NAME OF STUDENT:----------------------- Univ. Number:----------------

King Saud University
College of Engineering
Mechanical Engineering Department

First Semester Final Examination (1428/1429)

Subject: THERMAL SCIENCES FOR INDUSTRAIL ENGG. STUDENTS-ME 329

Question # (1) **MARKS (10)**

Find the answer of the following

(1) The atmospheric pressure at the top of a building is 96 kPa while the atmospheric pressure at the bottom is 95 kPa. If the density of air is 1.2 kg/m^3, then the height of the building is ____________m.

(2) A 2 kW electric resistance heater is kept on for 45 minutes. The energy transferred by it in this time is ___________kJ

(3) A 3 m^3 rigid vessel contains steam at 10MPa and 500^0C. The mass of the steam is ____________kg.

(4) A 3 m^3 vessel contains nitrogen gas at 500 kPa and 300K. Heat is transferred to the vessel till its pressure rises to 800 kPa. The change in internal energy of the nitrogen is __________kJ and work done is _________kJ.

(5) Air at 20^0C and 500kPa is throttled to 200 kPa in an adiabatic valve with out any change in kinetic energy. The change in temperature of the air is ________K.

(6) A heat pump of C.O.P 5.0 consumes 1kW of electricity. How much is the heat supplied by it ________ kJ/s.

(7) A Carnot engine works between 1000^0C and 50^0C. The heat supplied to the engine is 100 kJ/s. The power supplied by the engine is __________kW.

(8) Air is compressed from 100 kPa and 17^0C to 600 kPa and 57^0C. Using the constant values of the specific heat properties of air, the change in entropy of the air is _________kJ/kg-K.

(9) An ideal standard Brayton cycle has pressure ratio of 12. The efficiency of this cycle is _________%.

(10) The roof of a store house is 7mx10m in area. Its thickness is 0.25m and the thermal conductivity of the material of the roof is 0.95 W/m-^{0}C. On a day the inner side and outer side temperatures of the roof wall are 15^0C and 4^0C. Then the heat loss from the roof is __________kW.

Question # (2) **MARKS (8)**

Steam enters an adiabatic turbine at 10 MPa and 500^0C. The steam leaves at 10 kPa with a quality of 0.8. The changes in kinetic and potential energy are negligible and power out put of the turbine is 15 MW. Find

(1) Specific work out put of the turbine.
(2) Change in the specific entropy of the steam.
(3) Mass flow rate of the steam.

Question # (3) **MARKS (8)**

Air enters the compressor of an ideal standard Brayton cycle at 100 kPa and 300K. The pressure ratio of the cycle is 12. The inlet temperature of the turbine is 1200K. The net power out put of the cycle is 75 MW. Draw the system layout of the cycle, pv and Ts diagram of the cycle. For constant values of air specific heat properties, Calculate

(1) Specific work out put of turbine.
(2) Specific work in put of compressor.
(3) Mass flow rate of the air.
(4) Heat added to the cycle
(5) Heat rejected from the cycle
(6) Efficiency of the cycle.

Question # (4) **MARKS(11)**

(a) A vertical plate of size 5m x 4m is placed in water such that the tip of the plate is 2m below the free surface of water. Find the hydrostatic force on the plate and its point of application. The density of water is taken as 1000 kg/m^3.

(b) 20 kg/s of water at 100 kPa enters a pipe of internal diameter 100 mm. The Pipe has a nozzle at the exit and the diameter at the exit of the nozzle is 40 mm. If the density of water is taken as 1000 kg/m^3, find,

- Velocity in the pipe.
- Velocity at the exit of the nozzle.
- Pressure at the exit of then nozzle.

Question # (5) **MARKS (13)**

(a) Write the Laws of conduction heat transfer, convection heat transfer and radiation heat transfer. What are the units of the different quantities used in these laws?

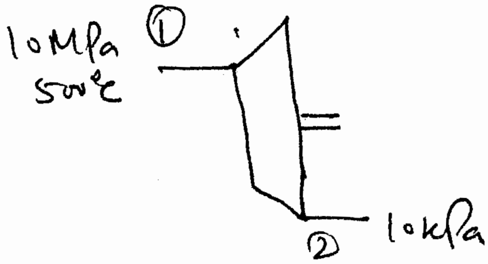
(b) A double pane window of size 0.8m x 1.5m consists of two 4 mm thick layers of glass of thermal conductivity ($k = 0.8 W/m\text{-}^0C$) separated by a 10 mm wide stagnant layer of air space of thermal conductivity ($k = 0.028 W/m\text{-}^0C$). Determine steady state heat transfer through the window on a day when the room is maintained at 20^0C and the outside temperature is -10^0C. Take the heat transfer coefficients on the inner and outer surface of the room to be (h_i= 10 $W/m^2\text{-}^0C$) and (h_o= 40 $W/ m^2\text{-}^0C$) respectively. Also find the temperature on the inner surface (toward room) of the window.

