperature

The quantity of heat required to convert 1 kg of water at 0 ^{0}c into superheated steam at constant pressure is known as enthalpy of superheated steam.

4. **Degree of superheat** :- It is the difference between the temperature of superheated vapour & saturation temperature corresponding at given pressure. *is said to be degree of superheat.* Degree of superheat = ($T_{sup} - T_{sat}$)

Q.1 b)

ii) Sources of air leakage in the condenser

i) Air leakage through the joint, packing and glands into the condenser where the pressure is below the atmospheric pressure.

ii) The lead water contains air in dissolved condition. The dissolved air gets liberated when steam is termed it carried with steam into condenser. 02

Effect of air leakage in condenser

i) It increases the pressure or backpressure of prime mover. It reduces the work done per kg of steam.

ii) The pressure of air lowers the partial pressure of steam & its corresponding temperature. It reduces overall efficiency of power plant.

iii) The heat transfer rates greatly reduced due to presence of air because air effect resistance to heat flow. 02

Q.1 b) iii) Heat transfer

Heat is energy, which flow from one region to another due to temperature differences.

Heat transfer is defined as the transmission of energy from one region to another as a result of temperature difference.

Modes of heat transfer 01

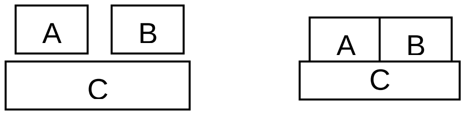
i) Conduction – It is transmission of heat energy between two bodies or two parts of same body through molecules which are more or less stationery e.g. (heating or solid) 01

ii) Convection – It is process of heat transfer from higher temperature to lower temperature due to movement of matter or fluid molecules (density differences) is called convention e.g. heating of water. 01

iii) Radiation – It is process of heat transfer between two bodies without any carrying medium through different kind of electro-magnetic wave. 01

Q.2 a)

a) Zeroth low of thermodynamic with suitable example.



Let 'A', 'B' & 'C' are three bodies at different temperature if 'A' & 'C' are brought into contact, energy in term of heat will from a body at higher temperature to body at lower temperature. After some time they will be in thermal equilibrium. Now if 'B' & 'C' are brought in good contact after some time they will be in thermal equilibrium.. The 'A' & 'B' also in thermal equilibrium. 02

Thus Zeroth law of thermodynamic state that "If two system are each in thermal equilibrium with a third system, they are also in thermal equilibrium with each other.

b) Boyle's law – when a perfect gas is heated at constant temperature, the volume of a given mass of *perfect gas* is inversely proportional to absolute pressure.

$$V \alpha \frac{1}{P}$$

$$\therefore V = \frac{C}{P}$$

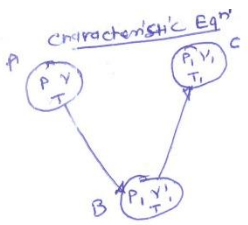
$$PV = C$$

Charle's law – If a perfect gas is heated at constant pressure, its volume varies directly with the absolute temperature. 01

$$V \alpha T$$

$$\frac{V}{T} = C$$

Characteristic equation – let a kilogram of gas at P, V, & T at A changes the stats from A & B at const. Temp. which follows Boyles law PV = P_1 V_1



$$V^1 = \frac{PV}{P_1}$$ 01

The change from B to C const. Pressure according Charle's law $\frac{V}{V_1} = \frac{T}{T_1}$ i.e. $V^1 = \frac{TV_1}{T_1}$ 02

Eqn.1 & 2

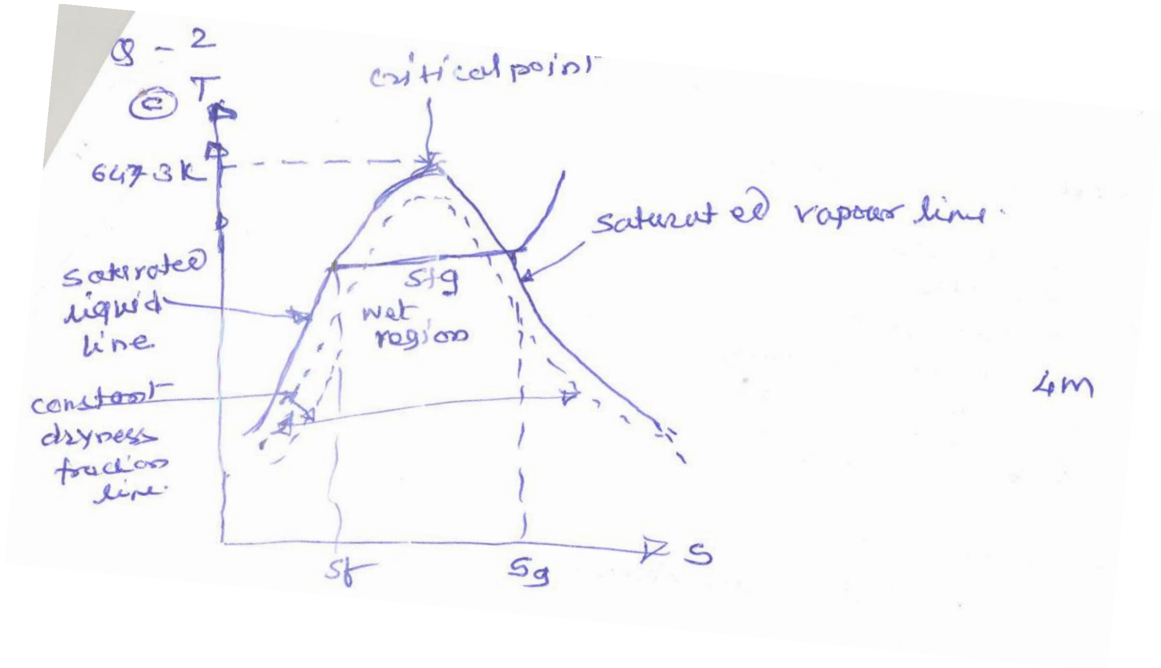
$$\frac{PV}{P_1} = \frac{TV_1}{T_1} \quad or \quad \frac{PV}{T} = \frac{P_1V_1}{T_1}$$ 02

