Total No. of Questions: 6 *Total No. of Printed Pages:3*

Enrollment No......................................

Faculty of Engineering

End Sem (Odd) Examination Dec-2022

AU3CO20 / FT3CO26 / ME3CO20

Engineering Thermodynamics

Programme: B.Tech. Branch/Specialisation: AU/FT/ME

Duration: 3 Hrs. **Maximum Marks: 60**

Note: (a) All questions are compulsory. Internal choices, if any, are indicated. Answers of Q.1 (MCQs) should be written in full instead of only a, b, c or d.

(b) Steam table is permitted.

Q.1 i. During a throttling process- **1**

(a) Internal energy remains constant
(b) Enthalpy of fluid remains constant
(c) Pressure remains constant
(d) Temperature remains constant

ii. A refrigerator and heat pump operates between same temperature limits. If COP of the refrigerator is 4, what is the COP of heat pump? **1**

(a) 3 (b) 4 (c) 5 (d) 3.4

iii. At critical point, the temperature of water is equal to- **1**

(a) 0^0C (b) 100^0C (c) 374^0C (d) -100^0C

iv. Throttling calorimeter is used to measure the dryness fraction up to- **1**

(a) 0.7 (b) 0.98 (c) 1.0 (d) None of these

v. Why Carnot vapour power cycle is considered non practical cycle? **1**

(a) Saturated steam enter the turbine
(b) Pump handles water-vapour mixture
(c) Incomplete condensation of steam in the condenser
(d) All of these

vi. Thermal efficiency of Rankine cycle can be improved by steam- **1**

(a) Superheating (b) Reheating
(c) Regeneration (d) None of these

vii. The function of condenser in a steam power plant is- **1**

(a) To reduce back pressure
(b) To condense the exhaust steam
(c) To reduce specific volume of fluid
(d) All of these

viii. The enthalpy of evaporation at 100^0C is- **1**
(a) 2527 kJ/kg (b) 2257 kJ/kg
(c) 2276 kJ/kg (d) 2557 kJ/kg

ix. In a reciprocating air compressor, the work input is minimum when compression is- **1**
(a) Isentropic (b) Polytropic (c) Isothermal (d) Isobaric

x. A nozzle is designed for- **1**
(a) Maximum pressure at outlet
(b) Minimum pressure at outlet
(c) Maximum discharge at outlet
(d) Both (b) and (c)

Q.2 i. State Carnot's theorem. **3**

ii. A system contains 0.15 m^3 of a gas at a pressure of 3.8 bar and 150^0C. It is expanded adiabatically till the pressure falls to 1 bar. The gas is then heated at a constant pressure till its enthalpy increases by 70 kJ. Calculate total work done. Take C_p=1 kJ/kg K & C_v=0.714 kJ/kg K. **7**

OR iii. One kg of air occupies 0.084 m^3 at 12.5 bar and 537^0C. It is expanded at a constant temperature to a final volume of 0.336 m^3. Calculate **7**
(a) The pressure at the end of expansion
(b) Work done during expansion
(c) Heat absorbed by the air, and
(d) Change of entropy

Q.3 Attempt any two:

i. Draw and explain P-V diagram of pure substance. **5**

ii. Determine the quantity of heat required to produce 1 kg of steam at a pressure of 6 bar at a temperature of 25^0C, under the following conditions: **5**
(a) When the steam is wet having a dryness fraction 0.9
(b) When the steam is dry saturated
(c) When it is super-heated at a constant pressure at 250^0C assuming the mean specific heat of superheated steam to be 2.3 kJ/kg K.

iii. In a throttling calorimeter, the steam is admitted at a pressure of 10 bar. If it is discharged at atmospheric pressure and 110^0C after throttling, determine the dryness fraction of steam. Assume specific heat of steam as 2.2 kJ/kg K. **5**

Q.4 i. What are the four basic components of a steam power plant? **2**

ii. Draw the schematic for an ideal Rankine cycle. Draw p-v, T-s and h-s diagram for this cycle. **8**

OR iii. A steam power plant works between pressure of 40 bar and 0.05 bar. If the steam supplied is dry saturated and the cycle of operation is Rankine cycle, find cycle efficiency and specific steam consumption **8**

Q.5 i. Define the following terms: **4**
(a) Equivalent evaporation of the boiler
(b) Efficiency of the boiler

ii. A coal fired boiler plant consumes 400 kg of coal per hour. The boiler evaporates 3200 kg of water at 44.5^0C into superheated steam at a pressure of 12 bar and 274.5^0C. if the calorific value of fuel is 32760 kJ/kg of coal, determine: **6**
(a) Equivalent evaporation from and at 100^0C.
(b) Thermal efficiency of the boiler
Assume specific heat of superheated steam as 2.1 kJ/kg K.