Final ME 329 1st Semester 1428/1429

Q.①

1 – 84.95 m
2 – 5400 kJ
3 – 91.49 kg
4 – 3150.6 kJ, 0.
5 – 0
6 – 5 kJ/s
7 – 74.63 kW
8 – −0.384 kJ/kg-K
9 – 50.87 %
10 – 2926 W.

Q2



$\Delta KE = 0$
$\Delta PE = 0$
$W_o = 15\,MW$
$x = 0.8$

Condition 1

$$\left.\begin{array}{l} P = 10\,MPa \\ T = 500^\circ C \end{array}\right] \begin{array}{l} h_1 = 3373.7\ kJ/kg \\ s_1 = 6.5966\ kJ/kg\text{-}K \end{array}$$

Condition 2 $P = 10\,kPa$ $x = 0.8$

$h = h_f + x\,h_{fg} = 191.83 + 0.8 \times 2392.8 = 2106.07\ kJ$

$s = s_f + x\,h_{fg} = 0.6493 + 0.8 \times 7.5009 =$
$= 6.6500\ \frac{kJ}{kg}$

SFEE

$\cancel{Q_{net}}_{in} - W_{net\,out} = m\,[\Delta h + \cancel{\Delta ke} + \cancel{\Delta pe}$

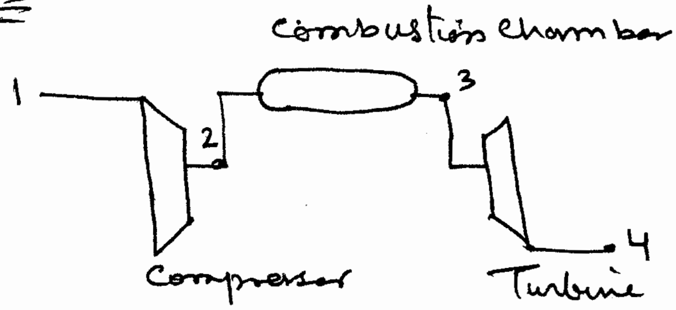
$\frac{-\cancel{W_o} + W_x'}{m} = \Delta h$

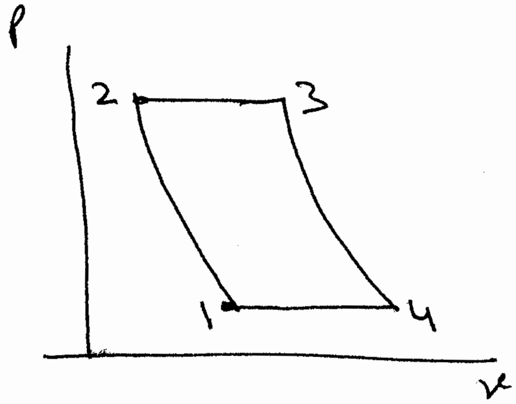
→ $\boxed{\frac{W_x'}{m} = \Delta h = h_1 - h_2 = 1267.63}\ \frac{kJ}{kg}$

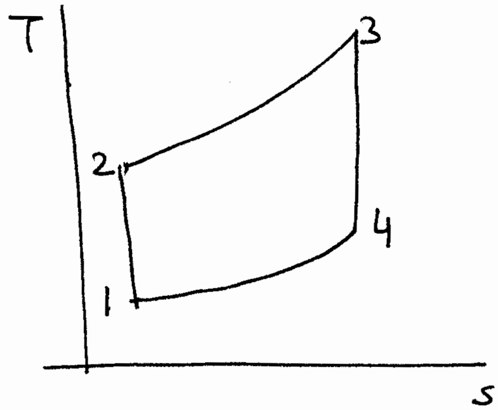
→ $\boxed{\Delta s = s_2 - s_1 = 0.0534\ \frac{kJ}{kg\text{-}K}}$

→ $\boxed{m' = \frac{W_o}{\Delta W} = 11.833\ kg/s}$

Q3







Conditions 1 - $P = 100\ kPa$ $T_1 = 300K$

$r_p = 12$ $T_3 = 1200K$ $\frac{P_2}{P_1} = 12$

$W_o = 75\ MW$

$c_p = 1.005\ \frac{kJ}{kg\text{-}K}$ $R = 0.287\ kJ/kg\text{-}K$

Process 1-2 Isentropic compression

$P_1 = 100\ kPa$ $\frac{P_2}{P_1} = 12$ $P_2 = 1200\ kPa$

$T_1 = 300\ K$ $\frac{k-1}{k} = 0.286$

$\therefore \frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}}$

$T_2 = T_1 \left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}} = 300 \times 12^{0.286}$

