King Saud University
College of Engineering
Mechanical Engineering Department

Midterm Examination-2nd Semester (1428/1429)

Course:- ME-329 **Time:-** 100 Minutes

Subject: THERMAL ENGINEERING FOR INDUSTRIAL ENGG. STUDENTS

QUESTION (1) (MARK 10)

(a) Determine the power transmitted through the shaft of a car when the torque applied is 200 N-m and the shaft rotates at a rate of 4000 revolutions per minute (rpm).

(b) A 2-kW electric resistance heater in a room is turned on and kept on for 30 min. Determine the amount of energy transferred to the room by the heater.

(c) A 3-m^2 hot surface at 80°C is losing heat to the surrounding air at 25°C by convection with a convection heat transfer coefficient of 12 W/m^2-°C. Determine heat lost in one hour.

(d) A piston cylinder device contains air at 0.4 m^3 and 100 kPa. It is compressed to 0.1 m^3 by an isothermal process. Determine the work done.

(e) Steam enters a diffuser steadily at 0.5 MPa, 300°C, and 122 m/s at a rate of 4 kg/s. Calculate the inlet area of the diffuser.

QUESTION (2) MARKS (20)

Complete the table

T °C	P kPa	v, m^3/kg	u kJ/kg	h kJ/kg	Fluid	Quality,
?	2000	?	4000	?	water	?
80	?	?	216	?	R-134a	?

QUESTION (3) **MARKS (7)**

A classroom that normally contains 50 people is to be air-conditioned with window air- conditioning units of 4- kW cooling capacity. A person at rest may be assumed to dissipate heat at a rate of 300kJ/h. There are 30 tube lights in the room of rating 40 W each. The heat transfer through the wall of the room, from the surroundings which are at 40^0C, is 18000kJ/h. If the room air is to be maintained at a constant temperature of 21°C, determine the number of window air-conditioning units required.

QUESTION (4) **MARKS (15)**

Refrigerant- 134a enters a diffuser steadily as saturated vapor at 700 kPa with a velocity of 140 m/s. The refrigerant gains heat at a rate of 3 kJ/s as it passes through the diffuser. It leaves the diffuser at 800 kPa and 40^0C. The exit area of the diffuser is 1.8 times the inlet area of the diffuser. Determine the velocity at the exit of the diffuser and the mass flow rate of the refrigerant.

QUESTION (5) **MARKS (4+4)**

(a) An automobile engine consumes 25 L/hr of fuel and produces 80 kW of power. The heating value of the fuel and the density of fuel are 45000 kJ/kg and 0.75 gm/ cm^3 respectively. Find the efficiency of the engine.

(b) A heat pump of C.O.P. 2.5 supplies heat to a house at a rate of 65000 kJ/h. Determine the power input to the heat pump and the rate of heat absorbed from the cold air.

ME329

2nd Midterm – IInd Semester 1428/29

Q①

(a) $W_{shaft} = \frac{2\pi N T}{60}$ $N = 4000\,rpm$ $T = 200\,Nm$

$W = 83.733\,kW$

(b) $W_e = \dot{W}_e \times t = 2 \times 30 \times 60 = 3600\,kW$

(c) $q = A h \Delta T$ $A = 3\,m^2$ $h = 12\,\frac{W}{m^2\text{-}°C}$ $\Delta T = 80 - 25$

$Q = 7128\,kJ$

(d) $V_1 = 0.4\,m$ $P_1 = 100\,kPa$ $V_2 = 0.1\,m^3$

$W_b = P_1 V_1 \ln \frac{V_2}{V_1} = -55.45\,kJ$

(e) $P = 0.5\,MPa$ $\dot{m} = \frac{A\vec{V}}{v}$

$T = 300\,°C$ $A = \frac{\dot{m} v}{\vec{V}} = \frac{4 \times 0.5226}{122}$

TA6 $v = 0.5226\,m^3/kg$

$A = 0.0171\,m^2$

Q2 $P = 2000\,kPa$ 2 MPa

$u = 4000\,\frac{kJ}{kg}$

At $P = 2\,MPa$ $u_g = 2600\,\frac{kJ}{kg} < u$ ∴ Superheated

T	P kPa	v	u	h
900	2000	0.2700	3849.3	4389.4
			4000	4634.6
1000		0.2933	4048	
100		0.0233	$\Delta u = 198.7$	245.2
			$\Delta u_a = 150.7$	
975		0.2877		4575.36