OR iii. In a surface condenser, the vacuum maintained is 700 mm of Hg. The barometer reads 754 mm. If the temperature of condensate is 18^0C, determine mass of air per kg of steam and vacuum efficiency **6**

Q.6 i. Classify air compressors. **2**

ii. A single stage reciprocating air compressor is required to compress 1 kg of air from 1 bar to 4 bar. The initial temperature is 27^0C. Compare the work requirement in the following cases: **8**
(a) Isothermal compression
(b) Compression with $pv^{1.2}$=constant
(c) Isentropic compression

OR iii. Dry saturated steam at a pressure of 15 bar enters in a nozzle and is discharged at a pressure of 1.5 bar. Find the final velocity of the steam when the initial velocity of steam is negligible.
If 10% of the heat drop lost in friction, find the percentage reduction in the final velocity. **8**

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Scheme of Marking

MEDI-CAPS UNIVERSITY Knowledge is Power	Faculty of Engineering End Sem (Odd) Examination Dec-2022 AU3CO20-FT3CO26-ME3CO20-Engineering Thermodynamics
	Programme: B.Tech. Branch/Specialisation:

Q.1	i)	During a throttling process b. Enthalpy of fluid remains constant	1
	ii)	A refrigerator and heat pump operates between same temperature limits. If COP of the refrigerator is 4, what is the COP of heat pump? c. 5	1
	iii)	At critical point, the temperature of water is equal to c. 374^{0}C	1
	iv)	Throttling calorimeter is used to measure the dryness fraction upto b. 0.98	1
	v)	Why carnot vapour power cycle is considered non practical cycle? d. All of the above	1
	vi)	Thermal efficiency of rankine cycle can be improved by steam a. superheating	1
	vii)	The enthalpy of evaporation at 100^{0}C b. 2257 kJ/kg	1
	viii)	The function of condenser in a steam power plant is d. all of the above	1
	ix)	In a reciprocating air compressor, the work input is minimum when compression is c. isothermal	1
	x)	A nozzle is designed for c. maximum discharge at outlet	1
Q.2	i.	State carnot's theorem. **1.5 marks for each statement**	3
	ii.	A system contains 0.15 m^3 of a gas at a pressure of 3.8 bar and 150^{0}C. It is expanded adiabatically till the pressure falls to 1 bar. The gas is then heated at a constant pressure till its enthalpy increases by 70 kJ. Determine the total work done. Take C$_P$=1 kJ/kg K and C$_V$=0.714 kJ/kg K.	7

Work done during adiabatic expansion **3 marks**
Work done during constant pressure heating **3 marks**
Total work done **1 mark**

kJ/kg K.

Solution. Given : $v_1 = 0.15\ m^3$; $p_1 = 3.8$ bar $= 0.38 \times 10^6$ N/m^2 ; $T_1 = 150°$ C $= 150 + 273 = 423$ K ; $p_2 = 1$ bar $= 0.1 \times 10^6$ N/m^2 ; $dH = 70$ kJ ; $c_p = 1$ kJ/kg K ; $c_v = 0.714$ kJ/kg K

In Fig. 3.12, process 1-2 represents adiabatic expansion of the gas and the process 2-3 represents heating at constant pressure.

First of all, let us find the temperature (T_2) and volume (v_2) after the adiabatic expansion.

We know that adiabatic index,

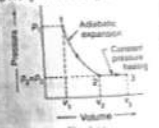

Fig. 3.12

$$\gamma = c_p / c_v = 1/0.714 = 1.4$$

$$\therefore \quad \frac{T_1}{T_2} = \left(\frac{p_1}{p_2}\right)^{\frac{\gamma-1}{\gamma}} = \left(\frac{3.8}{1}\right)^{\frac{1.4-1}{1.4}} = (3.8)^{0.286} = 1.465$$

or $$T_2 = T_1 / 1.465 = 423/1.465 = 288.7\ K$$

and $$\frac{v_1}{v_2} = \left(\frac{p_2}{p_1}\right)^{\frac{1}{\gamma}} = \left(\frac{1}{3.8}\right)^{\frac{1}{1.4}} = (0.263)^{0.714} = 0.385$$

$$\therefore \quad v_2 = v_1 / 0.385 = 0.15/0.385 = 0.39\ m^3$$

Now let us find the temperature (T_3) and volume (v_3) after constant pressure heating.