If mass remain on change $\frac{PV}{T}$ = constant

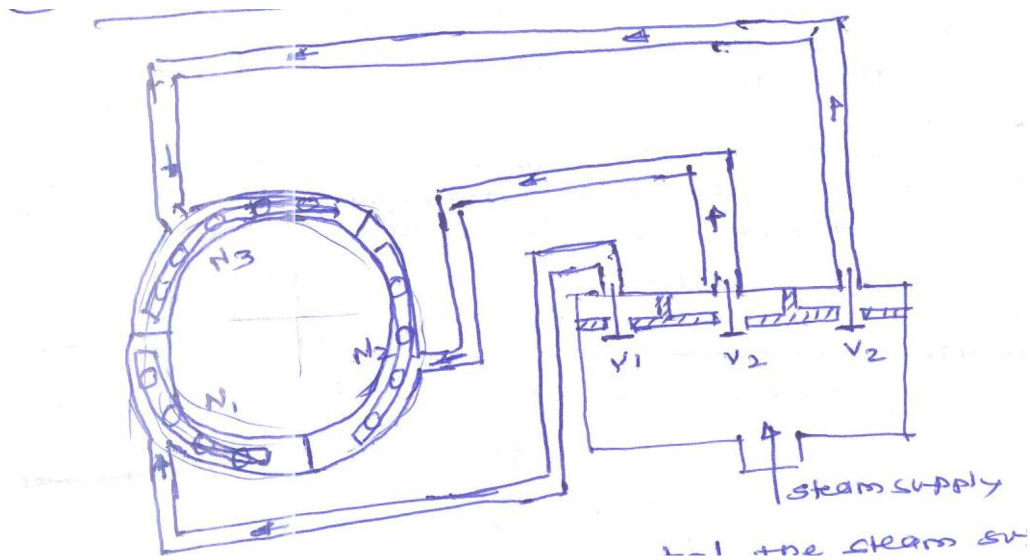
$$\therefore PV = RT$$

Where R is change *characteristic* gas const. equation is called characteristic gas law equation.

c)



d) Nozzle control governing 02



In this method of control, the steam supplied to different nozzle groups is controlled by uncovering as many steam passage as are necessary to meet the load by proper valves. 02

As arrangement show in figure. The number of nozzles supplying the steam to turbine are divided as N_1, N_2, N_3 and supply to these nozzles are control by the valves V_1,V_2,V_3

e) Classify steam turbine (each 1 mark)

i) Principles of action
(a) Impulse turbine (b) Reaction turbine

ii) Direction of steam flow
(a) Tangential flow (b) Radial flow (c) Axial flow (d) Mixed flow

iii) Method of governing
(a) Nozzle control governing (b) Throttle governing (c) Bypass governing

iv) Steam pressure
(a) High (b) Medium (c) Low

f) Differentiate (each 1 mark)

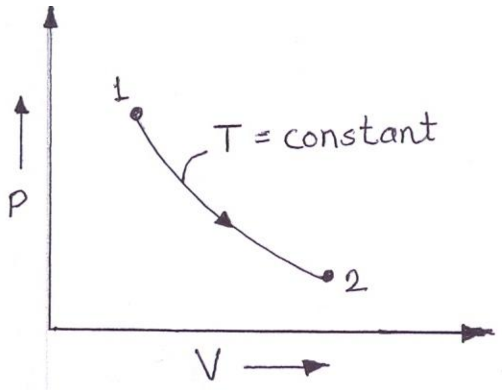
Heat pump	Refrigerator
1. It is a device to maintain temperature of system above atmospheric temperature.	1. It is a device to maintain the temperature of system below atmospheric temperature.
2. It transfer energy from LTR (low thermal reservoir) to HTR (high thermal reservoir) by supplying some external work.	2. It transfer the energy from LTR to HTR by supplying external work.
3. $COP = \frac{\text{Desired heating effect}}{\text{work supply}}$ $COP = \frac{QH}{QH.QC} = \frac{QH}{\text{workdone}}$	3. $COP = \frac{\text{Desired cooling effect}}{\text{workdone}}$ $= \frac{QL}{QH - QL} = \frac{QL}{\text{workdone}}$

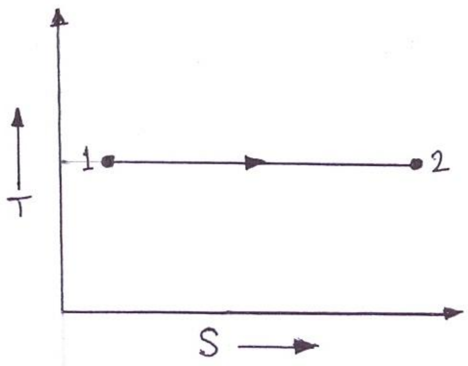
Q. 3 a) Difference between thermodynamic heat and work (Any three points, one mark each, one mark to application)

Sr. No.	Heat (Q)	Work (W)
1	It occurs due Temperature difference	It occurs due to Displacement or motion
2	Here is no restriction for transfer of	In stable system work transfer will be zero

