ROLL NO. | | - | | |

Internal Assessment Test I - Solution

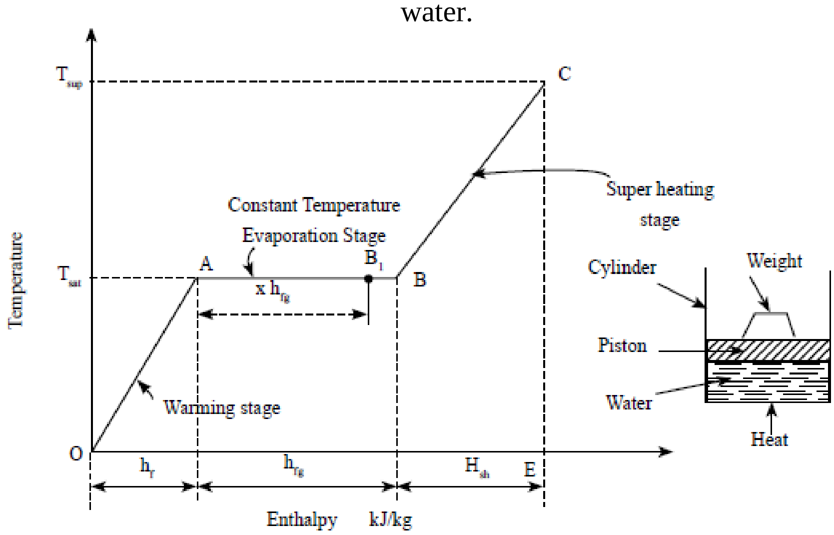
Sub:	Elements of Mechanical Engineering					Sub Code:	18ME25	Branch:	Chemistry Cycle	
Date:	23/06/2021	Duration:	90 min's	Max Marks:	50	Sem / Sec:	2^{nd} / A - G		OBE	
	Answer any Five Questions							MARKS	CO	RBT
1	Write short notes on : a) Ozone Depletion b) Fossil fuels							10	CO1	L2

Write short notes on : a) Ozone Depletion b) Fossil fuels

a. ozone shield is a region of earth's stratosphere that absorb most of the sun's ultraviolet radiation. It contains high concentration of ozone.
Ozone depletion is the gradual thinning of earth's ozone layers in the upper atmosphere. It is caused by the release of chemical compounds containing gaseous chlorine or bromine from industry and other human activities. The thinning is most pronounced in the polar region. Ozone depletion is a major environmental problem because it increases the amount of earth surface. These radiation increases the rate of skin cancer, eye cataracts and genetic and immune system damage. Halocarbons are produced by industry for a variety uses such as refrigerants, propellants
for aerosol cans blowing agents for making plastic foams, fire-fighting agents and solvents for dry cleaning and degreasing. The chlorine and bromine released from halocarbons in the stratosphere react with and destroy ozone.
Since ozone is a green house gas, the breakdown and anticipated recovery of the ozone layer affects earth's climate. The decrease in stratospheric ozone has counter acted a small part of the warming that has resulted from rising concentrations of CO_2 and other green house gases.
Compounds containing C -H bonds such as hydro fluorocarbon have been designed to replace chloro - fluro carbons in refrigerators and air conditioners. These replacement compounds are more reactive and legs likely to survive long enough in the atmosphere.
.

b. Fossil fuels are derived from organic matter which has been trapped between layers of sediments within the Earth for millions of years.
• The organic matter, typically plants, have decomposed and compressed over time, leaving what are known as fossil fuel deposits.
• These deposits and the materials produced from them, tend to be highly combustible, making them an ideal energy source.
• They are difficult to obtain as they are typically retrieved through drilling or mining, but fossil fuels are worth the effort for the sheer amount of energy they produce.
COAL: Coal is the most abundant fossil fuel in the world with an estimated reserve of one trillion metric tons. During the formation of coal, carbonaceous matter was first compressed into a spongy material called "peat," which is about 90% water. As the peat become more and more deeply buried, the increased pressure and temperature turns it into coal.
Different types of coal resulted from differences in the pressure and temperature that prevailed during formation. The softest coal (about 50% carbon), which also has the lowest energy output, is called lignite. Lignite has the highest water content (about 50%) and relatively low amounts of smog-causing sulfur. With increasing temperature and pressure, lignite is transformed into bituminous coal (about 85% carbon and 3% water). Anthracite (almost 100% carbon) is the hardest coal and also produces the greatest energy when burned.
OIL: Crude oil or liquid petroleum is a fossil fuel that is refined into many different energy products (e.g., gasoline, diesel fuel, jet fuel, heating oil). Oil forms underground in rock such as shale, which is rich in organic materials. After the oil forms, it migrates upward into porous reservoir rock such as sandstone or limestone, where it can become trapped by an overlying impermeable cap rock. Wells are drilled into these oil reservoirs to remove the gas and oil.