Let m = Mass of gas contained in the system.

We know that gas constant,

$$R = c_p - c_v = 1 - 0.714 = 0.286\ kJ/kg\ K = 286\ J/kg\ K$$

and $$p_1 v_1 = m R T_1$$

$$\therefore \quad m = \frac{p_1 v_1}{R T_1} = \frac{0.38 \times 10^6 \times 0.15}{286 \times 423} = 0.47\ kg$$

We also know that increase in enthalpy (dH),

$$70 = m c_p (T_3 - T_2) = 0.47 \times 1 (T_3 - 288.7)\ kJ$$

$$\therefore \quad T_3 = \frac{70}{0.47} + 288.7 = 437.6\ K$$

Since the heating is at constant pressure, therefore

$$\frac{v_2}{T_2} = \frac{v_3}{T_3} \text{ or } v_3 = \frac{v_2 T_3}{T_2} = \frac{0.39 \times 437.6}{288.7} = 0.59\ m^3$$

We know that work done during adiabatic expansion,

$$W_{1-2} = \frac{p_1 v_1 - p_2 v_2}{\gamma - 1} = \frac{0.38 \times 10^6 \times 0.15 - 0.1 \times 10^6 \times 0.39}{1.4 - 1}\ J$$

$$= \frac{57 \times 10^3 - 39 \times 10^3}{0.4} = 45\,000\ J = 45\ kJ$$

and workdone during constant pressure heating,

$$W_{2-3} = p_2 (v_3 - v_2) = 0.1 \times 10^6 (0.59 - 0.39) = 20\,000\ J = 20\ kJ$$

$\therefore$ Total work done, $W = W_{1-2} + W_{2-3} = 45 + 20 = 65$ kJ Ans.

OR	iii.	One kg of air occupies 0.084 m^3 at 12.5 bar and 537^{0}C. It is expanded at a constant temperature to a final volume of 0.336 m^3.	7

Calculate

1. The pressure at the end of expansion **1 mark**
2. Work done during expansion **2 marks**
3. Heat absorbed by the air, and **2 marks**
4. Change of entropy **2 marks**

1. *Pressure at the end of expansion*

Let p_2 = Pressure at the end of expansion.

We know that

$$p_1 v_1 = p_2 v_2$$

$$\therefore \quad p_2 = \frac{p_1 v_1}{v_2} = \frac{1.25 \times 10^6 \times 0.084}{0.336} = 0.3125 \times 10^6\ \text{N/m}^2$$

$$= 3.125\ \text{bar Ans.}$$

2. *Workdone during expansion*

We know that workdone during expansion,

$$W_{1-2} = 2.3\, mRT_1 \log\left(\frac{v_2}{v_1}\right) = 2.3\, p_1 v_1 \log\left(\frac{v_2}{v_1}\right) \qquad \ldots (\because p_1 v_1 = mRT_1)$$

$$= 2.3 \times 1.25 \times 10^6 \times 0.084 \log\left(\frac{0.336}{0.084}\right) = 145\,400\ \text{J}$$

$$= 145.4\ \text{kJ Ans.}$$

3. *Heat absorbed by the air*

We know that during constant temperature process, there is no change in internal energy and the heat absorbed is equal to the amount of work done by the air.

$\therefore$ Heat absorbed by the air,

$$Q_{1-2} = \text{Work done by the air} = 145.4\ \text{kJ Ans.}$$

4. *Change of entropy*

We know that change of entropy

$$S_2 - S_1 = \frac{\text{Heat absorbed}}{\text{Absolute temperature}} = \frac{145.4}{810} = 0.18\ \text{kJ/K Ans.}$$

Q.3 Attempt any two:

i. Draw and explain P-V diagram of pure substance. **5**

P-V diagram **2.5 marks**

Explanation of P-V diagram **2.5 marks**

ii. Determine the quantity of heat required to produce 1 kg of steam at a pressure of 6 bar at a temperature of 25^0C, under the following conditions: **5**

1. When the steam is wet having a dryness fraction 0.9 **1.5 marks**
2. When the steam is dry saturated **1.5 marks**
3. When it is super heated at a constant pressure at 250^0C assuming the mean specific heat of superheated steam to be 2.3 kJ/kg K. **2 marks**

superheated steam to be 2.3 kJ/kg K.

