00076

# The Open University of Sri Lanka
# Faculty of Engineering Technology

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|---|---|---|
| Study Programme | : | Bachelor of Technology Honours in Engineering |
| Name of the Examination | : | Final Examination |
| **Course Code and Title** | : | **MEX5231 Applied Thermodynamics** |
| Academic Year | : | 2016/17 |
| Date | : | 24th November 2017 |
| Time | : | 0930-1230h |
| Duration | : | **3 hours** |

**General instructions**

1. Read all instructions carefully before answering the questions.
2. This question paper consists of 8 questions. All questions carry equal marks.
3. Answer any **5 questions.**
4. *h-s* chart is provided.

(1) (a) How does regeneration affect the efficiency of a Brayton cycle, and how is it accomplished?

(04 marks)

(b) In an open cycle gas turbine plant two stages of compression with intercooling and two stages of expansion with reheating are incorporated. The pressure ratio across each stage of the compressor and the turbine is 3. The air enters each stage of the compressor at 300 K and each stage of the turbine at 1200 K. Assume isentropic expansion and compression.

Determine the back work ratio and the thermal efficiency of the cycle, assuming,

(i) no regenerator is used.
(ii) a regenerator with 75 percent effectiveness is used.

(16 marks)

(2) (a) Sketch and explain how the pressure and velocity vary when a fluid passes through fixed and moving blades of an impulse turbine and a reaction turbine.

(05 marks)

(b) In an impulse turbine the steam discharges from the nozzles with a velocity of 850 m/s. The nozzle angle is 20°. Mean blade velocity is 350 m/s. The blades are equiangular. The mass flow rate of steam is 1000 kg/min. Friction factor is 0.8.

Determine the

(i) blade angles.
(ii) axial trust on the end bearing.
(iii)) power developed in kW.
(iv) blade efficiency.
(v) stage efficiency, if nozzle efficiency is 93%.

(15 marks)

(3) (a) Why is condensation of steam, undesirable for blades of a steam turbine? What are the advantages of having reheating stages in a steam power plant ?

(06 marks)

(b) A steam power plant operates on an ideal reheat–regenerative Rankine cycle and has a net power output of 80MW. Steam enters the high-pressure turbine at 10 MPa and 550°C and leaves at 0.8 MPa. Some steam is extracted at this pressure to heat the feedwater in an open feedwater heater. The rest of the steam is reheated to 500°C and is expanded in the low-pressure turbine to the condenser pressure of 10 kPa. Neglect the feed pump work.

(i) Sketch the layout diagram for steam power plant and draw thermodynamic cycle on a *T-s* diagram.
(ii) Determine the mass flow rate of steam through the boiler.
(iii) Calculate the thermal efficiency of the cycle.

(Take saturated liquid enthalpy($h_f$) at 0.8 Mpa and 10 kPa are 721 and 192 kJ/kg respectively.)

(14 marks)

(4) A refrigeration machine using R-12 as the refrigerant, operates between pressures 2.2 bar and 9.2 bar. The compression is isentropic and there is no under-cooling in the condenser. The vapour is in dry saturated condition at the beginning of the compression. Actual coefficient of performance is 0.6 of theoretical value and the refrigerant flow is 6 kg per minute.

(i) Sketch the process on T-S or p-h diagram.
(ii) Calculate the temperature at the end of compression.
(iii) Estimate the theoretical coefficient of performance.
(iv) Calculate the net cooling produced and refrigerator capacity.

Properties of refrigerant are given in table Q4.

| Pressure (bar) | Saturation temperature (°C) | Enthalpy kJ/kg | | Entropy of saturated vapour, kJ/kgK |
|---|---|---|---|---|
| | | liquid | vapour | |
| 9.2 | 38 | 72.56 | 202.51 | 0.6830 |
| 2.2 | -10 | 26.87 | 183.2 | 0.7019 |

Table Q4

(4 x 05 marks)

(5) (a) What is the function of a nozzle? (04 marks)

(b) Air enters a converging nozzle at 78 kPa, 313 K, and a velocity of 300 m/s. Assuming isentropic flow, determine the temperature and velocity of air at a location where the pressure is 117 kPa. Also calculate the ratio of cross sectional areas at inlet and area where the pressure is 117kPa.