(B) R134a

$T = 80°C$ $u_g = 262.4$

$U = 216 \frac{kJ}{kg}$ $u_f = 169.88$

$u_f > u_g > u$ ∴ Mixture

P	T	v_f	v_g	u_f	u_g	h_f	h_{fg}
P_{sat}	80°C	0.0010766	0.0064	169.88	262.4	172.71	106.41

$$x = \frac{u - u_f}{u_g - u_f} = 0.5$$

$P_{sat} = 2.6324$ MPa
$= 2632.4$ kPa

$$v = v_f + x(v_g - v_f) = 0.00374 \, m^3/kg$$

$$h = h_f + x(h_{fg}) = 225.915$$

T °C	P kPa	v m³/kg	u kJ/kg	h kJ/kg	liquid	Condition
975.8	2000	0.2877	4000	4575.4	Water	Superheated
80	2632.4	0.00374	216	225.915	R-134a	Mixture

(3) No of Persons = 50

dissipation Rate = 300 $\frac{kJ}{hr}$

$\therefore \dot{Q}_p = \frac{5 \times 300}{3600} = 4.17 \; kJ/s$

No of Bulbs = 30

Wattage = 40 W

$\dot{Q}_b = \frac{40 \times 30}{1000} = 1.2 \; kJ/s$

Rate of heat transfer $\dot{Q}_w = 18000 \; kJ/hr$

$= \frac{18000}{3600} = 5 \; \frac{kJ}{s}$

$Q_{net\,in} - W_{net\,out} = \Delta U$ T = const

Cooling Capacity of Airconditioner = 4 kJ/s = $\dot{Q}_o$

let n be no of A/c

$Q_i = Q_o$

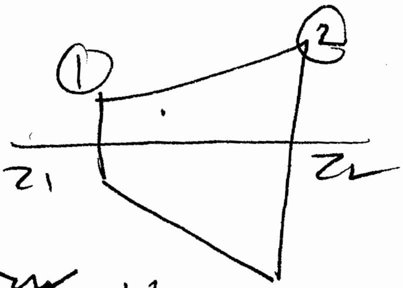
$n \times \dot{Q}_o = \Sigma \dot{Q}_i = 4.17 + 1.2 + 5$

$n = \frac{4.17 + 1.2 + 5}{4} = 2.6$

$\therefore n = 3$

R-134a

Q4 Entrance condition ①



$P_1 = 700\ kPa$ — sat vapour $V = 140\ m/s$

$P_2 = 800\ kPa$ $T_2 = 40°C$ $\frac{A_2}{A_1} = 1.8$

$\dot{Q}_{in} = 3\ kW/s$

$P_1 = 700\ kPa$ $h_1 = h_g = 261.85\ kJ/kg$
A-12 $v_1 = v_g = 0.0292\ m^3/kg$

A13 $P_2 = 800\ kPa$ $T_2 = 40°C$ $h_2 = 273.66\ kJ/kg$
$v_2 = 0.02691\ m^3/kg$

$Q_{net\,in} - W_{net\,out} = \dot{m}\left[(h_2 - h_1) + \frac{V_2^2 - V_1^2}{2000} + pe\right]$

$(Q_{in} - Q_{out}) - W_{net\,out} = \dot{m}\left[(h_2 - h_1) + \frac{V_2^2 - V_1^2}{2000}\right]$

$Q_{in} = \dot{m}\left[(h_2 - h_1) + \frac{V_2^2 - V_1^2}{2000}\right]$

$3 = \dot{m}\left[(273.66 - 261.85) + \frac{71.68^2 - 140^2}{2000}\right]$

$\dot{m} = 0.6552\ kg/s$

$\dot{m} = \frac{A_1 V_1}{v_1} = \frac{A_2 V_2}{v_2}$ $V_2 = \frac{A_1}{A_2} \frac{v_2}{v_1} V_1$

$A_2 = 1.8 A_1$ $V_2 = \frac{A_1}{1.8 A_1} \frac{0.02691}{0.02920} \times 140$

$V_2 = 71.68\ m/s$

Q5

(a) $\dot{V} = 25\, l/hr = \frac{25 \times 3600}{1000 \times 3600}\, m^3/s$

$\rho = 0.75\, gm/cm^3 = \frac{0.75}{1000} \times 1000 \times 1000 = 750\, kg/m^3$

$\dot{m}_f = \rho \dot{V} = \frac{750 \times 25}{1000 \times 3600} = 0.00521\, kg/s$

$q_f = 45000\, kJ/kg$

$\therefore Q_H = \dot{m}_f \times q_f = 45000 \times 0.00521 = 234.375\, kJ/s$

$W_o = 80\, kW$

$\eta = \frac{W_o}{Q_H} = \frac{80}{234.375} = 34.13\%$

(b) $Q_H = 65000\, kJ/hr = 18.06\, kJ/s$

$C.O.P = \frac{Q_H}{W_{in}} = 2.5$

$W_{in} = \frac{Q_H}{2.5} = \frac{18.06}{2.5} = 7.22\, kW$

$\dot{Q}_H = \dot{Q}_L + \dot{W}$

$Q_L = \dot{Q}_H - \dot{W} = 18.06 - 7.22$

$= 10.833\, kJ/s$