Solution. Given: $p = 6$ bar ; $t_w = 25°$C ; $x = 0.9$; $t_{sup} = 250°$C ; $c_p = 2.3$ kJ/kg K

From steam tables, corresponding to a pressure of 6 bar, we find that

$$h_f = 670.4\ \text{kJ/kg} ;\ h_{fg} = 2085\ \text{kJ/kg and } t = 158.8°\text{C}$$

1. *When the steam is wet*

We know that enthalpy or total heat of 1 kg of wet steam,

$$h = h_f + x\,h_{fg} = 670.4 + 0.9 \times 2085 = 2546.9\ \text{kJ}$$

Since the water is at a temperature of 25° C, therefore

Heat already in water $= 4.2 \times 25 = 105$ kJ

$\therefore$ Heat actually required $= 2546.9 - 105 =$ [illegible] kJ Ans.

2. *When the steam is dry saturated*

We know that enthalpy or total heat of 1 kg of dry saturated steam,

$$h_g = h_f + h_{fg} = 670.4 + 2085 = 2755.4\ \text{kJ}$$

$\therefore$ Heat actually required $= 2755.4 - 105 =$ [illegible] kJ Ans.

3. *When the steam is superheated*

We know that enthalpy or total heat of 1 kg of superheated steam,

$$h_{sup} = h_g + c_p(t_{sup} - t) = 2755.4 + 2.3\,(250 - 158.8) = 2965.16\ \text{kJ}$$

$\therefore$ Heat actually required $= 2965.16 - 105 =$ [illegible] kJ Ans.

iii. In a throttling calorimeter, the steam is admitted at a pressure of 10 bar. If it is discharged at atmospheric pressure and 110^0C after throttling, determine the dryness fraction of steam. Assume specific heat of steam as 2.2 kJ/kg K. **5**

Dryness fraction **5 marks**

Solution. Given: $p_1 = 10$ bar ; $p_2 = 1.013$ bar ; $t_{sup} = 110°$ C ; $c_p = 2.2$ kJ/kg K

Let x = Dryness fraction of steam.

From steam tables, corresponding to a pressure of 10 bar, we find that

$$h_{f1} = 762.6\ \text{kJ/kg} ;\ \text{and}\ h_{fg1} = 2013.6\ \text{kJ/kg}$$

and corresponding to a pressure of 1.013 bar,

$$h_{g2} = 2676\ \text{kJ/kg} ;\ \text{and}\ t_2 = 100°\ \text{C}$$

We know that

$$h_{f1} + x\,h_{fg1} = h_{g2} + c_p(t_{sup} - t_2)$$

$$762.6 + x \times 2013.6 = 2676 + 2.2\,(110 - 100) = 2698$$

$$\therefore \quad x = \frac{2698 - 762.6}{2013.6} = 0.961\ \text{Ans.}$$

Q.4

i. What are the four basic components of a steam power plant? **2**

ii. Draw the schematic for an ideal rankine cycle. Draw p-v, T-s and h-s diagram for this cycle. **8**

Schematic of rankine cycle **2 marks**

p-v diagram **2 marks**

T-s diagram **2 marks**

h-s diagram **2 marks**

OR iii. A steam power plant works between pressure of 40 bar and 0.05 bar. If the steam supplied is dry saturated and the cycle of operation is rankine cycle, find **8**

1. Cycle efficiency **4 marks**

2. Specific steam consumption **4 marks**

Given Rankine cycle with dry saturated steam

$p_1 = 40$ bar $= 4000$ kPa,
$p_2 = 0.05$ bar $= 5$ kPa

To find

(i) Rankine cycle efficiency, and
(ii) Specific steam consumption.

Analysis *Properties of steam at principal states (From table A-13)*

State 1: Dry saturated steam,

$p_1 = 4000$ kPa
$h_1 = 2800.36$ kJ/kg
$s_1 = 6.0685$ kJ/kg·K

State 2: Wet steam;

$p_2 = 5$ kPa
$h_{f_2} = 137.79$ kJ/kg
$h_{fg_2} = 2423.66$ kJ/kg
$s_{f_2} = 0.4763$ kJ/kg·K
$s_{fg_2} = 7.9187$ kJ/kg·K

State 3: Saturated liquid;

$p_3 = 5$ kPa;
$h_3 = h_{f_3} = 137.79$ kJ/kg
$v_{f_3} = 0.001005\ m^3/kg$

State 4: Compressed liquid;

