The Open University of Sri Lanka
Faculty of Engineering Technology

Study Programme	:	Bachelor of Technology Honours in Engineering
Name of the Examination	:	Final Examination
Course Code and Title	:	**DMX4202 Applied Thermodynamics I**
Academic Year	:	2020/21
Date	:	11th February 2023
Time	:	1330-1630h
Duration	:	**3 hours**

General instructions

1. Read all instructions carefully before answering the questions.
2. This question paper consists of **Six (6)** questions in **Four (4)** pages.
3. Answer any **Five (5)** questions.
4. All questions carry equal marks.
5. Answer for each question should commence from a new page.
6. This is a Closed Book Test (CBT).
7. Answers should be in clear handwriting.
8. Do not use red colour pen.
9. h-s chart is provided.

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(1) (a) Describe briefly two main types of feed water heaters used in steam power plants.

(b) A power plant is designed to generate 200MW of electricity. The pressure at the outlet of the boiler is 160 bar and the temperature is controlled at 600°C. The steam is passed through the first stage of the turbine and reduced in pressure to 40 bar, with 20% being taken for heating in an open feed water heater. The rest of the steam is heated back up to 600°C and then passed through the second stage of the turbine, finally reaching a pressure of 0.035 bar in the condenser. By neglecting the feed pump work,

(i) Calculate the steam rating of the boiler in kg per hour.

(ii) Determine the thermal efficiency of the cycle.

(iii) If there is a 15°C rise in the cooling water temperature, what is the rate of flow of the cooling water in the condenser.

- Take enthalpy of saturated liquid water at 0.035bar as 112kJ/kg
- C_p for water is 4.187 kJ/kgK
- h-s chart is provided.

(2) (a) Briefly explain the processes of an open cycle gas turbine and a closed cycle gas turbine with suitable diagrams.

(b) An open gas turbine power plant operates with an inlet air temperature of 20°C and a pressure of 1 bar. The compression ratio of the turbine is 10:1. The turbine has a mechanical efficiency of 85% and the exhaust temperature is 550°C. The plant's output is 20MW.

(i) Determine the temperature of the air after compression.
(ii) Determine the thermal efficiency of the open gas turbine cycle.
(iii) Suggest an appropriate procedure to compare the theoretical and practical rate of heat rejection and discuss any discrepancies.
(iv) If the plant is needed to generate more than 20MW output, what parameters may be changed in the existing system in order to increase the output?

(3) (a) Explain the regenerative cycle with closed feed heater with suitable diagrams and provide some applications related to that.

(b) A steam power plant operates on a regenerative cycle with a closed feed heater. The following data is given:

- The working fluid is water.
- The boiler pressure is 8 MPa and the temperature is 450°C
- The turbine inlet pressure is 0.05 MPa
- The condenser pressure is 0.01 MPa
- 15% of the steam is extracted from the turbine for feed heating in a closed feed water heater before being reheated to 450°C
- The feed water heater efficiency is 85%
- The pump work is negligible.
- Cp for water is 4.187 kJ/kgK

(i) Sketch the T-s diagram of the regenerative cycle.
(ii) Determine the thermal efficiency of the cycle.
(iii) Determine the mass flow rate of the working fluid.
(iv) Determine the rate of heat added in the boiler.

Take specific enthalpy at the turbine outlet is 3312.8 kJ/kg, specific enthalpy at the condenser outlet is 110.5 kJ/kg, and specific enthalpy at the pump inlet as 165.5 kJ/kg.

(4) A single-acting, **two stage** air compressor runs at 200 rev/min and compresses air at 1.013 bar and 15°C to 40 bar. Inlet air flow rate is 7.8 m^3/min.

Sketch the indicator diagram and calculate,

(i) The optimum pressure ratio for each stage.

(ii) The theoretical power consumption of each stage if the compression index (n) is 1.3.

(iii) The net heat transfer in each cylinder.

(iv) If the clearance ratios for the low- and high-pressure cylinders are 0.05 and 0.07 respectively, calculate volumetric efficiency for the first stage.

The gas constant for air, R = 0.287 kJ/kg.K, specific heat value C_p = 1.005 kJ/kgK

You may use following expressions with their usual notations.

Compression work (*Wc*),

$$W_c = m\left[\frac{n}{n-1}\right]RT_2\left[\left(\frac{p_2}{p_1}\right)^{\frac{n-1}{n}} - 1\right]$$

Volumetric efficiency (η_{vol}),

$$\eta_{vol} = 1 - \frac{V_d}{V_s}\left[\left(\frac{p_2}{p_1}\right)^{\frac{1}{n}} - 1\right]$$

(5) (a) What is the velocity diagram of an impulse turbine and how are the velocity components named?

(b) In an impulse turbine (with a single raw wheel), steam enters with a velocity of 1000 ms^{-1} and the nozzle angle is 20°. The mean blade velocity is 400 ms^{-1}. Assuming the blades of the impulse turbine are symmetrical,

(i) What are the blade angles when the steam is entering the blades without shock.