The refining process required to convert crude oil into usable hydrocarbon compounds involves boiling the crude and separating the gases in a process is known as fractional

	distillation. Besides its use as a source of energy, oil also provides base material for plastics, provides asphalt for roads and is a source of industrial chemicals. Over 50 percent of the world's oil is found in the Middle East; sizeable additional reserves occur in North America. Most known oil reserves are already being exploited, and oil is being used at a rate that exceeds the rate of discovery of new sources found Oil supplies may be exhausted in another 30 years or so. Despite its limited supply, oil is a relatively inexpensive fuel source. **NATURAL GAS:** Natural gas production is often a by-product of oil recovery, from the two commonly shared underground reservoirs. Natural gas is a mixture of gases, the most common being methane (CH_4). It also contains some ethane (C_2H_5), propane (C_3H_8), and butane (C_4H_{10}). Natural gas is usually not contaminated with sulfur and is therefore the cleanest burning fossil fuel. After recovery, propane and butane are removed from the natural gas and made into liquefied petroleum gas (LPG). LPG is shipped in special pressurized tanks as a fuel source for areas not directly served by natural gas pipelines (e.g., rural communities). The remaining natural gas is further refined to remove impurities and water vapor, and then transported in pressurized pipelines. Natural gas is highly flammable and is odorless. The characteristic smell associated with natural gas is actually that of minute quantities of a smelly sulfur compound which is added during refining to warn consumers of gas leaks. The use of natural gas is growing rapidly. Besides being a clean burning fuel source, natural gas is easy and inexpensive to transport once pipelines are in place.			
2	Explain the process of steam formation with suitable diagrams. Also define the terms a) Dryness fraction, b) Sensible heat of water, c) Latent heat of vaporization. Consider 1kg of water at 0^oC taken in a cylinder fitted with a freely moving frictionless piston as shown in below Fig. The weight on the piston applies a constant pressure on water.  The formation of steam follows the following steps. 1. When the water is heated at constant pressure, its temperature rises till the boiling point is reached. This temperature is called saturation temperature(t_s). Saturation temperature depends on the pressure at which water is heated. The amount of heat supplied during this process is called **enthalpy of water or enthalpy of fluid(**h_f). This process is represented by a line OA on temperature-enthalpy diagram. This process is called as warming stage. 2. Further addition of heat initiates the evaporation of water. During this process temperature remains at saturation temperature (t_s). This is because the water will be saturated with heat and any further addition of heat changes only the phase from liquid to gas. This evaporation will be continued at t_s until the whole of water is completely converted into steam. The amount of heat supplied during this process is called **latent heat or enthalpy of evaporation** (h_{fg}). It is indicated by the line AB on T-H diagram. The steam at B is called as dry steam. Between A & B condition of water is wet steam. 3. On heating the steam further, increases its temperature above the saturation temperature. The temperature of the steam above the saturation temperature at a given pressure is called **superheated temperature**. During this stage the dry steam will be heated from its dry state. The amount of heat supplied during this process of heating is called as enthalpy of super heat(Hsh). This process is called as superheating stage. The steam when superheated is called superheated steam.	10	CO1	L1,L2

This process is indicated by the line BC on the T-H diagram.

Dryness Fraction: It is defined as the ratio of mass of the actual dry steam present in a known quantity of wet
steam to the total mass of the wet steam.

$$\text{Dryness fraction } x = \frac{\text{mass of dry particles}}{\text{Total mass of wet steam}} = \frac{m_s}{m_s + m_w}$$

m_s = mass of dry steam particles

m_w = mass of water particles.