$p_4 = 4000$ kPa
$h_4 = h_3 + w_p$

The state 2, after isentropic expansion can be defined by equating entropy at states 1 and 2;

$$s_1 = s_2 = (s_f + x s_{fg})_{@\,5\,kPa}$$
$$6.0685 = 0.4763 + x(7.9187)$$
$$x = \frac{6.0685 - 0.4763}{7.9187} = 0.7064$$

Specific enthalpy at the state 2

$$h_2 = (h_{f_2} + x h_{fg_2})_{@\,5\,kPa} = 137.79 + 0.7064 \times 2423.66 = 1849.84 \text{ kJ/kg}$$

The pump work;

$$w_P = v_f(p_4 - p_3) = 0.001005 \times (4000 - 5) = 4.015 \text{ kJ/kg}$$

Enthalpy at the state 4;

$$h_4 = h_3 + w_P = 137.79 + 4.015 = 141.8 \text{ kJ/kg}$$

Turbine work;

$$w_T = h_1 - h_2 = 2800.36 - 1849.84 = 952.52 \text{ kJ/kg}$$

Net work of cycle;

$$w_{net} = w_T - w_P = 952.52 - 4.015 = 946.5 \text{ kJ/kg}$$

Heat supplied;

$$q_{in} = h_1 - h_4 = 2800.36 - 141.8 = 2658.56 \text{ kJ/kg}$$

(i) Rankine cycle efficiency,

$$\eta_{Rankine} = \frac{w_{net}}{q_{in}} = \frac{946.50}{2658.56} = 0.3562 \text{ or } \mathbf{35.62\%}$$

(ii) Specific steam consumption by Eq. (12.14);

$$ssc = \frac{3600 \text{ kJ/kWh}}{w_{net} \text{ kJ/kg}} = \frac{3600}{946.50} = \mathbf{3.78 \text{ kg/kWh}}$$

Q.5	i.	Define: 1. Equivalent evaporation of the boiler **2 marks** 2. Efficiency of the boiler **2 marks**	4
	ii.	A coal fired boiler plant consumes 400 kg of coal per hour. The boiler evaporates 3200 kg of water at 44.5^{0}C into superheated steam at a pressure of 12 bar and 274.5^{0}C. if the calorific value of fuel is 32760 kJ/kg of coal, determine: 1. Equivalent evaporation from and at 100^{0}C. **3 marks** 2. Thermal efficiency of the boiler **3 marks** Assume specific heat of superheated steam as 2.1 kJ/kg K.	6
OR	iii.	In a surface condenser, the vacuum maintained is 700 mm of Hg. The barometer reads 754 mm. If the temperature of condensate is 18^{0}C, determine: 1. Mass of air per kg of steam **3 marks** 2. Vacuum efficiency **3 marks**	6

1. Equivalent evaporation 'from and at 100° C'

We know that mass of water evaporated per kg of coal

$$m_e = m_s / m_f = 3200 / 400 = 8 \text{ kg}$$

From steam tables, corresponding to a feed water temperature of 44.5° C, we find that

$$h_{f1} = 186.3 \text{ kJ/kg}$$

and corresponding to a steam pressure of 12 bar, we find that

$$h_g = 2782.7 \text{ kJ/kg}, \text{ and } t = 188° \text{C}$$

We know that enthalpy or total heat required for 1 kg of superheated steam,

$$h_{sup} = h_g + c_p(t_{sup} - t) = 2782.7 + 2.1(274.5 - 188) = 2964.4 \text{ kJ/kg}$$

∴ Equivalent evaporation 'from and at 100° C',

$$E = \frac{m_e(h_{sup} - h_{f1})}{2257} = \frac{8(2964.4 - 186.3)}{2257} \text{ kg/kg of coal} = 9.85 \text{ kg/kg of coal Ans.}$$

Thermal efficiency of the boiler

We know that thermal efficiency of the boiler,

$$\eta = \frac{m_e(h_{sup} - h_{f1})}{C} = \frac{8(2964.4 - 186.3)}{32\,760} = 0.678 \text{ or } 67.8\% \text{ Ans.}$$