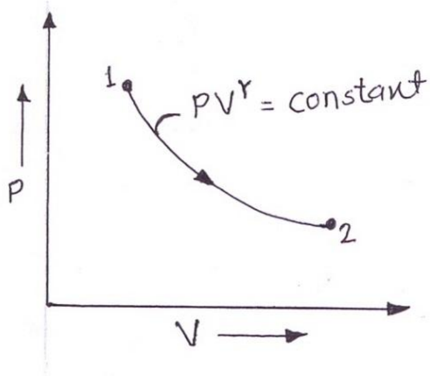
	heat	
3	The sole effect external to system could be reduced to raise the weight but heat transfer of the effect are also consider	The sole effect external to the system could be reduced to rise of a weight
4	Body or system contain heat	Body or system never contain work
5	Heat is low grade energy	Heat is high grade energy
6	Entire heat cannot be converted into work	Entire work can be converted into heat
7	Heat Received by system is consider as Positive (+Q)	Work done on the System is consider as Negative (-W)
8	Heat rejected by system is consider as Negative (-Q)	Work done by the System is consider as Positive (+W)
9	Application :- Any example related from Conduction, Convection or Radiation	Application :- Any example were force and displacement occurs

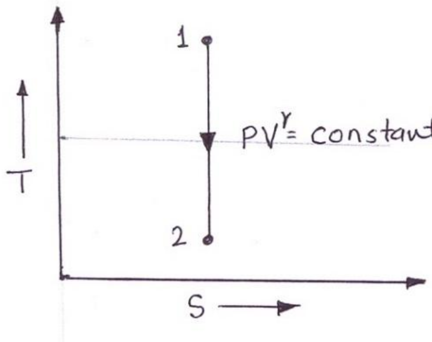
Q. 3 b) i) PV and TS diagram of Isothermal process (one mark each diagram)





ii) PV and TS diagram of Adiabatic process.





Q.3 c) Given data: - (Diagram 01 mark)

Pressure at inlet to compressor = P_1 = 05 bar

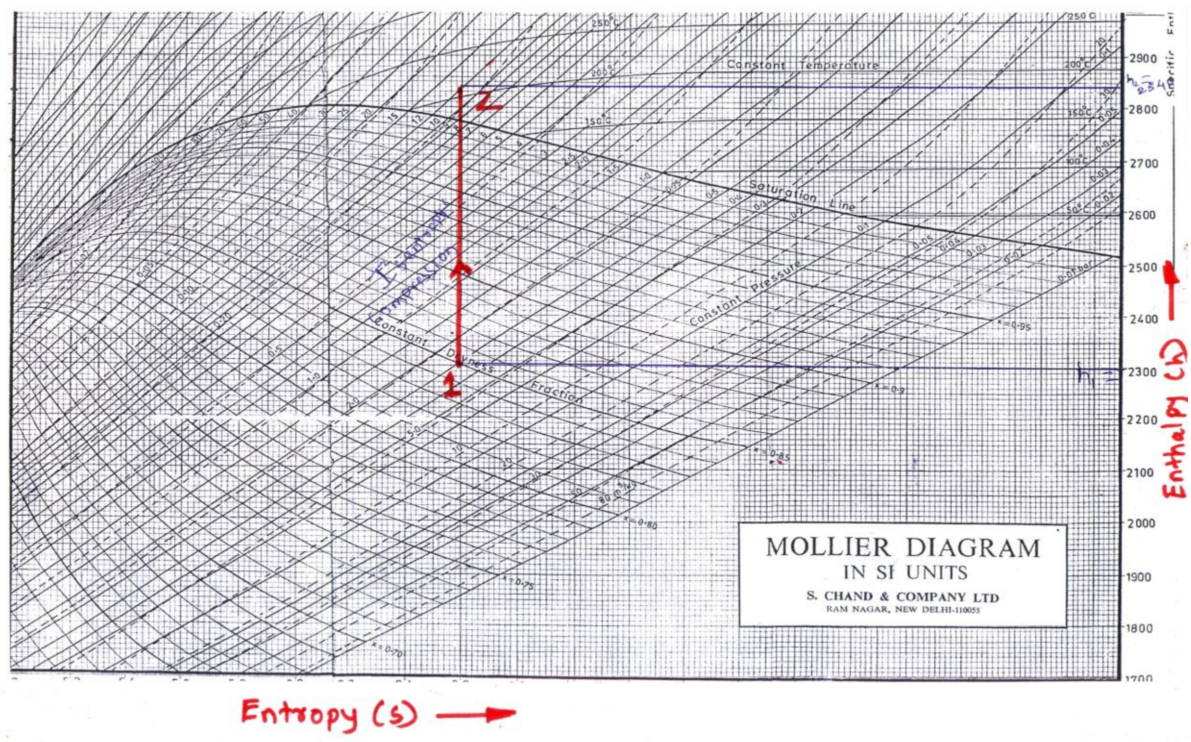
Dryness fraction at inlet to compressor = 0.85

Pressure at exit of compressor = P2 = 12 bar

Asked: - Work input (W) =?

Solution: -

First of all, mark point 1 where the pressure P_1 (i.e. 0.5 bar) and dryness fraction x_1 (0.85) meet as shown in figure. Since the steam is compressed adiabatically (i.e. Isentropically) therefore draw vertical line through point 1 to meet the pressure line P_2 (i.e. 12bar) at point 2



