00034

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	:	**DMX5531 Applied Thermodynamics**
Academic Year	:	2020/21
Date	:	25th February 2022
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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(01) A steam turbine plant with one open feed water heater, operates at a boiler pressure of 40bar, a superheat temperature of 450°C and a condenser pressure of 0.07bar. The turbine develops a gross power of 30MW. Steam is bled from the turbine to a open heater at 9bar, and the saturated liquid from the condenser is pumped into the feed water heater by a feed pump. Saturated liquid coming from the open heater is pumped into the boiler by a second feed pump.

Assume heat transfer from the Open heater to atmosphere is negligible.

Take saturated liquid enthalpy of steam at 0.07bar and 9bar as 163kJ/kgK and 743kJ/kgK respectively.

Calculate the following on the assumption of isentropic flow through the turbine.

(a) Mass of bled steam per kg of steam generated
(b) Rate of steam generation
(c) Net power developed and
(d) Thermal efficiency of the plant.

00034

(02) In an open cycle gas turbine plant, two stage compression with perfect intercooling and one reheating stage is employed. The air is drawn in at a pressure and temperature of 1 bar and 27°C. The overall pressure ratio of compression is 6:1. The temperature of the gases at inlet to the High Pressure (HP) turbine is 560°C and the gases are reheated to 560°C after expansion and then fed to the Low Pressure (LP) turbine. The HP turbine drives the compressor and the LP turbine drives the alternator.

(a) Find the following

(i) Calculate the exit temperature of HP Turbine.

(ii) Determine the reheat pressure.

(iii) Find the temperature of LP turbine exhaust gas.

(iv) Determine the thermal efficiency of the plant

(b) How would you improve the thermal efficiency of the gas turbine plant further? Explain with reasons.

Neglect mass of fuel

Assume isentropic expansions and compressions.

Take Cp as = 1.005 kJ/kgK throughout the cycle

(03) (a) Briefly explain the difference between an impulse turbine and a reaction turbine.

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

(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%.

(04) (a) When selecting a refrigerant for a certain application, what qualities would you look for in the refrigerant?

(b) Refrigerant 134a is the working fluid in an ideal vapor-compression refrigeration cycle that communicates thermally with a cold region at 0°C and a warm region at 26°C. Saturated vapor enters the compressor at 0°C and saturated liquid leaves the condenser at 26°C. The mass flow rate of the refrigerant is 0.08 kg/s.

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

(ii) Calculate the compressor power, in kW.

(iii) Determine the refrigeration capacity, in tons.

(iv) Determine the coefficient of performance.

(v) Calculate the coefficient of performance of a Carnot refrigeration cycle operating between same warm and cold regions and compare results.

Some properties of R134a at specified temperatures are given below.

Temp °C	Sat. pressure (bar)	Enthalpy (kJ/kg)	
		Sat. liquid	Sat. vapour
0	3	-	247.23
26	6.85	85.75	-

Enthalpy at the end of compression process – 264.7 kJ/kg

(05) (a) Coal is used predominantly to produce electricity and to provide fuel for industries that require large amounts of heat. Briefly describe the types of coal used in industry.

(b) Calorimetry is the quantitative measurement of the heat generated during a chemical process. What are the two basic types of calorimetry? State the measurements taken under each type.

(c) Define internal energy of combustion of fuel.

(d) When all the products of the gaseous ethane (C_2H_6) are in the gaseous phase, the enthalpy of combustion at 25°C is – 47,590kJ/kg. Find the internal energy of combustion.

The mean specific heat values in kJ/kg in the temperature are:

C_2H_6 – 2.800, O_2 – 0.989, CO_2 – 1.049, H_2O (vap) – 1.987, N_2 – 1.066

(06) (a) Why are heat transfer coefficients for natural convection much less than those for forced convection?

(b) A nuclear reactor with its core constructed of parallel vertical plates 2.5m high and 1.5m wide, has been designed on free convection heating of liquid Bismuth. The maximum temperature of the plate surfaces is limited to 970°C while the lowest allowable temperature of Bismuth is 330°C. Calculate the maximum possible heat dissipation from both sides of each plate.

You are given following equations with their usual notations.

$$Nu = 0.13(Gr.Pr)^{1/3}$$

$$Gr = \frac{g\beta\theta L^3}{\vartheta^2}$$

where the properties evaluated at the mean film temperature of 650°C for Bismuth are,

ρ = 104 kg/m^3
Cp = 150.7 J/kgK.
β = 1.08 x 10^{-3}K^{-1}

μ = 8.66 x 10^{-4} kg/ms
k = 13.02 W/mK

(07) (a) Why are counter flow heat exchangers mostly used?

(b) Alcohol passes through a counter flow heat exchanger at a rate of 0.2 kg/s and is cooled from 65°C to 40°C by a flow of cooling water, which enters the heat exchanger at 12°C and at a rate of 0.16kg/s.

(c) The mean values of the convection heat transfer coefficients are 340W/m^{2}K between alcohol and tube wall, and 225W/m^{2}K between tube wall and water. The tubes have a wall thickness of 3mm. The thermal conductivity of the tube material is 385 W/mK. Take Cp for alcohol as 2520 J/kgK and for water as 4187 J/kgK.

Calculate the following.

