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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	:	27th January 2022
Time	:	1400-1700h
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 advantages of having reheating stages in a steam power plant? Why is condensation of steam inside a turbine undesirable?

(b) A steam power plant operates with a net power output of 80 MW on an ideal reheat-regenerative Rankine cycle. 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 feed water 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. (Saturated liquid enthalpy values at 0.8 MPa and 10 kPa are 721 kJ/kg and 192 kJ/kg respectively).

(i) Sketch the layout diagram for steam power plant and draw thermodynamic cycle on T-S diagram

(ii) Determine the mass flow rate of steam through the boiler

(iii) Calculate the thermal efficiency of the cycle.

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

(b) Air enters the compressor of an open cycle constant pressure gas turbine at 100 kN/m^2. The pressure of air after compression is 400 kN/m^2. The isentropic efficiencies of compressor and turbine are 74% and 80% respectively. The air fuel ratio is 75:1. The rate of flow of air is 2.5kg/sec.

Following data are given.

Specific heat (C_p) of the products of combustion is equal to 1.005 kJ/kg K.
Ratio of specific heats for both air and gas (γ) = 1.4
Calorific value of the fuel 42000 kJ/kg

(i) Draw the thermodynamic cycle in a T-S coordinates.

(ii) Determine the following.

A. Temperature at the end of compression and expansion.
B. Heat supplied, heat rejected and the network per kg of air.
C. Power developed and the thermal efficiency of the cycle.

(3) (a) Briefly explain the advantages and disadvantages of a closed gas turbine over an open gas turbine.

(b) The following data refers to a gas turbine plant in which the compression is carried out in one stage and expansion is carried out in two stages with reheating.

- Temperature at which air is supplied to the compressor: 303 K
- Air inlet pressure: 1 bar
- Pressure ratio: 5.5
- Maximum temperature of the cycle: 1100K
- Gas is reheated to maximum temperature after expansion in high pressure turbine.
- Pressure ratio for each stage of expansion (high pressure and low-pressure turbine): 2.5
- Assume isentropic expansion in turbine and compression.

(i) Sketch the layout diagram for steam power plant and draw thermodynamic cycle on T-S coordinates

(ii) Calculate the thermal efficiency of the cycle.

(iii) If the capacity of the gas turbine plant is 4 MW, calculate the rate of air supplied to the plant.

(4) (a) Explain the regenerative cycle with open feed heater with suitable diagrams.

(b) A power plant with a power output of 250 MW maintains the outlet pressure of the boiler at 170 bar and the temperature at 600°C. After expansion through the first stage of the turbine to a pressure of 40 bar, 12% 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 10°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.

(5) A single-acting, **two stage** air compressor runs at 300 rev/min and compresses air at 1.013 bar and 15°C to 40 bar. Inlet air flow rate is 8.5 m³/min.

Air gas constant (R) = 0.287kJ/kgK

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 0.04 and 0.06 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/kg.K

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}),

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

(6) (a) Explain briefly the function of blades which are used in an impulse turbine?

(b) In an impulse turbine (with a single raw wheel), steam from the nozzles discharges with a velocity of 500 ms^{-1} and directs 30^{o} to the plane of the wheel. The blade wheel rotates at 3000 rev/min and the mean blade radius is 0.6 m. The axial velocity of the steam is 164 ms^{-1}. Assuming the blades of the impulse turbine are symmetrical,

(i) Draw the velocity diagram and name the velocity components.

(ii) Calculate the following.

A. Blade angles.
B. Diagram efficiency.
C. Blade velocity coefficient.

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

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

(b) Briefly explain the subsonic and supersonic flow effect in nozzles and diffusers using a suitable diagram.

(c) A supersonic jet is flying at the velocity of 1000km/h through still air having a pressure of 78 kN/m^2 at $-8°C$. Considering the stagnation point on the nose of the plane, calculate,

(i) Stagnation temperature and stagnation pressure.

(ii) Sonic velocity and Mach number.

Assume isentropic flow through the nozzle.
Cp for air is 1.005 kJ/kgK, $\gamma = 1.4$
Air gas constant (R) = 0.287 kJ/kgK

You may use the following equations with their usual notations.