..01 mark

From Mollier chart

Enthalpy at inlet to compressor = h_1 = 2300 KJ/Kg

Enthalpy at Outlet from compressor = h_2 = 2840 KJ/Kg

……………….01 mark

We know that Work required to run compressor for unit mass (W_1) = $h_2 - h_1$

………………01 mark

= 2840 – 2300

= 540 KJ/kg ………………01 mark

Q. 3 d) Construction of Impulse turbine. (02 marks diagram, 2 marks explanation)

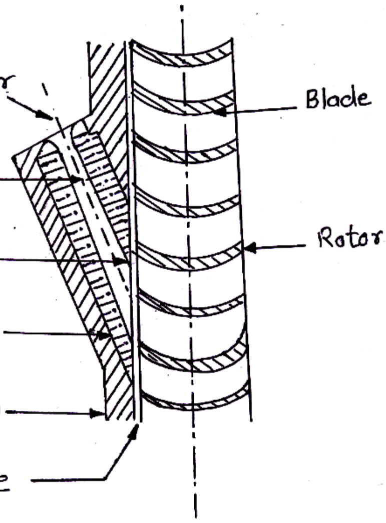


Fig. Impulse turbine

1. The impulse turbine consists of one set of nozzle, which is followed by one set of moving blades as shown as in figure.
2. In this type of turbine, power is developed by the impulsive force.
3. The high velocity steam jets are obtained by expansion of steam in the stationary nozzle only
4. Steam then passes at high velocity through moving blade with no drop in pressure but a gradual reduction in velocity.
5. Thus in pure impulse turbine the high velocity jet having nozzle strikes on the blades mounted on the wheel attached to the shaft.
6. These blades changes the direction of steam and hence momentum of the jet of steam, which rotates the shaft.
7. The nozzle axis is inclined to an angle to the tangent of the rotor.

Q. 3 e) Comparison between Jet and Surface condenser on the basis of following points

Sr. No.	Particular to Compare	Jet Condenser	Surface Condenser
1	Construction	Simple in construction	Complicated in construction
2	Performance	Less efficient because of vacuum created is less	High efficient because of high vacuum created
3	Amount of cooling water circulated	Less amount of cooling water required	More amount of cooling water required
4	Application	These type of condenser used for low capacity plants	These type of condenser used for large capacity plants

Q. 3 f) Construction of shell and coil type of heat exchanger (2 mark for diagram, 2 marks Explanation)

Diagram: -

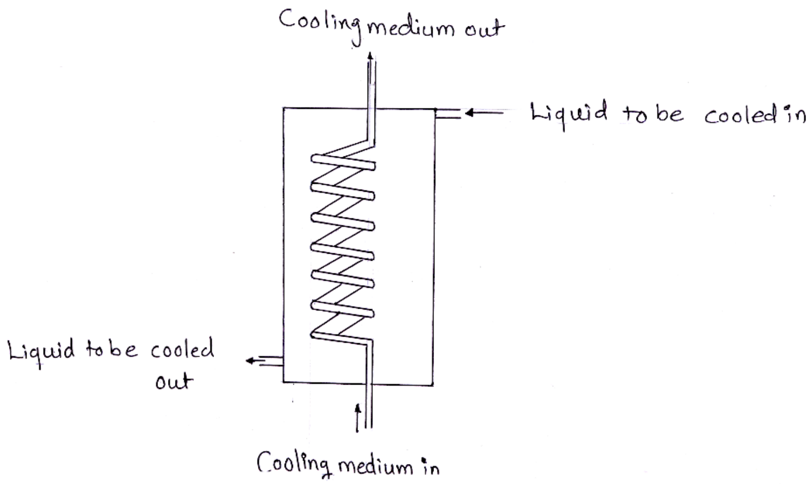


Fig. Shell and coil heat exchanger

Construction of Shell and Coil Heat Exchanger

1. Shell and coil type heat exchanger consist of helical coil.
2. Helical coil is compact in shell.
3. Cooling medium is passed though the coil and liquid to be cooled is passed from top of shell.
4. Cooled liquid is taken out from bottom of shell.
5. Generally in this type of heat exchanger counter flow arrangement is used.

Q. 4 a) Thermodynamic System: - ($^1/_2$ mark)

Thermodynamic system is defined as a prescribed region, or space or finite quantity of matter surrounded by an envelope called boundary

OR

It is defined as quantity of matter or a region in space upon which attention is focused foe study or analysis of problem.

OR

Thermodynamic system may be broadly defined as area or a space where thermodynamic process takes place.

OR

The term system is defined as a specified region where transfer of energy or mass takes place.

OR

Thermodynamic system is nothing but a model of equipment to be analyzed.

Classification of system: - ($^1/_2$ mark)

1. **Closed system**
2. **Open system**
3. **Isolated system**

Explanation with Suitable Example: - (1 mark each)

1. **Closed System: -** Explanation of any Example in which Mass is not transfer but heat is transfer

2. **Open system:** Explanation of any Example in which both Mass and heat transfer.
3. **Isolated system:** Explanation of any Example in which both Mass and heat not transfer.

Q. 4 b) Boiler draught: - (01 mark)

The small static pressure difference which causes a flow of gas to take place is termed as a draught.

OR

The difference of pressure required to maintain the constant flow of air and to discharge the gases through the chimney to atmosphere is known as boiler draught.

OR

Boiler draught is the pressure difference, which is necessary to draw the required quantity of air for combustion and to remove the flue gases out of the boiler combustion chamber.

Necessity of boiler draught (01 mark)

1. To provide sufficient quantity of air for combustion.
2. To expel out the hot gases to flow through the boiler.
3. To discharge these gases to atmosphere through chimney.