$T_2 = 610.61K$

Process 2-3 Isobaric heat addition

$P_3 = P_2 = 1200\ kPa.$

$T_3 = 1200K$

Process 3-4 Isentropic expansion

$P_4 = P_1 \quad P_2 = P_3$

$$\frac{T_4}{T_3} = \left(\frac{P_4}{P_3}\right)^{\frac{k-1}{k}} = \left(\frac{1}{12}\right)^{0.286}$$

$$T_4 = T_3 \times \left(\frac{1}{12}\right)^{0.286} = 1200 \times \left(\frac{1}{12}\right)^{0.286}$$

$$T_4 = 589.57\ K$$

sp. work output of turbine

$$(\cancel{Q_i} - \cancel{Q_o}) - (w_o - \cancel{w_i}) = \dot{m}(\Delta h + \cancel{\Delta ke} + \cancel{\Delta pe})$$

$$-\Delta W_t = \frac{-w_o}{m} = \Delta h = h_4 - h_3$$

$$\Delta W_t = h_3 - h_4$$

$$\Delta W_t = C_p(T_3 - T_4) = 1.005(1200 - 589.57)$$

$$\boxed{\Delta W_t = 613.48\ KW}$$

sp work output of Compressor.

$$(\cancel{Q_i} - \cancel{Q_o}) - (\cancel{w_o} - w_i) = m(\Delta h + \cancel{\Delta ke} + \cancel{\Delta pe})$$

$$W_i' = m\,\Delta h$$

$$\Delta W_c = \frac{W_i'}{m} = h_2 - h_1 =$$

$$\Delta W_c = C_p(T_2 - T_1) = 1.005(610.61 - 300)$$

$$\boxed{\Delta W_c = 312.163\ KW}$$

Q. I

Heat added – Q_H Process 2–3

$(\dot{Q}_{in} - \cancel{\dot{Q}_o}) + \cancel{(\dot{W}_o - \dot{W}_{in})} = \dot{m}(\Delta h + \cancel{\Delta ke} + \cancel{\Delta pe})$

$\dot{Q}_H$

$$\dot{Q}_H = \dot{m}\,\Delta h$$

$$\frac{\dot{Q}_H}{\dot{m}} = \Delta h = h_3 - h_2$$

$$\dot{Q}_H = c_p(T_3 - T_2) = 1.005(1200 - 610.61)$$

$$\dot{Q}_H = 592.34 \text{ kJ/s}$$

Heat released $\dot{Q}_L$ Process 4-1

$(\cancel{\dot{Q}_{in}} - \dot{Q}_o) - \cancel{(\dot{W}_o - \dot{W}_{in})} = \dot{m}(\Delta h + \cancel{\Delta ke} + \cancel{\Delta pe})$

$$-\dot{Q}_o = \dot{m}\,\Delta h =$$

$$-\frac{\dot{Q}_o}{\dot{m}} = h_1 - h_4$$

$$\dot{Q}_L = \frac{\dot{Q}_o}{\dot{m}} = h_4 - h_1$$

$$\dot{Q}_L = c_p(T_4 - T_1) = 1.005(589.57 - 300)$$

$$\dot{Q}_L = 291.02 \frac{\text{kJ}}{\text{kg}}$$

$$\dot{W}_{net\,out} = \dot{Q}_H - \dot{Q}_L = 301.32 \frac{\text{kJ}}{\text{kg}}$$

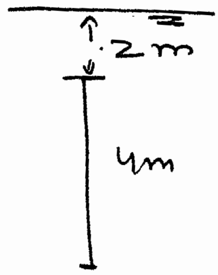
$$W_o = 75 \text{ MW}$$

$$\therefore \dot{m} = \frac{W_o}{W_{net\,out}} = \frac{75000}{301.32} = 248.9 \text{ kg/s}$$

$$\eta = 1 - \frac{1}{r_p^{\frac{k-1}{k}}} = 50.87\%$$

Q4

(a)



$A = 4 \times 5 = 20\, m^2$

$h_c = 2 + \frac{4}{2} = 4\, m$

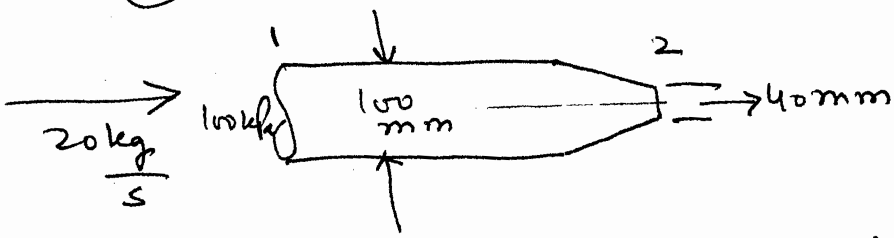
$I = \frac{5 \times 4^3}{12} = 26.67\, m^4$