(ii) Calculate following for the mass flow rate of 0.8kg/s.

a. Tangential force on the blades
b. Diagram power
c. Axial thrust
d. Diagram efficiency

(iii) If the relative velocity at exit is reduced by friction to 75% of that of inlet, find the axial thrust, diagram power and diagram efficiency.

(6) (a) Define the terms of 'Isentropic stagnation state' and 'Mach number' in compressible flow.

(b) Air is flowing through a convergent-divergent nozzle and inlet conditions are given below.

Pressure: $300 kN/m^2$
Velocity: $180 ms^{-1}$
Temperature: $220^{o}C$

Determine the following,

(i) Stagnation temperature and stagnation pressure.

(ii) Sonic velocity and Mach number at inlet.

(iii) Pressure, temperature, and sonic velocity at the throat of the nozzle.

Assume isentropic flow through the nozzle,

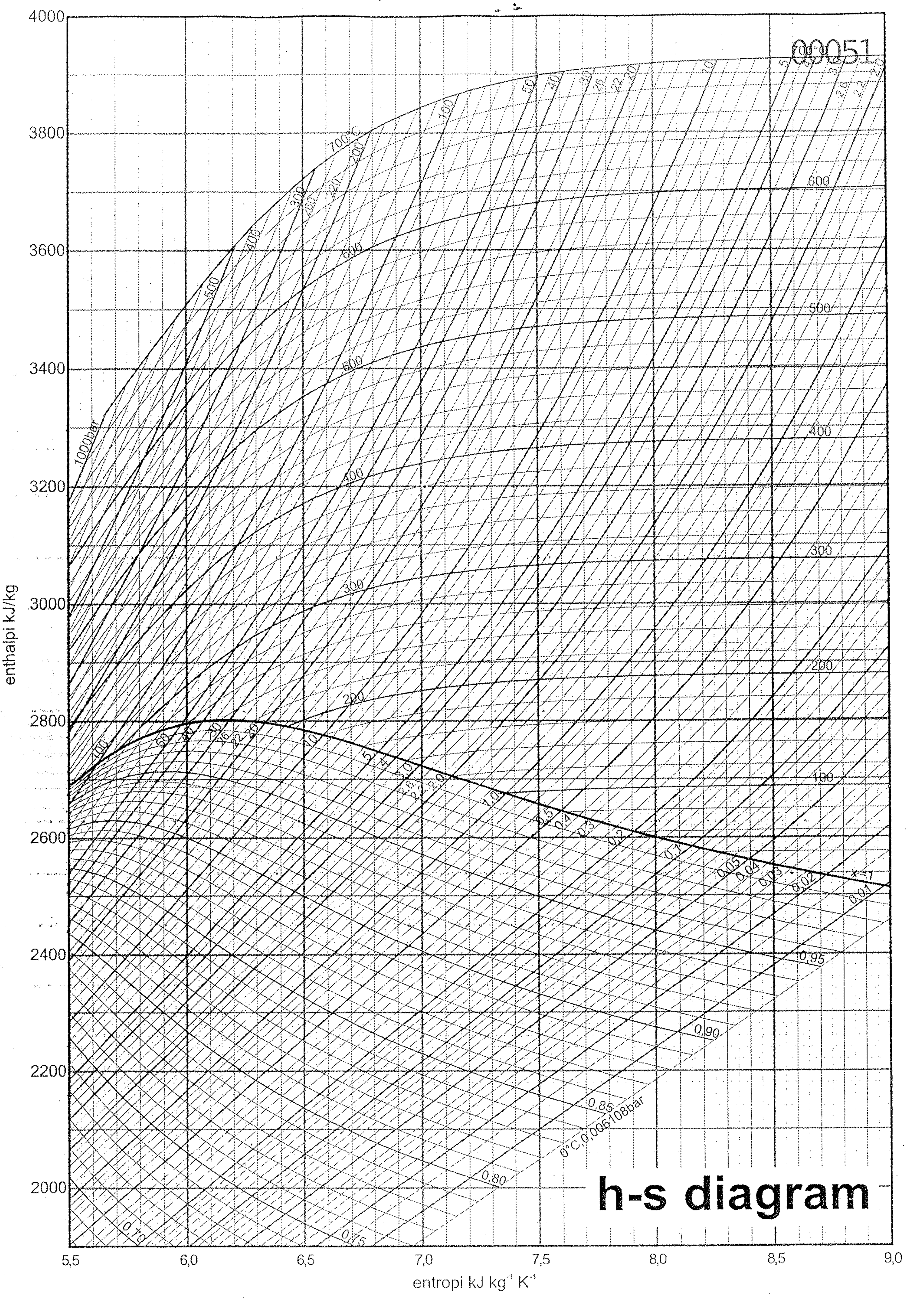
C_p for air = 1.005 kJ/kgK

Air gas constant (R) =0.287 kJ/kgK

You may use the following equations with their usual notations.

$$T_s = T_1 + \frac{V_1^2}{2C_p} \qquad \frac{T_s}{T_t} = \left[1 + \left(\frac{\gamma-1}{2}\right) M_t^2\right]$$

$$\frac{P_s}{P_1} = \left(\frac{T_s}{T_1}\right)^{\frac{\gamma}{\gamma-1}}$$



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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
0,70
0°C,0,006108bar