Boiler draught is classified as: - (2 marks)

1. Natural or chimney draught
2. Artificial draught
   a) Fan draught (Produced by mechanical fan)
      i) Forced draught
      ii) Induced draught
      iii) Balanced draught
   b) Steam jet draught (Produced by steam jet)
      i) Induced draught
      ii) Forced draught

Q.4 c) Regenerative feed heating (01 mark Diagram, 02 marks Explanation, 1 mark advantages)

Diagram

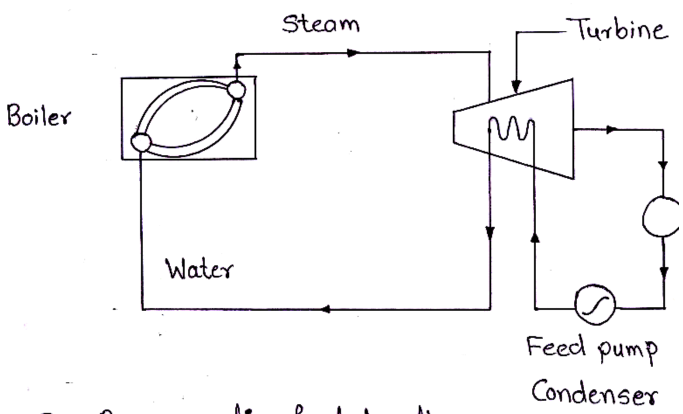


Fig. Regenerative feed heating

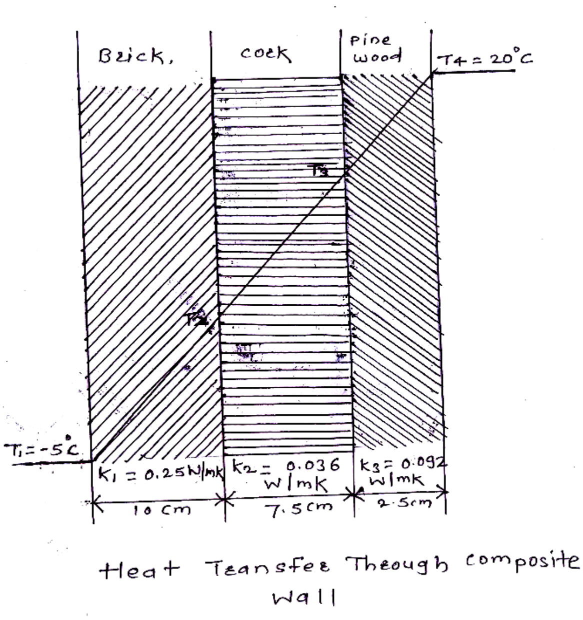
Construction and Working: -

1. The process of heating feed water is known as “regenerative feed heating”.
2. The dry saturated steam, from the boiler enters the turbine at a higher temperature
3. Then this high temperature dry steam expands adiabatically to a lower temperature
4. The expansion of steam in the same way as that in Rankine and Carnot cycle.
5. Now the condensate from the condenser is pumped back and circulated around the turbine casing.
6. The circulated condensate is in direction opposite to the steam flow in turbine.
7. The steam is thus heated before entering the boiler.
8. Such a system of heating is known as regenerative feed heating

Advantages of feed heating

1. The thermal efficiency of boiler increases as heat input decreases.
2. Capacity of Condenser reduced.
3. Reduce fuel consumption.
4. Thermal stress in the boiler reduces as hot feed water is supplied.

Q.4 d) Given data: - (Diagram 01 mark)



Area of wall = A = 3 X 4 = 12 m^2.

Thickness of brick = L_1 = 10 cm

Thickness of cork = L_2 = 7.5 cm

Thickness of pin wood = L_3 = 2.5 cm

Temperature on inner face of wall = $T_1 = -5^0C$

Temperature on outer face of wall = $T_2 = 20^0C$

Thermal Conductivity for brick = K_1 = 0.25 W/mk

Thermal Conductivity for cork = K_2 = 0.036 W/mk

Thermal Conductivity for pin wood = K_3 = 0.092 W/mk

Asked: - Heat leakage per unit time = Q=?

Solution: -

We know that

Heat leaked inside the composite wall is given as

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

…………………………………..01 mark

$$Q = \frac{12\ (-5-20)}{\frac{0.1}{0.25} + \frac{0.075}{0.036} + \frac{0.025}{0.092}}$$

…………………………………..01 mark

Q = -108.89 watt

…………………………………..01 mark

Q.4 e) Given data: -

Water inlet temperature (T_{wi}) = 28^0C

Water outlet Temperature (T_{wo}) = 39^0C

Vacuum produced in Condenser = 705 mm of Hg

Barometric reading = 760 mm of Hg

Asked: -Condenser efficiency (η) = ?

Solution: -

We know that

Absolute pressure in Condenser = Barometric Reading – Vacuum produced in Condenser

= 760 – 705

55 mm of Hg ……………..01 mark

$$\frac{Absolute\ pressure\ in\ mm\ of\ Hg}{Barometric\ pressure\ in\ mm\ of\ Hg}\ X\ Atmospheric\ pressure\ of\ air$$

Absolute pressure in bar = $\frac{55}{760}\ X\ 1.01325$

= 07332 bar ………………..01 mark

From steam table temperature corresponding to 0.07332 bar is $t_s = 40^0C$

$$\text{Condenser efficiency} = \frac{\text{(Temperature of cooling water outlet)} - \text{(Temperature of cooling water at inlet)}}{\text{(Temperature corresponding to absolute pressure)} - \text{(Temperature of cooling water at inlet)}}$$

$$= \frac{T_{wo} - T_{wi}}{T_s - T_{wi}}\ X100$$

……………………01mark

$$= \frac{39 - 28}{40 - 28}\ X100$$

Condenser efficiency = 91.67 % ……………………01mark

Q.4 f) Important provision made on IBR. (Any four, one mark each)

Registration of New Boiler:

1. The owner of any boiler which is not registered under the provisions of act (Section 7 of Indian Boiler Act, 1923) may apply to the inspector to have the boiler register.
2. On receipt of an application under subsection (I), the inspector shall fix a date, within thirty days or such shorter period as may be prescribed from the date of the receipt, for the examination of the boiler and shall give the owner there of not less than ten days' notice of the date so fixed.
3. On the said date, the inspector shall proceed to measure and examine the boiler and to determine in the prescribed manner the maximum pressure, if any, at which such boiler, may be used, and shall report the result of the examination to the Chief Inspector in the prescribed from.
4. The Chief Inspector, on receipt of the report, may

a) Register the boiler and assign a register number thereto either forthwith or after satisfying himself that any structural alteration, addition or renewal which he may deem necessary has been made in or to the boiler or any steam-pipe attached, or

b) Refuse to register the boiler: Provided that where the Chief Inspector refuses to register a boller, he shall forthwith communicate his refusal to the owner of the boiler together with the reasons therefore.

