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/MEX5231 Applied Thermodynamics**
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) Define back work ratio as applied to the gas turbine power cycle.

(b) A gas turbine power plant operating on regeneration cycle uses air as the working fluid. Air enters the compressor at 1 bar, 300K with a mass flow rate of 0.4kg/s, and is compressed to 4bar. The temperature at the inlet to the high pressure turbine is 1200K. All the power developed by the high-pressure turbine is used to run the compressor. The low-pressure turbine provides the net power output. Assume isentropic processes in compressor and turbines. The regenerator effectiveness is 80%.

(i) Sketch the T-S diagram to show all processes.

(ii) Determine the inlet pressure of the power turbine.

(iii) Calculate net power output in kW and the thermal efficiency of the plant.

(iv) Calculate the back work ratio.

(2) (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 feed pump work.

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

(3) (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 = 1.005kJ/kgK
Air gas constant (R) = 0.287kJ/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

(4) (a) Define Coefficient of Performance (COP) for a refrigerator.

(b) A one tonne refrigerator operating on vapour compression cycle works within the temperature limits of 261K and 295K. T-S diagram of the cycle is given below in figure Q(4). Refrigerant leaves the compressor dry saturated.

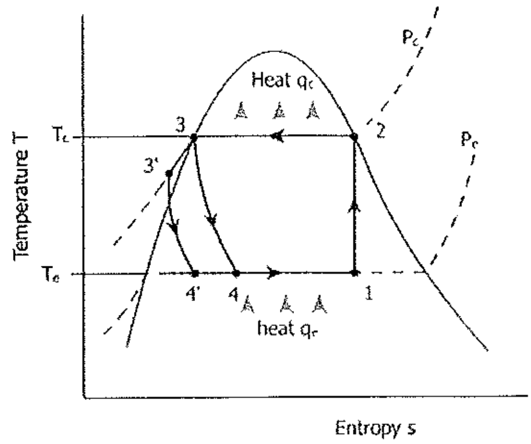


Figure Q(4)

Calculate the COP under following conditions,

(i) no under cooling
(ii) undercooling of 25°C.

(c) Hence show that the subcooling reduces the power requirement of a refrigerator.

You may take 1TR = 3.5kW

Properties of refrigerant is given below.

Temperature (K)	Enthalpy(kJ/kg)		Entropy(kJ/kgK)		Cp (kJ/kgK) (liquid)
	liquid	vapour	liquid	vapour	
261	56.32	322.58	0.226	1.2464	1.03
295	151.96	293.29	0.554	1.0332	

(5) (a) Differentiate between higher and lower calorific values.

(b) What is meant by the stoichiometric air/fuel ratio as applied to combustion of fuels?

(c) The fuel supplied to a boiler contains 70% carbon, 12% hydrogen, 10% oxygen, and 8% ash by mass. The air supplied to the boiler is 40% in excess of theoretically required for complete combustion. The boiler house ambient temperature and flue gas temperature are measured as 33°C and 400°C respectively. 00083

Assuming air contains 23% oxygen by mass and the mean specific heat capacity of the dry flue gas is 1.006 kJ/kgK, calculate the following.

- (i) Actual air supplied in kg/kg_{fuel}
- (ii) Mass of dry flue gas per kg of fuel
- (iii) Energy carried away by the dry flue gas per kg of fuel burn

(6) In a simple impulse turbine steam enters through the nozzle with an angle of 20°and at 1000 m/s. The blade speed is 400m/s and the blades are symmetrical. The steam enters the blades without shock. Steam mass flowrate is 0.75kg/s. Neglect the friction effects on the blades.

- (i) Determine the blade angles.
- (ii) Calculate the tangential force on the blades
- (iii) What is the diagram efficiency?
- (iv) If the relative velocity coefficient is 0.8 what is then diagram efficiency?

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

(7) (a) Define the emissive power and state the units.

(b) Grashoff number is given by the following expression. Identify each parameter and state the units of each parameter.

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

(c) An electric heater 30 mm diameter and 0.4m long is used to heat a room. The bulk of the air in the room is at 20°C. The walls are at 16°C and the surface of the heater is at 540°C.
Calculate the,

- (i) Grashoff number and Nusselt number
- (ii) convection heat transfer coefficient
- (iii) electrical input to the heater

Assume black body condition.
Take Emissivity of the heater surface as 0.55

You may use following data

$Nu = 0.4(Gr)^{1/4}$ where all properties are at mean film temperature

Air Properties at mean temperature:
Kinematic viscosity (ν) $= 4.48 \times 10^{-5}$ m^2/s
Thermal conductivity (k) $= 4.375 \times 10^{-5}$ kW/mK
Coefficient of cubic expansion (β)= $1/293$ K^{-1}

(8) (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.

