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	:	2019/20
Date	:	2nd October 2020
Time	:	0930-1230h
Duration	:	**3 hours**

General instructions

1. Read all instructions carefully before answering the questions.
2. This question paper consists of **Eight (8)** questions in **Five(5)** 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 hand writing.
8. Do not use red colour pen.
9. h-s chart is provided.

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(1) (a) What are the three methods by which efficiency of a simple gas turbine plant can be improved considerably?

(b) In a gas turbine plant, air is compressed from 1bar and 31°C through a pressure ratio of 1:8. It is then heated to 927°C in a combustion chamber and expanded in a turbine to the initial pressure. Calculate the cycle efficiency of the plant under each of the following conditions.

<u>Condition I</u>
If a perfect heat exchanger is employed between the compressor and the combustion chamber

<u>Condition II</u>
If the heat exchanger is removed and reheating stage is incorporated before expanding to the initial pressure. Therefore the gas at 927°C is expanded to 3 bar and then reheated to 827°C and expanded to the initial pressure.

(c) Under which condition that the higher thermal efficiency could be obtained? Explain briefly.

Assume 100% isentropic efficiencies in compressor and turbines for both conditions. Assume Cp of working fluid as 1.005 kJ/kgK throughout the cycle.

(2) (a) Briefly explain the working principle of a closed cycle gas turbine plant with the aid of a schematic diagram.

(b) In a gas turbine plant, working on the Brayton cycle, Helium at 30°C and 22bar is compressed to a pressure of 64bar and then heated to a temperature of 1200°C. After expansion in the turbine, the gas is cooled to initial pressure and temperature.

Following data are given.
Isentropic efficiencies of the compressor and turbine are – 100%
Pressure loss in the combustion chamber : 1.2 bar
Pressure loss in the cooler : 0.5 bar

Specific heat (C_p) of the products of combustion is the same as that of Helium and it is equal to 5.1926kJ/kg K. Ratio of specific heats of Helium (γ) = 1.667

Determine the following;

(i) Temperature at the end of compression and expansion.

(ii) Heat supplied, heat rejected and the net work per kg of Helium.

(iii) Thermal efficiency of the plant.

(iv) Flow rate of Helium required to give an output of 12MW.

(3) (a) Briefly explain the common methods of improving the thermal efficiency of a Rankine cycle.

(b) In a steam power plant, the inlet state to the high pressure stage of the steam turbine is 40bar and 350°C. After expansion, the exit steam of this stage is dry saturated. The steam is reheated at constant pressure to 350°C before being expanded in the low pressure stage to 0.7bar.

- Assume 100% isentropic efficiency for feed pump and for turbine.
- Take enthalpy of saturated liquid water at 0.7bar as 377kJ/kg
- h-s chart is provided

(i) Sketch the cycle on the T-S diagram.

(ii) Calculate the feed pump work.

(iii) Calculate the network done and thermal efficiency of the cycle.

(4) (a) What are the two main types of feed water heaters used in steam power plants? Explain them briefly.

(b) A power generating station is designed to provide a power output of 200MW. The outlet pressure of the boiler is to be 170bar and the temperature 600°C. After expansion through the first stage of the turbine to a pressure of 40bar, 15% of the steam is extracted for feed heating in an open feed water heater. The remainder is reheated to 600°C and is then expanded through the second turbine stage to a condenser pressure of 0.035 bar. Neglect 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.
- Cp for water is 4.187 kJ/kgK.
- h-s chart is provided.

(5) A single-acting, single cylinder air compressor running at 350rev/min is driven by an electric motor.

The following data are given.

Air inlet condition	:	1bar and 31°C
Delivery pressure	:	10bar
Clearance volume	:	8% of swept volume
Index of compression and re-expansion (n)	:	1.3
Electric motor output	:	25kW
Cylinder bore	=	Stroke
Air gas constant (R)	=	0.287kJ/kgK

Sketch the indicator diagram and calculate,

(i) Mass flow rate of air (m) in kg/s

(ii) Free air delivery in m^3/min

(ii) Volumetric efficiency

(iii) Stroke length.

You may use following expressions with their usual notations.

Compression work (W_c),

$$W_c = \frac{n}{n-1} mR[T_2 - T_1]$$

Volumetric efficiency (η_{vol}),

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

(6) (a) Explain briefly the difference between a impulse turbine and a reaction turbine.

(b) In an impulse turbine (with a single raw wheel) the mean diameter of the rotor is 0.8m and its speed is 2800rev/min. The nozzle angle is 18° and the ratio of blade speed to steam speed is 0.4. The ratio of relative velocity at outlet from the blades to that at inlet is 0.95. The outlet angle of the blade is 4° less than the inlet angle. The steam flow rate is 12kg/s.

(i) Draw the velocity diagram and name the velocity components.
(ii) Determine the blade angles.
(iii) Calculate the tangential thrust and the axial thrust on the blades.
(iv) Calculate the diagram efficiency.