5. The Chief Inspector shall, on registering the boiler, order the issue to the owner of a certificate in the prescribed form authorizing the use of the boiler for a period not exceeding twelve months at a pressure not exceeding such maximum pressure as he thinks fit and as is in accordance with the regulations made under this Act.
6. The Inspector shall forthwith convey to the owner of the boiler the orders of the Chief Inspector and shall in accordance therewith issue to the owner any certificate of which the issue has been ordered, and, where the boiler has been registered, the owner shall within the prescribed period cause the register number to be permanently marked thereon in the prescribed manner.

Renewal of Certification of a Boiler:

1. A certificate authorizing the use of a boiler shall cease to be in force
   a) On the expiry of the period for which it was granted, or
   b) When any accident occurs to the boiler, or
   c) When the boiler is moved (excluding vertical boilers with heating surface less than 200 sq.ft., (portable boilers or vehicular boilers), or
   d) When any structural alteration, addition or renewal is made in or to the boiler, or
   e) If the Chief Inspector in any particular case so directs when any structural alteration, addition or renewal is made in or to any steam pipe attached to the boiler, or
   f) On the communication to the owner of the boiler of an order of the Chief Inspector or Inspector prohibiting its use on the ground that it or any steam pipe attached thereto is in a dangerous condition.
2. Where an order is made under Clause (f) of Sub Section (1) the grounds on which the order is made shall be communicated to the owner with the order.

3. When a certificate ceases to be in force, the owner of the boiler may apply to the inspector for a renewal thereof for such period not exceeding twelve months as he may specify in the application. [Provided that where the certificate relates to an Economizer or an unfired boiler which forms an integral part of a processing plant in which steam is generated solely by use of oil, asphalt or bitumen as a heating medium, the application for its renewal may be for a period not exceeding twenty-four months.]
4. An application under Sub Section (3) shall be accompanied by the prescribed fee and, on receipt thereof, the Inspector shall fix a date, within thirty days or such shorter period as may be prescribed from the date of the receipt, for the examination of the boiler and shall give the owner thereof not less than ten days' notice of the date so fixed. Provided that, where the certificate has ceased to be in force owing to the making of any structural alteration, addition or renewal, the Chief Inspector may dispense with the payment of any fee.

Chief Inspector

[Provided further that in the case of an Economizer or an unfired boiler which forms an integral part of a processing plant in which steam is generated solely by use of oil, asphalt or bitumen as a heating medium, the date fixed for its examination shall be within sixty days from the date of the receipt of the application and the owner shall be given not less than thirty days' notice of the date so fixed.]

(5) On the said date, the Inspector shall examine the boiler in the prescribed manner and if he is satisfied that the boiler has a steam pipe or steam pipes attached thereto are in good condition shall issue a renewed certificate authorizing the use of the boiler for the specified period at a pressure not exceeding such maximum pressure as he thinks fit and as is in accordance with the regulations made under this Act.

[Provided that renewed certificate issued under this subsection in respect of an Economizer (or of an unfired boiler which forms an integral part of a processing plant in which steam is generated solely by use of oil, asphalt or bitumen as a heating medium) may authorize its use for a period not exceeding twenty four months] Provided further that if the Inspector

a. Proposes to issue any certificate -
   i) having validity for a less period than the period entered in the application or
   ii) Increasing or reducing the maximum pressure at which the boiler may be used or
b. Proposes to order any structural alteration, addition or renewal to be made in or to the boiler or to any steam pipe attached thereto or
c. Is of opinion that the boiler is not fit for use the Inspector shall within 48 hours of making the examination inform the owner of the boiler in writing of hid opinion and the reasons therefore and shall forthwith report the case for orders to the Chief Inspector.

d.The Chief Inspector, on receipt of a report under Sub Section (5), may, subject to the provisions of this Act, and of the regulations made thereafter, order the renewal of the certificate in such terms and on such conditions, if any, as he thinks fit, or may refuse to renew it: Provided that where the Chief inspector refuses to renew a certificate, he shall forthwith communicate his refusal to the owner of the boiler, together with the reasons therefore. Nothing in this section shall be deemed to prevent an owner of a boiler from applying for a renewed certificate therefore at any time during the currency of a certificate

Q5. Attempt any **TWO** of the following: (4 X 2)

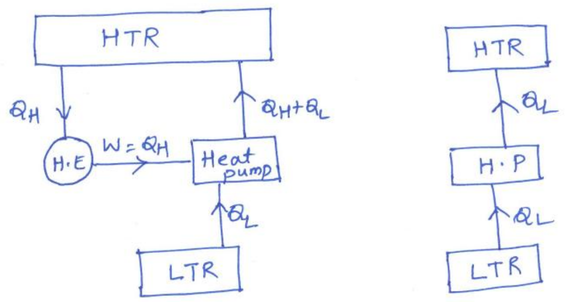
i) Kelvin Planck statement: " It is impossible to construct a heat engine working in a cyclic process, whose sole effectis to convert the heat energy supplied into equivalent amount of work. It means that heat engine can't fully convert the heat supplied into mechanical work."

Clausius statement: "It is impossible for machine (heat pump or refrigerator) to transfer heat from a body at low temperature to a body at high temperature to a body at high temperature, without aid of external source."

ii) Equivalence of Kelvin Planck statement: (4 X 2)

Though Kelvin Planck and Clausius statement for second law of thermodynamics seems to be different, but they are equivalent to each other. It can be proved; if it is shown that violation of one statement means the violation of other and vice versa.