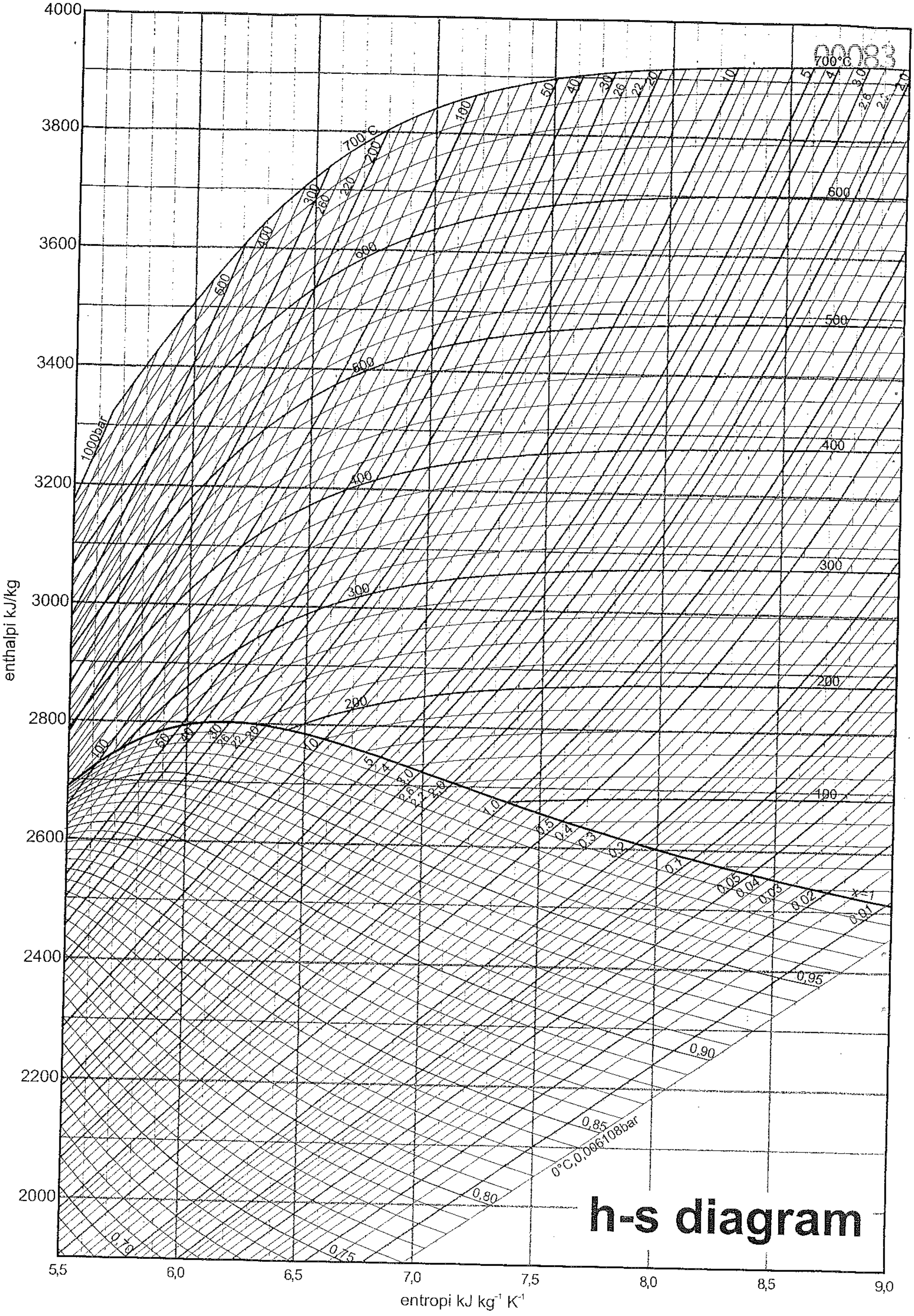
$$Nu = 0.13(Gr.Pr)^{1/3}$$

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

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


00083
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
600
500
400
300
200
100
x=1
0,95
0,90
0,85
0,80
0,75
0,70
0°C,0,006108bar
h-s diagram