(i) Logarithmic Mean Temperature Difference (LMTD)

(ii) Overall heat transfer coefficient

(iii) Total surface area required for heat exchange

(iv) LMTD and the total surface area, if the heat exchanger was of the parallel-flow type

(08) A supersonic wind tunnel nozzle is to be designed for exit Mach no M_2 = 2 with a throat section 0.14m^2 in area. The supply pressure and the temperature at the nozzle inlet, where the velocity is negligible are 90 kPa and 33°C respectively.

Determine the following;

(i) Exit area
(ii) Pressure, temperature and velocity at the throat and exit

Take γ = 1.4

You may use following equations with usual notations.

$$\frac{A_2}{A_1} = \left[\left(\frac{2}{\gamma+1}\right)\left(1+\frac{\gamma-1}{2}M_2^2\right)\right]^{\frac{\gamma+1}{2(\gamma-1)}} \times \frac{1}{M_2}$$

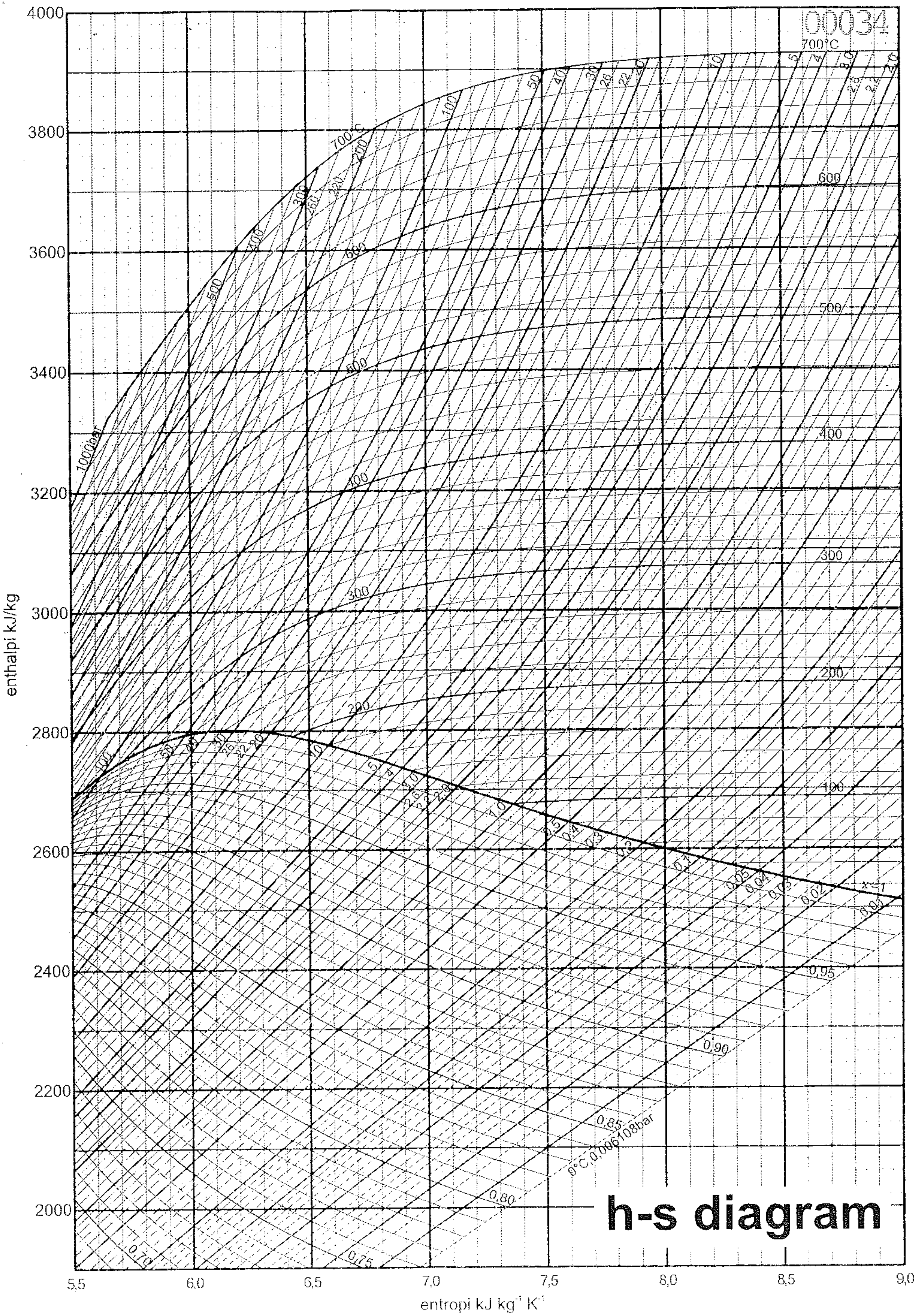
$$\frac{T_1}{T_o} = \frac{2}{\gamma+1}$$

$$\frac{P_o}{P_2} = \left[1+\frac{\gamma-1}{2}M_2^2\right]^{\frac{\gamma}{\gamma-1}}$$

$$\frac{P_1}{P_o} = \left(\frac{2}{\gamma+1}\right)^{\frac{\gamma}{\gamma-1}}$$

$$\frac{T_o}{T_2} = \left[1+\frac{\gamma-1}{2}M_2^2\right]$$

Where subscripts 1,2 and t denote the inlet, exit and throat areas respectively.



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