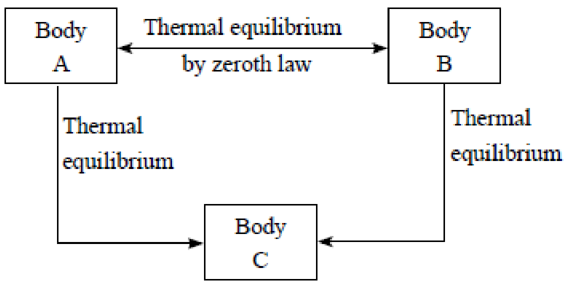
Sensible heat It is the amount of heat supplied to 1kg of water to rise its temperature from 0^0C to saturation temperature at the given pressure. It is given by $h_f = Cp_w(t_s - 273)$ in kJ/kg, where Cp_w = Specific heat of water = 4.2 kJ/kg K.

Latent Heat : It is the amount of heat required to convert 1kg of liquid into completely dry steam at saturation temperature at the given pressure. It is represented by h_{fg} in kJ/kg. Latent heat decreases with the increase of pressure.

3 | Write briefly about the laws of thermodynamics. Also explain thermodynamic concept of work. | 10 | CO1 | L2

Zeroth Law of Thermodynamics

"It states that if two bodies are independently in thermal equilibrium with a third body, then they are in thermal equilibrium with each other".



Consider three bodies A, B and C as shown in figure. Let bodies A and B are in thermal equilibrium with body C independently. Then according to zeroth law, the two bodies A & B shall also be in thermal equilibrium with each other.

First Law of thermodynamics for a closed system under going a cycle(Cyclic process)

Statement : It states that "unless a system undergoes a cyclic change, the algebraic sum of the work transfers is proportional to the algebraic sum of the heat transfers".

or

" When a system undergoes a thermodynamic cycle then the net heat supplied to the system from the surroundings is equal to the net work done by the system on its surroundings.

$$\text{ie. } \oint \delta W = J \oint \delta Q$$

$$\oint \rightarrow \text{Cyclic integral for the closed path}$$

$$J \rightarrow \text{Proportionality constant (Joule's equivalent)} = 1\ Nm/J$$

$$\therefore \oint \delta W = \oint \delta Q$$

First law of thermodynamics may also be stated as follows. "Heat and work are mutually convertible but since energy can neither be extracted nor destroyed, the total energy associated with an energy conversion remains constant".

Law of thermodynamics for a closed system undergoing a change in state (Non - Cyclic Process)

It states that " for a closed system under going a non - cyclic process if Q is the amount of heat transferred to the system and 'W' is the amount of work transferred from the system, the net energy transfer Q-W will be stored in the system which is called internal energy or energy of the system".

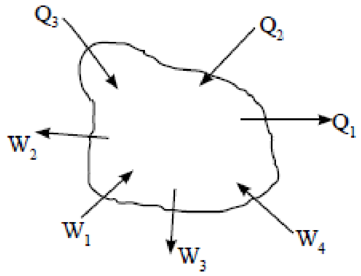
i.e., $Q - W = \Delta E$

where ΔE = Change in internal energy of the system

or $Q = \Delta E + W$

If there are more energy transfer quantities involved in the process as shown in fig, then the I Law gives

$Q_2 + Q_3 - Q_1 = (W_2 + W_3 - W_1 - W_4) + \Delta E$



Statements of II law of thermodynamics

Kelvin - Planck Statement :

It states that ***"it is impossible to construct a cyclically operating device such that it produces no other effect other than the absorbing of energy as heat from a single thermal reservoir and performs an equilibrium amount of work"***.

OR

It is impossible to construct a cyclically operating device whose effect is to convert supplied heat into equivalent amount of work.

Kelvin - Planck statement also tells that ***it is impossible to construct a heat engine which operates in a cycle receives a given amount of heat from a higher temperature body and does an equal amount of work***.

Clausius statement of second law of thermodynamics.

It states that ***"it is impossible to construct a device that working cyclically, produce no effect other than the transfer of heat from a low temperature body to a high temperature body without any external aid".***

This statement is related to the heat pump. It says that ***"it is impossible to construct a heat pump that operates without an input of work"***.

Absolute Zero temperature (III Law of thermodynamics)

Absolute zero temperature mainly based on third law of thermodynamics. It says that ***"it is impossible by any procedure to reduce any system to the absolute zero temperature in a finite number of operations"***.

Thermodynamic concept of work:

In thermodynamics, work transfer is considered as occurring between the system and surroundings.

Work is said to be done by a system if the sole effect on things external to the system could be reduced to raising of a weight.

It can be explained as follows :

In the fig (i) , the motor drives a fan. The system is doing work upon the surroundings.

When the fan is replaced by a pulley and weight as in fig(ii), the weight may be raised with the pulley driven by the motor. The sole effect on thing external to the system is thus raising of a weight.