We know that pressure in the condenser,

$$p_c = 754 - 700 = 54 \text{ mm of Hg}$$

From steam tables, corresponding to 18° C, we find that absolute or ideal pressure of steam,

$$p_s = 0.0206 \text{ bar} = \frac{0.0206}{0.001\,33} = 15.5 \text{ mm of Hg}$$

and specific volume of steam, $v_s = 65.09\ m^3/kg$

Mass of air per kg of steam

We know that pressure of air (as per Dalton's law),

$$p_a = p_c - p_s = 54 - 15.5 = 38.5 \text{ mm of Hg} = 38.5 \times 0.001\,33 = 0.0512 \text{ bar} = 0.0512 \times 10^5 \text{ N/m}^2$$

and mass of air per kg of steam,

$$m_a = \frac{p_a v}{RT} = \frac{0.0512 \times 10^5 \times 65.09}{287 \times 291} = 4 \text{ kg Ans.}$$

Vacuum efficiency

We know that ideal vacuum = Barometer reading − Ideal pressure

$$= 754 - 15.5 = 738.5 \text{ mm of Hg}$$

and vacuum efficiency,

$$\eta_v = \frac{\text{Actual vacuum}}{\text{Ideal vacuum}} = \frac{700}{738.5} = 0.948 \text{ or } 94.8\% \text{ Ans.}$$

Q6.	i.	Classify air compressors.	**2**
	ii.	A single stage reciprocating air compressor is required to compress 1 kg of air from 1 bar to 4 bar. The initial temperature is 27°C. Compare the work requirement in the following cases: 1. Isothermal compression **2.5 marks** 2. Compression with $pv^{1.2}$=constant **2.5 marks** 3. Isentropic compression **3 marks** Work required for isothermal compression We know that work required by the compressor, $W = 2.3\, p_1 v_1 \log\left(\frac{p_2}{p_1}\right) = 2.3\, m R T_1 \log\left(\frac{p_2}{p_1}\right)$ ($\because p_1 v_1 = mRT_1$) $= 2.3 \times 1 \times 287 \times 300 \log\left(\frac{4}{1}\right) = 119\,230$ J = 119.23 kJ Ans. ($\because$ R for air = 287 J/kg K) Work required for polytropic compression (i.e. $pv^{1.2}$ = constant) We know that work required by the compressor, $W = \frac{n}{n-1} \times m R T_1 \left[\left(\frac{p_2}{p_1}\right)^{\frac{n-1}{n}} - 1\right]$ $= \frac{1.2}{1.2-1} \times 1 \times 287 \times 300 \left[\left(\frac{4}{1}\right)^{\frac{1.2-1}{1.2}} - 1\right] = 134\,320$ J = 134.32 kJ Ans. Work required for isentropic compression We know that work required by the compressor, $W = \frac{\gamma}{\gamma-1} \times m R T_1 \left[\left(\frac{p_2}{p_1}\right)^{\frac{\gamma-1}{\gamma}} - 1\right]$ $= \frac{1.4}{1.4-1} \times 1 \times 287 \times 300 \left[\left(\frac{4}{1}\right)^{\frac{1.4-1}{1.4}} - 1\right] = 146\,630$ J = 146.63 kJ Ans.	**8**
OR	iii.	Dry saturated steam at a pressure of 15 bar enters in a nozzle and is discharged at a pressure of 1.5 bar. Find the final velocity of the steam when the initial velocity of steam is negligible. If 10% of the heat drop lost in friction, find the percentage reduction in the final velocity. Final velocity of steam **4 marks** Percentage reduction in final velocity **4 marks**	**8**
		Final velocity of the steam From steam tables, corresponding to a pressure of 15 bar, we find that enthalpy of dry saturated steam $h_1 = 2789.9$ kJ/kg and corresponding to a pressure of 1.5 bar, enthalpy of dry saturated steam, $h_2 = 2693.4$ kJ/kg $\therefore$ Heat drop, $h_d = h_1 - h_2 = 2789.9 - 2693.4 = 96.5$ kJ/kg We know that final velocity of the steam, $V_2 = 44.72\sqrt{h_d} = 44.72\sqrt{96.5} = 439.3$ m/s Ans. Percentage reduction in the final velocity We know that heat drop lost in friction $= 10\% = 0.1$ $\therefore$ Nozzle coefficient or nozzle efficiency $K = 1 - 0.1 = 0.9$ We know that final velocity of the steam, $V_2 = 44.72\sqrt{K h_d} = 44.72\sqrt{0.9 \times 96.5} = 416.8$ m/s $\therefore$ Percentage reduction in final velocity $= \frac{439.3 - 416.8}{439.3} = 0.051$ or 5.1% Ans.	

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