Consider the heat-engine-refrigerator combination shown in figure below left, operating between the same two reservoirs. The heat engine is assumed to have, in violation of the Kelvin-Planck statement, a thermal efficiency of 100 percent, and therefore it converts all the heat QH it receives to work W. This work is now supplied to a heat pump that removes heat in the amount of QL from the low-temperature reservoir and rejects heat in the amount of QL+ QH to the high temperature reservoir. During this process, the high-temperature reservoir receives a net amount of heat QL (the difference between QL+ QH and QH). Thus the combination of these two devices can be viewed as a heat pump, as shown in figure at right that transfers heat in an amount of QL from a cooler body to a warmer one without requiring any input from outside. This is clearly a violation of the Clausius statement. Therefore, a violation of the Kelvin-Planck statement results in the violation of the Clausius statement. It can also be shown in a similar manner that a violation of the Clausius statement leads to the violation of the Kelvin-Planck statement. Therefore, the Clausius and the Kelvin Planck statements are two equivalent expressions of the second law of thermodynamics.



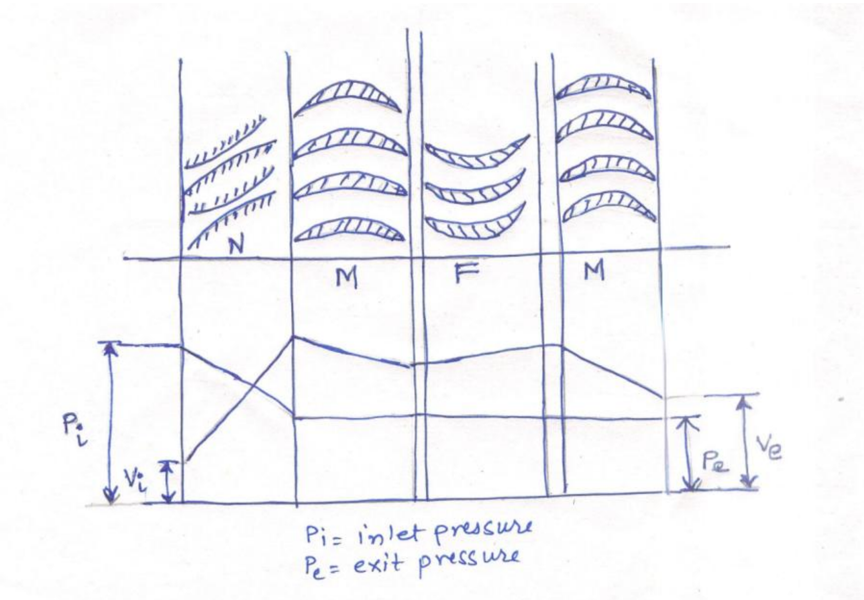
Equivalence of Kelvin Planck's statement and Clausius statement.

b) Compounding to steam turbine: (4 X 2)

If high velocity of steam is allowed to flow through one row of moving blades, it produces a rotor speed of about 30000 rpm which is too high for practical use. It is therefore essential to incorporate some improvements for practical use and also to achieve high performance. This is possible by making use of more than one set of nozzles, and rotors, in a series, keyed to the shaft so that either the steam pressure or the jet velocity is absorbed by the turbine in stages. This is called compounding. Two types of compounding can be accomplished: (a) velocity compounding and (b) pressure compounding. Either of the above methods or both in combination are used to reduce the high rotational speed of the single stage turbine.

The Velocity - Compounding of the Impulse Turbine

The velocity-compounded impulse turbine was first proposed by C.G. Curtis to solve the problems of a single-stage impulse turbine for use with high pressure and temperature steam. The *Curtis stage* turbine, as it came to be called, is composed of one stage of nozzles as the single-stage turbine, followed by two rows of moving blades instead of one. These two rows are separated by one row of fixed blades attached to the turbine stator, which has the function of redirecting the steam leaving the first row of moving blades to the second row of moving blades. A Curtis stage impulse turbine is shown in Fig a. with schematic pressure and velocity changes through the stage. In the Curtis stage, the total enthalpy drop and hence pressure drop occur in the nozzles so that the pressure remains constant in all three rows of blades.



c) **Given:** (4 X 2)

V_1= 0.14 m^3, $P_1 = P_2$ = 1.5 bars, T_1=100°C, V_2 = 0.112 m^3, assume Cp = 1 KJ/Kg

For constant pressure process $\frac{V1}{T1} = \frac{V2}{T2}$,

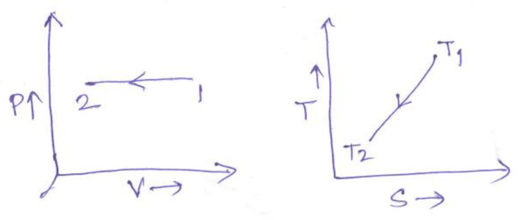
$$\frac{0.14}{373} = \frac{0.112}{T2}$$

$$\mathbf{T_2 = 298.4\ ^0K}$$

Work output dW = P (V_2- V_1) = 1.5 X 10^5 (0.112 – 0.14) = - 4200 J = **- 4.20 KJ……….**2

Heat given out by gas dQ = dU + dW= m Cp (T_2-T_1) = 1 X 1 (298.4 – 373) = **-74.6 KJ….**2