Work is a transient quantity which only appears at the boundary while a change of state is taking place with in a system.

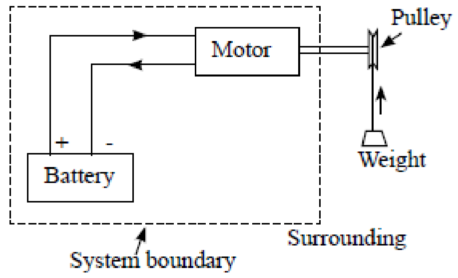


Fig Work done according to the thermodynamics

Sign Convention for work

1. When work is done by the system on the surroundings, for example, expansion of fluid pushing a piston outward, then work is said to be positive.
2. If work is done on the system by the surroundings, for example, when a force is applied to a piston to compress fluid, the work is said to be negative.

The SI unit of work done is Nm or Joule or kJ

1 Joule = 1 Nm

4 | 10 | CO2 | L2

Explain the construction and working of Lancashire boiler with neat diagrams.

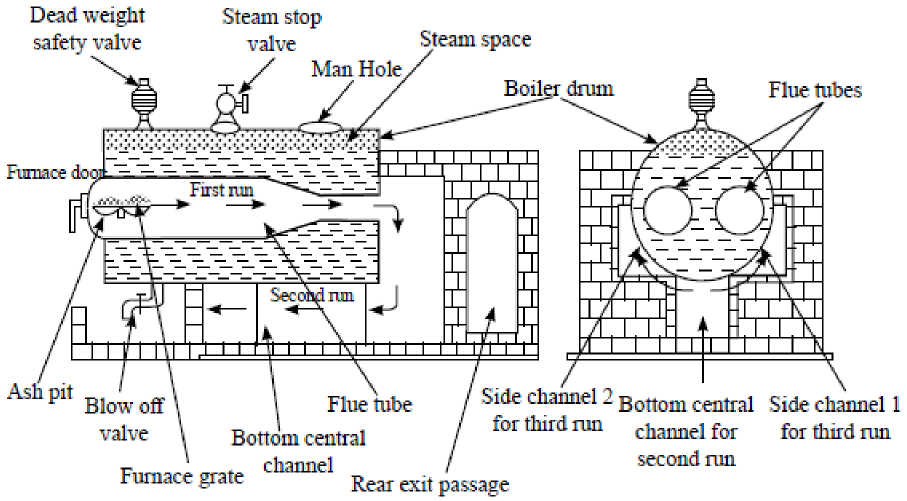


Fig 2.1 Lancashire Boiler

Lancashire boiler is a horizontal, internally fired, natural circulation fire tube boiler. This boiler produces steam upto a pressure of 15 bar. Its capacity is 8500 kg of steam per hour. It is used widely in sugar mills and chemical industries.

The construction of Lancashire boiler is shown in Fig 2.1.