$\therefore F = \gamma h_c A =$ ~~8~~

$= 784.8\ kN$

$h_p = h_c + \frac{I_{xxc}}{h_c \times A} = 4.33\, m$

(b)



$A = \frac{\pi}{4} d_p^2$

$0.00785\, m^2$

$A_N = \frac{\pi}{4} d_N^2$

$=$

$\dot{m}_p = \rho A_p V_p \qquad V_p = \frac{\dot{m}}{\rho A} = 2.55\, m/s$

$\dot{m} = \rho A_N V_N \qquad V_N = \frac{\dot{m}}{\rho A_N} = 15.92\, m/s$

Apply. Bernoulli's Equation

$P_1 + \frac{1}{2}\rho V_1^2 + \cancel{g z_1} = P_2 + \frac{1}{2}\rho V_2^2 + \cancel{g z_2}$

$P_2 = P_1 + \frac{1}{2}\rho V_1^2 - \frac{1}{2}\rho V_2^2$

$100 + 3.25 - 126.72$

$P_2 = -23.47\ kPa$

Q5

(a) Law of conduction heat transfer

$$\dot{Q} = \frac{K A \Delta T}{L} \; (W)$$

$\dot{Q}$ = Watt, $K = \frac{W}{m\text{-}^{\circ}C}$, $A = m^2$, $\Delta T = {}^{\circ}C$

$L = m$

Law of convection transfer

$$\dot{Q} = h A \Delta T$$

$\dot{Q}$ = Watt, $h = \frac{W}{m^2\text{-}^{\circ}C}$, $A = m^2$, $\Delta T = {}^{\circ}C$.

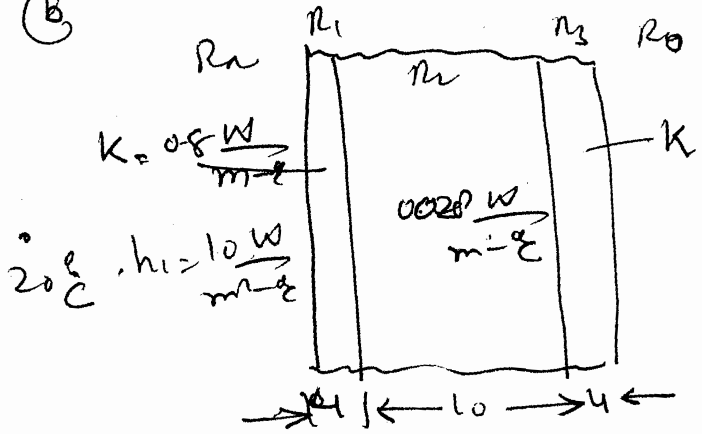
Law of Radiation heat transfer

$$\dot{Q} = \sigma \epsilon A_s (T_s^4 - T_\infty^4)$$

$\dot{Q} = W$ $\quad A_s = m^2$

$\sigma = \frac{W}{m^2 - K^4}$ $\quad T_s, T_\infty \;\; K$

(b)



$A = 0.8 \times 1.5 = 1.2 \; m^2$

$K = 0.8 \frac{W}{m\text{-}^{\circ}C}$

$-10^{\circ}C$

$h_o = 40 \frac{W}{m^2\text{-}^{\circ}C}$

$$R_i = R_{conv,i} = \frac{1}{h_i A} = \frac{1}{10 \times 1.2} = 0.08333 \ ^{o}C/W$$

$$R_1 = R_{cond,1} = \frac{L_1}{k_1 A} = \frac{0.004}{0.8 \times 1.2} = 0.00416 \ ^{o}C/W$$

$$R_2 = R_{cond,2} = \frac{L_2}{k_2 A} = \frac{0.01}{0.028 \times 1.2} \quad 0.29762 \ ^{o}C/W$$

$$R_3 = R_1 = 0.00416 \ ^{o}C/W$$

$$R_o = R_{conv} = \frac{1}{h_o A} = \frac{1}{40 \times 1.2} = 0.02083 \ ^{o}C/W$$

$$R_t = 0.4101 \ ^{o}C/W$$

$$\dot{Q} = \frac{\Delta T}{R_t} = \frac{20-(-10)}{0.4101} = 73.153 \ W$$

$$Q = \frac{T_i - T_1}{R_i} = \frac{20 - T_i}{0.08333} = 73.15$$

$$T_i = 13.9 \ ^{o}C$$