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

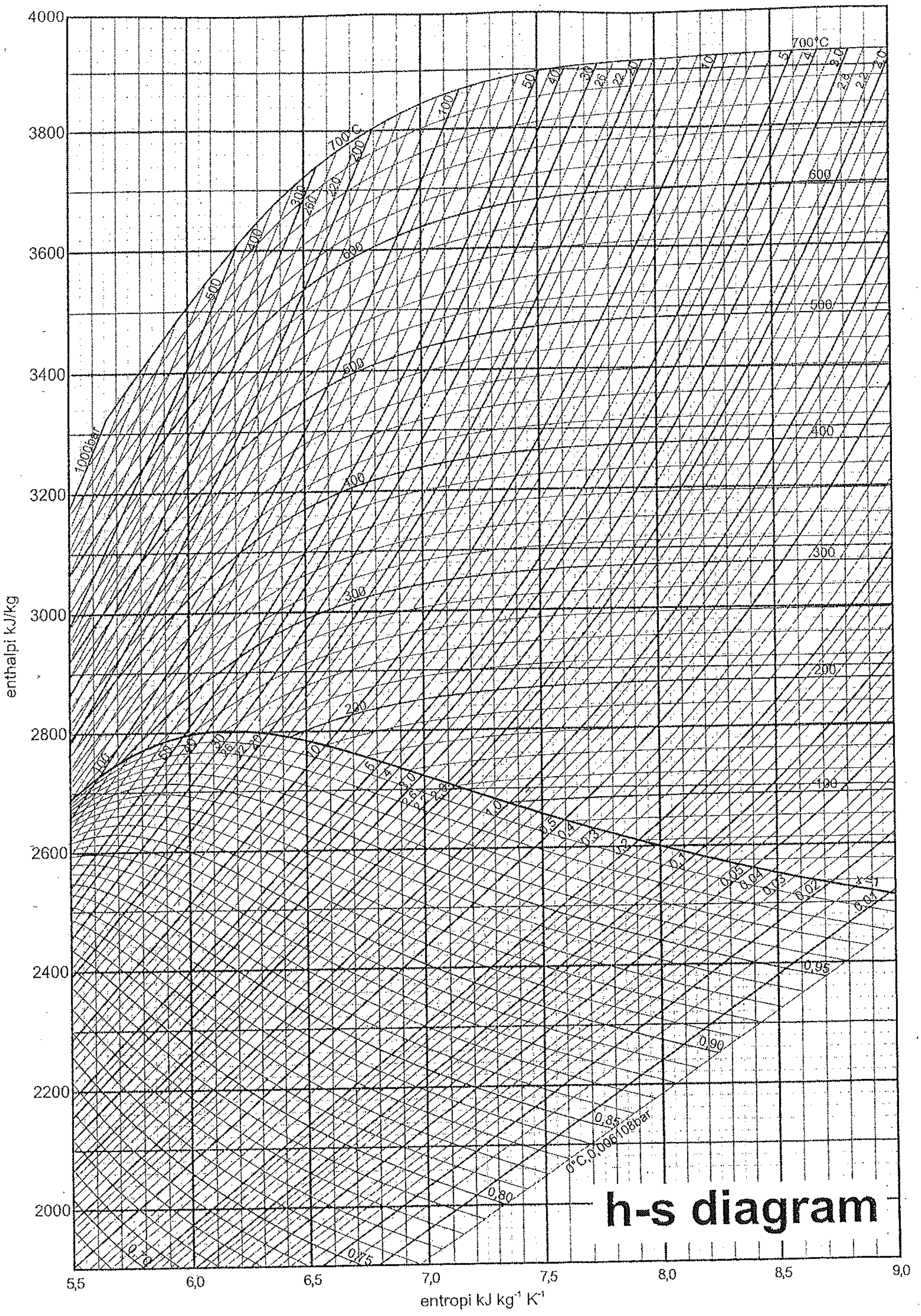
$$\frac{P_S}{P_1} = \left(\frac{T_S}{T_1}\right)^{\frac{\gamma}{\gamma-1}}$$

(8) (a) Explain the reheating and intercooling of a practical gas turbine plant the aid of a schematic diagram.

(b) What is the principle of jet propulsion? Briefly explain the ideal jet propulsion cycle and the classification of jet propulsion engines.

(c) Write a short note on vapor power cycle application in nuclear power plants.

(d) Describe the difference between positive displacement and non-positive displacement in rotary air compressors.


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