Working

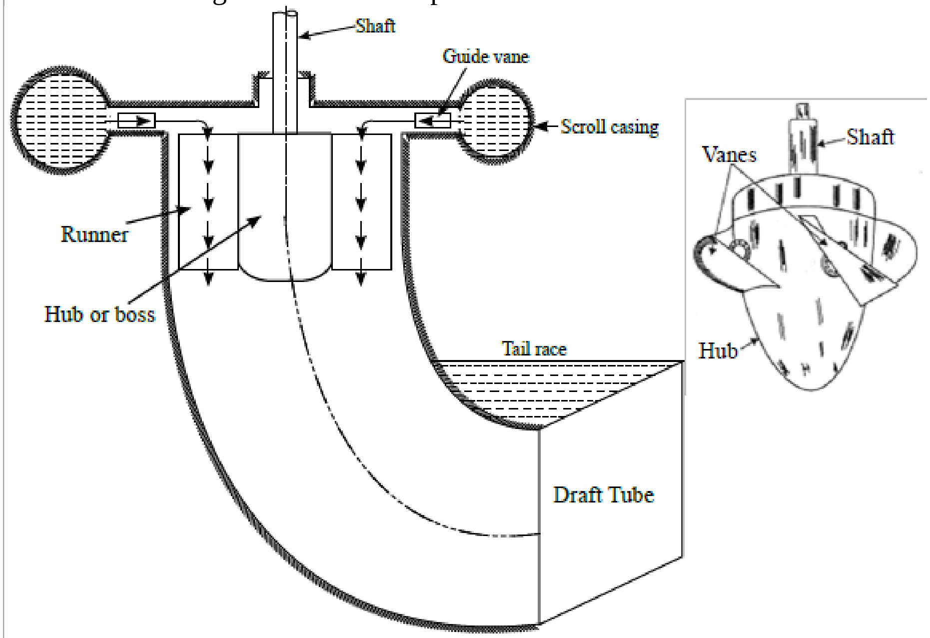
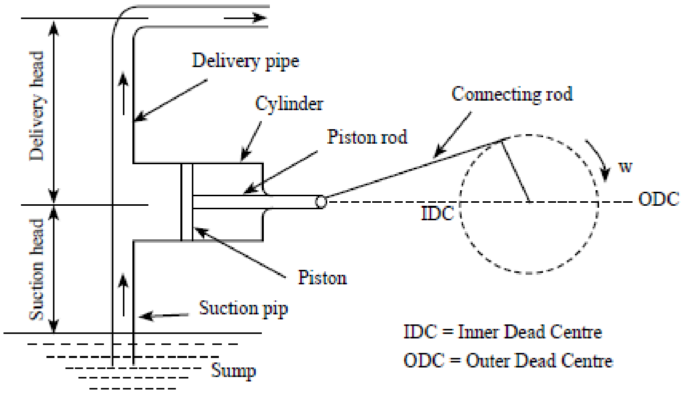
The boiler shell is filled with water to 3/4th of its volume. The fuel is charged through the furnace door onto the grate and burnt. The hot gases produced from the combustion of fuel pass through the flue tubes from the front end to the rear end of the boiler. This is called first run of flue gases. In the first run about 83% of total heat is transferred to the water. Then the gases pass down ward and unite in the bottom central channel and travel from rear end to the front end of the boiler. This is called second run of the gases. In this run 9.5% of total heat is transferred to the water. Now the hot gases divide at the front end of the boiler and enter into the side channels 1 & 2 and travel from front end to rear end of the boiler. This is called third run of the flue gases. In this run about 7.5% of heat is transferred to the water. Now the gases from channel (1) & (2) unite in the rear passage and make their exit to the atmosphere through a chimney. Since heat is transferred to the water in all sides of the boiler, water gets evaporated producing steam. Steam is accumulated in the steam space and is taken out through a steam stop value.

The boiler is mounted with essential mountings and accessories like steam stop valve, safety valve, blow off valve etc.

Advantages

1. It is economical, easy to operate, clean and inspect.
2. Low maintenance lost.
3. Load fluctuation can be easily met due to large water storage.
4. Overall efficiency is high (85%) due to superheater and economiser.

Disadvantages

	1. Steam generation is slow 2. Occupies more space 3. Low pressure boiler			
5	With neat drawings, explain construction and working of a low head reaction turbine. Also define and give classification of hydraulic turbines. **Kaplan Turbine** Kaplan turbine (V Kaplan, Austrian engineer invented it) is an axial flow reaction turbine. It is used for low head and large discharge of water. Kaplan turbine has a ring of fixed guide vanes. These are fixed around the circumference of the hub or boss. Hub acts as a runner. There is a passage between the guide vanes and the rotor of the Kaplan turbine. The rotor of the Kaplan turbine is similar to the propeller of a ship. The rotor blades are attached to the central shaft of the turbine. The blades are connected to the shaft with moveable joints such that the blades can be swiveled according to the flow rate and water head available. Figure 2.5 shows Kaplan turbine.  **Working** Water from the reservoir flows through the penstock and enters the scroll casing. A part of the pressure energy is converted into kinetic energy in the scroll casing. Water then flows through the guide blades. From the guides blades, water turns through 90^{0} and flows axially through the runner blades. During its flow over the runner blades, the blade passages act as the water leaves the blades at high velocity a reaction force is set up and thus force rotates the runner. The water discharging at the centre of the runner enters the draft tube from which water reaches the tailrace at little higher atmospheric pressure.	10	CO2	L1, L2
6	With neat sketches explain construction and working of reciprocating pump. Write a short note on cavitation and priming.  The construction details of single acting reciprocating pump are shown in figure. Working : The crank of the pump is run by an electric motor . Initially, the crank is at inner dead centre and it rotates in clockwise direction. As the crank rotates, the piston moves	10	CO2	L2

towards right and a vaccum is created on the left side of the piston. The vaccum causes suction valve to open. Due to this, liquid from the sum is forced into the left side of the piston. When the crank is at outer dead centre, the suction strike is completed and the left side of the cylinder is full of liquid.