(You may use graphical method or calculation method to determine velocities.)

(7) (a) Define the terms "Isentropic stagnation state" and "Mach number" used in compressible flow.

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

Pressure : 200kN/m^2
Velocity :170m/s
Temperature : 200°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.
Cp for air = 1.005 kJ/kgK
Air gas constant (R) = 0.287 kJ/kgK

You may use the following equations with their usual notations.

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

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

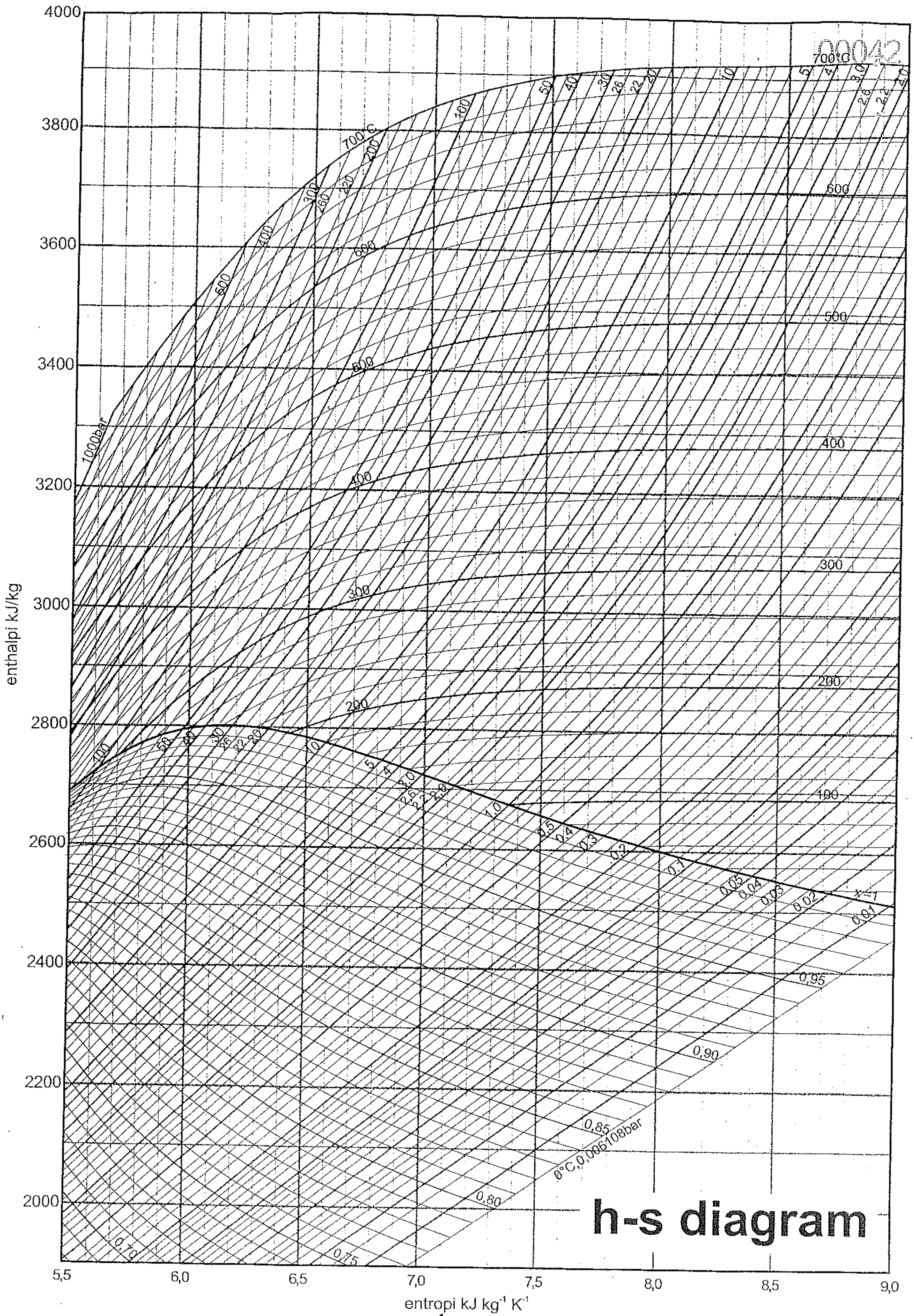
Subscript "s" refers stagnation point, "t" refers the throat of the nozzle and "1" refers inlet section.

(8) (a) Briefly explain the difference between axial flow turbine and a radial flow turbine.

(b) Write down five differences between reciprocating compressors and rotary compressors .

(c) What do you understand by compounding of steam turbines? What are the different types of compounding of steam turbines?

(d) What do you understand by multistage compression? What are its' merits over single stage compression?


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
00042