Change in internal energy dU = dQ – dW **= -74.6 – (-4.2) = -70.4 KJ.** …………………2



…………………….2

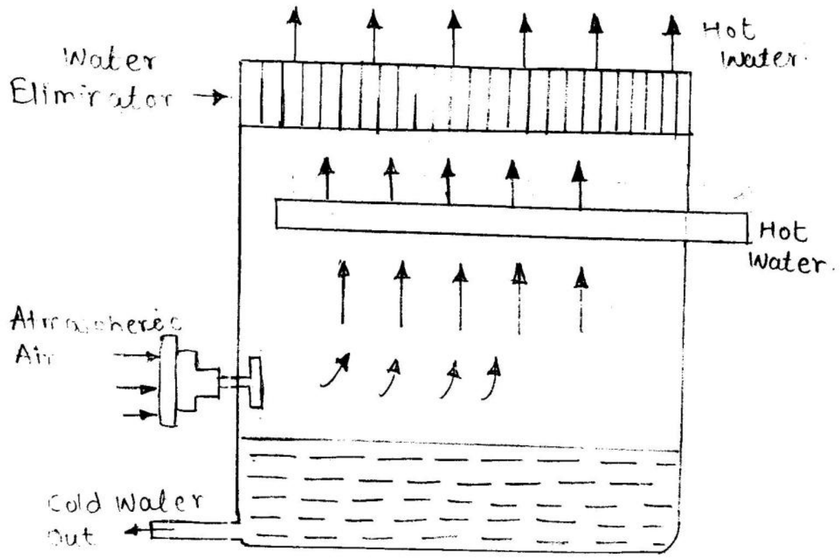
Q6. Attempt any two of the following:

a) ……………………………………………………………………………………….. (2 X 2)

i) Function of cooling tower-. It cools the condensate cooling water condenser cooling water absorbs heat from the steam .This steam is discharged to atmosphere in cooling water.

Uses of cooling tower: For HVAC, Power Generation Station, Industrial and any other heat rejection application.

ii) Forced draught cooling tower: In forced draught cooling tower, the fan is placed at the bottom of the tower to produce circulation of air. Hot water coming from condenser is sprinkled from top and cold water is taken from bottom to circulate in condenser. (2 X 2)



b) Working Babcock and Wilcox Boiler: ………….. (2 X 2)

Coal is fed to the grate through the fire door and is burnt.

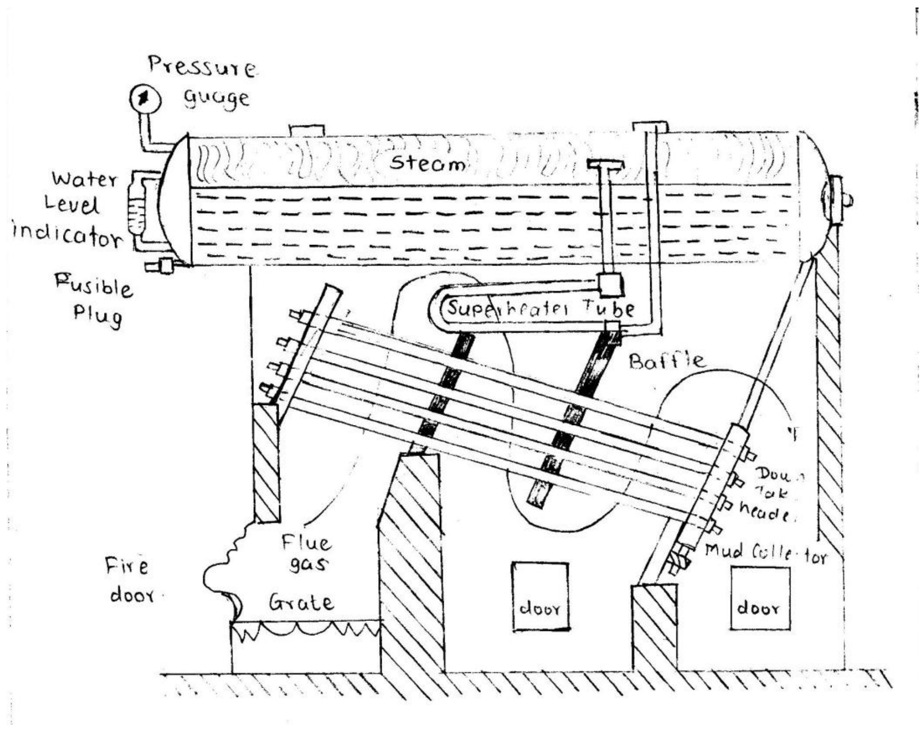
Flow of flue gases:

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.

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 to regulate the flue gas outlet and hence the draught. The boiler is fitted with necessary mountings. Pressure gauge and water level indicator are mounted on the boiler at its left end. Steam safety valve and stop valve are mounted on the top of the drum. Blow-off cock is provided for the periodical removed of mud and sediments collected in the mud box.



c)

i) Stefan Boltzmann law: The Stefan–Boltzmann law states that "the total energy radiated per unit surface area of a black body across all wavelengths per unit directly proportional to the fourth power of the black body's thermodynamic temperature *T*."………………….. (2)

The law states that the emissive power of a black body is directly proportional to the fourth power of its absolute temperature T.

$$E \propto T^4$$

$$E = \sigma T^4$$

Where, E= energy radiated per unit time per unit area in W/m^2
T= absolute temperature in K.
σ = Stefan Boltzmann constant.
E=5.67 X 10^{-8} W/m^2K^4

ii) Perfect black body: "A body which absorbs all the incident radiations is called as black body *irrespective of its colour"*. For a black body, condition is $\alpha = 1$, $\gamma = 0$, $\tau = 0$.

The fraction of incident energy absorbed by the surface is called the absorptivity. For a black body it is equal to one.

It is the ratio of amount of energy absorbed to the amount of energy incident on a body.

The fraction of incident energy transmitted by the surface is called the transmitivity. For a black body it is equal to zero.

It is the ratio of amount of energy transmitted to the amount of energy incident on a body.

The fraction of incident energy reflected by the surface is called the reflectivity. For a black body it is equal to zero. ……………………………………………………..(2 X 3)

It is the ratio of amount of energy reflected to the amount of energy incident on a body.