(16 marks)

(6) (a) Define Nusselt number and Prandtle number. (05 marks)

(b) A square flat plate of 2m each side is maintained at a uniform temperature of 230°C by means of an embedded electric wire heater.

If the atmospheric air at 25°C flowing over the plate with a velocity of 60 m/s,

(i) determine the Reynolds number and Prandtle number
(ii) calculate the convective heat transfer coefficient
(iv) estimate the required electrical power input in order to keep the plate temperature at 230°C.

Properties of air at mean film temperature of 127.5°C.

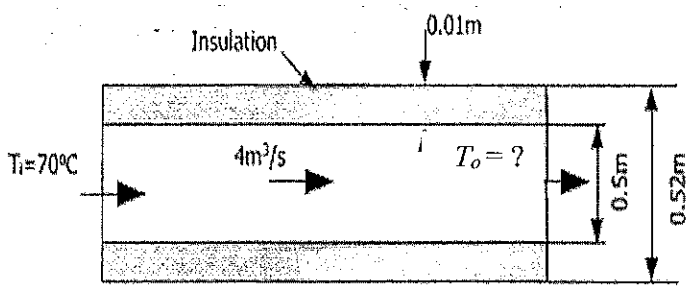
$\mu = 2.301 \times 10^{-5}$ Ns/m$^2$
$\rho = 0.871$ kg/m$^3$
$C_p = 1014$ J/kgK
$k = 0.0338$ W/mK

You may use following equation.

$$N_u = (0.037Re^{0.8} - 871)Pr^{1/3}$$

(3 x 05 marks)

(7) As shown in figure Q7, air is heated in a furnace and distributed to heated space through a circular sheet metal duct of 50 cm diameter. The length of the duct is 80 m and it passes through an open space where ambient temperature ($T_a$) is 10°C. The outer surface of the duct is covered with 10 mm of expanded polyurethane having a thermal conductivity of 0.023W/mK. The volume flow rate of air is 4 $m^3/s$.




$T_a$ = 10°C

Figure Q7

The following data are available.

The density of heated air = 0.9 $kg/m^3$

The inlet air temperature ($T_i$) = 70°C

Specific heat capacity of heated air ($C_p$)= 1005 J/kgK

Surface heat transfer coefficient (inside) $h_i$= 39.67 $W/m^2K$

Surface resistance outside the duct insulation = 0.1 $m^2K/W$

(i) Draw the electrical resistance analogy circuit considering each term of thermal resistance.

(ii) Write down an expressions for thermal resistances for conduction and convection heat transfer and hence calculate the total thermal resistance.

(iii) Calculate the temperature of air at the exit ($T_o$) of the duct and the rate of heat loss from the duct.

You may use the following relationship with usual notations.

$$\frac{L}{R_{total}} = -mCpln\frac{(T_o - T_a)}{(T_i - T_a)}$$

(20 marks)

(8) (a) A mixture of 85% methane ($CH_4$) and 15% hydrogen (by volume) is burnt in air at atmospheric pressure.

Determine

(i) stoichiometric air to fuel ratio by volume.
(ii) air to fuel ratio by volume if 30% excess air is supplied.
(iii) wet volumetric composition of the products if 30% excess air is supplied.

(10 marks)

(b) (i) Define enthalpy of combustion.