When the rank further turns from ODC to IDC inclockwise direction, the piston moves inward to the left and high pressure valve opens and the liquid is forced into the delivering pipe. At the end of delivery stroke, the crank comes to IDC and the piston is at the extreme left position. Thus the cycle repeats.

7

A piston & cylinder machine contains a fluid system which passes through a complete cycle of four processes. During a cycle, the sum of heat transfers is -170 kJ. The system completes 100 cycles per min. Complete the following table showing the method for each item and compute the net rate of work output in kW.

Process	**Q(kJ/min)**	**W(kJ/min)**	**ΔE(kJ/min)**
a-b	0	2170	-------
b-c	21000	0	-------
c-d	-2100	-------	-36600
d-a	-------	-------	-------

Process a-b:

$$Q - W = \Delta E \Rightarrow 0 - 2170 = \Delta E \Rightarrow \boxed{\Delta E_{a-b} = -2170 \text{ kJ/min}}$$

Process b-c:

$$Q - W = \Delta E \Rightarrow 21000 - 0 = \Delta E \Rightarrow \boxed{\Delta E_{b-c} = 21000 \text{ kJ/min}}$$

Process c-d:

$$Q - W = \Delta E \Rightarrow -2100 - W = -36600 \Rightarrow \boxed{W_{c-d} = 34500 \text{ kJ/min}}$$

Now $\oint \Delta E = 0$; $\Delta E_{a-b} + \Delta E_{b-c} + \Delta E_{c-d} + \Delta E_{d-a} = 0.$

$$-2170 + 21000 - 36600 + \Delta E_{d-a} = 0 \Rightarrow \boxed{\Delta E_{d-a} = 17{,}770 \text{ kJ/min}}$$

$$Q_{net}\ \oint_{cycle} Q = -170 \text{ kJ} \Rightarrow 0 + 21000 - 2100 + Q_{d-a} = -17000 \text{ (}\ldots\text{)}.$$

$$\boxed{Q_{d-a} = -35900 \text{ kJ/min}}$$

Process d-a:-

$$Q - W = \Delta E \Rightarrow -35900 - W_{d-a} = 17770$$

$$\boxed{W_{d-a} = -53670 \text{ kJ/min}}$$

10 CO1 L3

8

A mixture of saturated water and saturated steam at a temperature of 250 ºC is contained in a closed vessel of 0.1m^3 capacity. If the mass of the saturated water is 2 kg, find the mass of the steam in the vessel. Also find the pressure, specific volume, dryness fraction and enthalpy of the mixture.

10 CO1 L3

Given data:-

Total volume, $V_T = 0.1\ m^3$

$T_{sat} = 250°C$

From steam table (Temperature based)

@ $T_{sat} = 250°C$, pressure (p) = 39.77 ~~bar~~ MPa

$v_f = 0.00125173$; $v_g = 0.050083\ m^3/kg$

$h_f = 1085.8\ kJ/kg$; $h_{fg} = 1715.2\ kJ/kg$

given
↳ mass of saturated water, $m_f = 2\ kg$.

We know, vessel is occupied by mixture of saturated water & steam
↳ It is wet steam.

Wet steam = Dry steam + water molecules.

$\therefore \quad V_T = V_{steam} + V_{water\ molecules}$

$0.1 = m_g \times v_g + m_f \times v_f$

$0.1 = m_g \times 0.050083 + 2 \times 0.00125173$

$\boxed{m_g = 1.95\ kg}$

Dryness fraction, $x = \dfrac{m_g}{m_f + m_g} = \dfrac{1.95}{(2+1.95)}$

$= 0.493.$

Specific volume of mixture (m^3/kg) $= \dfrac{V_T}{(\text{Total mass of mixture})}$

$= \dfrac{0.1}{m_f + m_g} = \dfrac{0.1}{3.95} = 0.0253\ m^3/kg$

Enthalpy of mixture per kg:-

$h_{(1kg)} = h_f + x\, h_{fg} \quad kJ/kg$

Total enthalpy ($m = 3.95$) $\quad H_{(3.95kg)} = 3.95\,(h_f + x\,h_{fg}) \quad kJ$

$= 3.95\,(1085.8 + 0.493 \times 1715.2)$

$\boxed{H = 7629}$ kJ

CI CCI HOD