THE OPENUNIVERSITY OF SRI LANKA
FACULTY OF ENGINEERING TECHNOLOGY
BACHELOR OF TECHNOLOGY (ENGINEERING)– LEVEL 05
FINAL EXAMINATION– 2011/2012
MEX5231 – APPLIED THERMODYNAMICS

DATE : 8th MARCH 2012
TIME : 0930 HRS. – 1230 HRS.
DURATION : THREE HOURS

ANSWER FIVE QUESTIONS ONLY. ALL QUESTIONS CARRY EQUAL MARKS.

(1) In a marine gas turbine unit HighPressure (HP) turbine drives the compressor and a Low Pressure (LP) turbine drives the propeller through suitable gearing. The overall pressure ratio is 4/1 and the inlet temperature to the HP turbine is 850°C. The air intake conditions are 1.01bar and 27°C and the mass flow rate is 80kg/s. The isentropic efficiencies of the compressor, HP turbine and LP turbine are 0.8, 0.83 and 0.85 respectively.Mechanical efficiency of both shafts is 98%. Neglecting kinetic energy changes and the pressure loss in combustion, calculate

(i) the pressure between turbine stages,
(ii) the net power output,
(iii) the cycle efficiency.

(2) Single stage of an impulse turbine consists of a converging nozzle and one ring of moving blades. The nozzles are inclined at 22 ° to the blades having equal inlet and outlet angles of 35°.

(i) (a) If the velocity of steam at exit from the nozzle is 660m/s, find the blade speed so that the steam shall pass on without shock.

(b) If the blades run at this speed find the diagram efficiency.

(ii) (a) If the relative velocity of steam is reduced by 15% in passing through the blade ring, find the new diagram efficiency.

(b) Calculate the end thrust on the shaft if the power developed by the turbine is 1.7 kW.

(3) A convergent-divergent nozzle expands air at 7bar and 500°C into a space at 1 bar. The throat area of the nozzle is 800mm^2 and the exit area is 1100mm^2. The exit velocity is found to be 700m/s when the inlet velocity is negligible. Assume that friction in the nozzle is negligible.

(i) Calculate the mass flow through the nozzle.
(ii) Determine whether the nozzle is under-expanding or over-expanding.
(iii) Find the nozzle efficiency and the coefficient of velocity.

(4) A food storage locker requires a refrigeration capacity of 12 TR and works between the evaporating temperature of -8°C and condensing temperature of 30°C. The refrigerant R-12 is subcooled by 5°C before entry to expansion valve and the vapour is superheated to -2°C before entering the compressor.

Use the following data for R12

Saturation temperature (°C)	Pressure (bar)	Enthalpy (vapour) kJ/kgK	Entropy (vapour) kJ/kgK
-8	2.354	184.07	0.7007
30	7.451	199.62	0.6853

Take 1TR = 210kJ/min

Determine,

(i) coefficient of Performance,
(ii) mass flow rate of the refrigerant.

(5) A design for a steam power plant includes:

- A boiler delivering saturated steam at 55 bar.
- A superheater, bringing steam temperature up to 500°C.
- A high pressure (HP) turbine with isentropic efficiency 80% and exhausting at 12 bar.
- A reheater, bringing steam temperature up to 500°C.
- A low pressure (LP) turbine with isentropic efficiency 85% and exhausting at 0.06 bar.
- A condenser, bringing steam to saturated liquid state at the LP turbine outlet pressure.
- A feed pump, with isentropic efficiency 90% bringing the pressure of the feed water up to 55 bar before entry to the boiler.

(i) Sketch the T-S diagram for the cycle.
(ii) Calculate the net work output, the external heat supplied and hence the thermal efficiency of the cycle. Take enthalpy of saturated liquid (h_f) at 0.06 bar as 152 kJ/kg.

(6) A boiler in a power station is fired with coal having an ultimate composition of C - 82% , H_2 - 8.1 % and O_2 - 8.9% and the rest non combustibles. The coal is burnt with 80% excess air and the mean temperature of the flue gases leaving the boiler is found to be 317°C when the ambient temperature in the boiler is 32°C.
You may take following data,

- air to be consisting of 23% of O_2 and 77% of N_2 by weight.
- specific heat of flue gases as 1.115 kJ/kgK.

(i) Calculate the quantity of air actually supplied per kg of coal burnt.
(ii) Find the mass of flue gases released per kg of fuel burnt.
(iii) If the calorific value of coal is 33900 kJ/kg, estimate the percentage of energy carried away by flue gas per kg of fuel burnt.

(7) As shown in the figure Q7 hot water is flowing through a 4cm diameter pipe at a velocity of 2.2m/s. Pipe wall thickness is 0.36cm and the thermal conductivity of pipe wall material is 43 W/mK. The inlet temperature is 110°C and the length of the pipe is 18m. A 2cm thick layer of insulation having thermal conductivity k_c = 0.12 W/mK covers the pipe. The outside film coefficient is 10W/m^{2}K and the ambient temperature is 20°C.

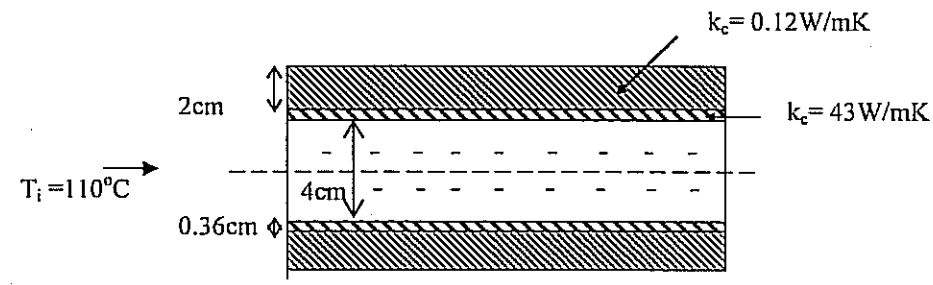


Fig. Q7

(i) Calculate the convection heat transfer coefficient for the pipe inside surface and overall heat transfer coefficient.