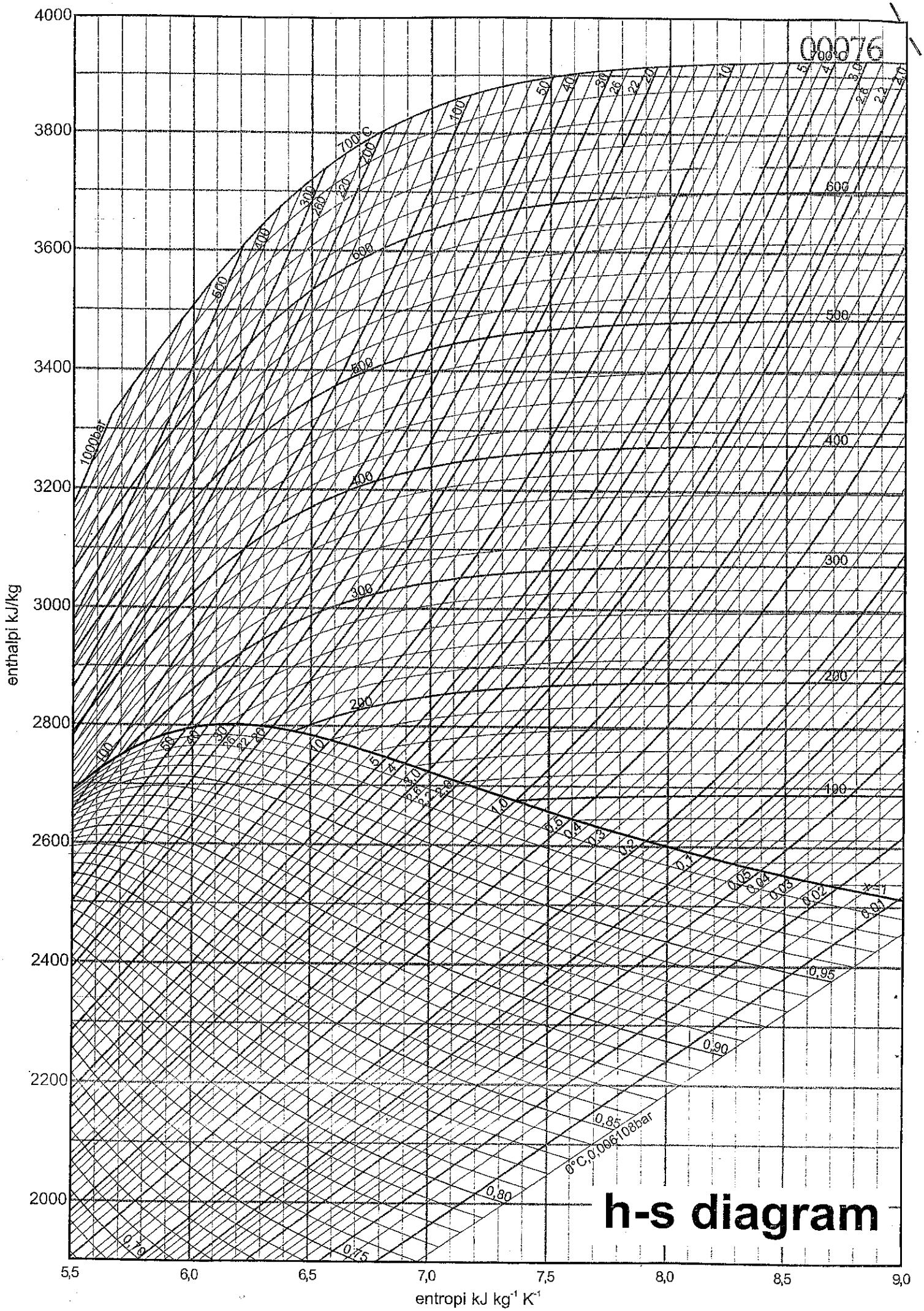
(ii) Calculate the enthalpy of combustion for gaseous propane ($C_3H_8$) at 25°C, 1atm with liquid water in the products. Enthalpy of formation values are given in table Q8.

| Substance | $\bar{h}_f^\circ$ (kJ/mol) |
|---|---|
| $C_3H_8(g)$ | -103.8 |
| $H_2O(l)$ | -285.8 |
| $CO_2$ | -393.5 |

Table Q8

(10 marks)

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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
9,0
1000bar
700°C
600
500
400
300
200
100
x=1
0,95
0,90
0,85
0,80
0,75
0°C,0,006&108bar