(ii) Show that the drop in the water temperature as it flows through the pipe is negligible.

Following data with usual notations can be used

- Nu = 0.023 $(Re)^{0.8}$ $(Pr)^{0.3}$
- Properties of water at 110°C
  ρ = 950 kg/m^3
  C_p = 4.23 kJ/kgK
  k = 0.685 W/mK
  μ = 2.55 x10^{-4} kg/ms

(8) A steam pipe of outside diameter 12cm passes through a large room where the temperature of the surroundings is 300K. The pipe surface temperature is 550K and the emissivity is 0.80.

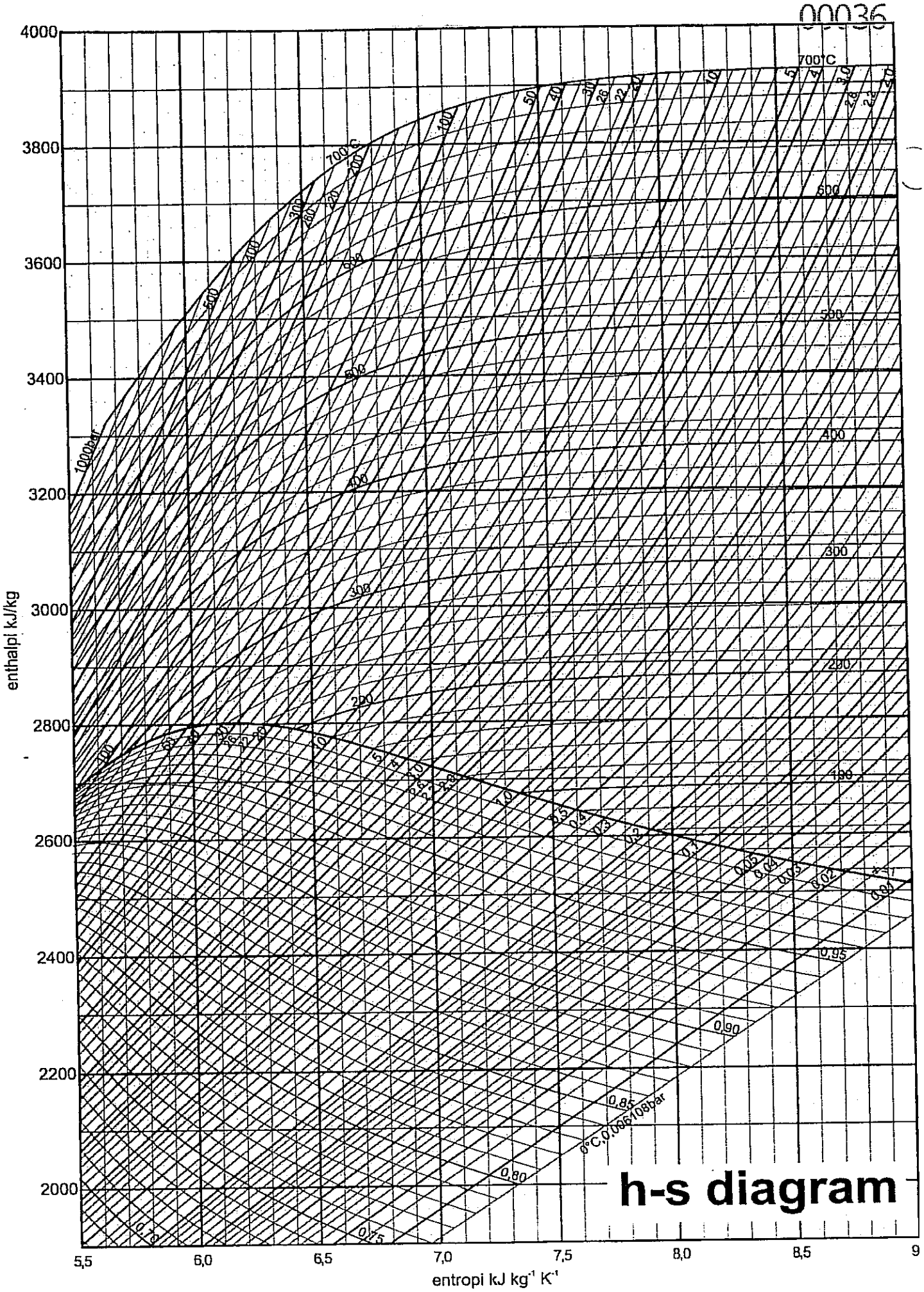
(i) Calculate the surface emissive power of the pipe.

(ii) Find total radiation falling upon the pipe.

(iii) If the heat transfer coefficient by natural convection is 15 W/m^{2}K, estimate the rate of heat loss from the surface of the pipe.

(Stefan Boltzmann constant σ = 5.67 x 10^{-8} W/m^{2}K^4)

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h-s diagram
enthalpi kJ/kg
entropi kJ kg⁻¹ K⁻¹
4000
3800
3600
3400
3200
3000
2800
2600
2400
2200
2000
5,5
6,0
6,5
7,0
7,5
8,0
8,5
9
700°C
1000bar
0°C;0,006108bar