The Open University of Sri Lanka
Faculty of Engineering Technology

00056

Study Programme	:	Bachelor of Technology Honours in Engineering
Name of the Examination	:	Final Examination
Course Code and Title	:	**MEX5231Applied Thermodynamics**
Academic Year	:	2014/15
Date	:	3rd September 2015
Time	:	0930-1230h
Duration	:	**3 hours**

General instructions

1. Read all instructions carefully before answering the questions.
2. Answer any **five questions.** All questions carry equal marks.
3. Density of water 1000 kg/m^3. Acceleration due to gravity = 9.81 m/s^2.
4. For air C_p = 1.005 kJ/kgK, C_v = 0.718 kJ/kgK R = 0.287 kJ/kgK γ = 1.4

1 a State three important modifications that could be made to a simple gas turbine plant to improve performance. (03 marks)

b In an open cycle gas turbine plant air with 30°C and 1 bar is compressed through a pressure ratio of 9. The compression of air is achieved in two stages with complete intercooling in between at optimum pressure. Temperature of the compressed air after second stage of compression is 800°C and air at this state is sent for expansion in two stages of the gas turbine. First stage expansion occurs up to 2 bar and is subsequently reheated up to 700°C before being sent to second stage of the turbine where gas is expanded to the original pressure. Assume specific heat capacity (Cp) and ratio of specific heat capacities (γ) as 1.005 kJ/kgK and 1.4 throughout the cycle. Take isentropic efficiency of compression and expansion to be 85% and 100% respectively. Air flows into compressor at 30 kg/s.

i Sketch the T-S diagram to show all processes. (02 marks)
ii What is the optimum pressure ratio for each stage of compression? (02 marks)
iii Calculate the net power output of the plant neglecting mass of fuel. (08 marks)
iv Calculate the thermal efficiency of the plant. (03 marks)
v Can the thermal efficiency of this plant be improved further? Justify your answer. (02 marks)

2 a Explain the concept of regeneration that can be used to improve thermal efficiency of a steam power plant. (04 marks)

b The following data relate to a regenerative steam power plant of 50 MW capacity.
Condition of steam supplied to the steam turbine – 60 bar, 450°C
Condenser pressure – 0.4 bar
Pressure at which steam is bled from the steam turbine – 3 bar
Boiler efficiency – 85%
Mechanical efficiency from the turbine to generator – 97%

Neglect the feed pump work and determine the
i steam bled per kg of steam supplied to the turbine (04 marks)
ii steam generated in tonnes per hour (06 marks)
iii overall efficiency of the plant. (06 marks)

3 a Briefly describe the Rotodynamic machines and its classification. (04 marks)

b In an impulse turbine the steam discharges from the nozzles with a velocity of 900 m/s. The nozzle angle is 20°. Ratio of blade speed to whirl component of steam speed at inlet (absolute velocity of steam) is 0.3. Blade velocity coefficient is 0.7. Calculate for a mass flow of 1kg/s, and symmetrical blading,
i blade inlet angle (04 marks)
ii driving force on the wheel (04 marks)
iii axial thrust (04 marks)
iv diagram power (02 marks)
v diagram efficiency. (02 marks)

4 a What are the desirable properties of a good refrigerant? (04 marks)

b Discuss the effect of superheating of vapour after compression and sub cooling of liquid after condenser in a vapour compression refrigeration system. (02 marks)

c A cold storage room requires a refrigeration system of 20 tonnes capacity. The evaporator temperature is - 8°C and condenser temperature is 30°C. The refrigerant is sub cooled by 5°C and the vapour is superheated by 6°C before entering the compressor.

i Draw the P-V or T-S diagram to represent the process. (04 marks)
ii Calculate the Mass flow rate of refrigerant .
iii Determine the Coefficient of Performance (COP) (04 marks)
iv Calculate the consumption of electricity for 8 hours of operation of the refrigeration system. Overall efficiency of the compressor motor drive is 70% . (04 marks)

Properties of refrigerant are given below.

Temperature (°C)	Enthalpy(kJ/kg)		Entropy(kJ/kgK)	
	liquid	vapour	liquid	vapour
- 8	28.72	184.07	0.11149	0.7007
30	64.59	199.62	0.2400	0.6853

Take specific heat capacity of liquid refrigerant and vapour refrigerant are 1.235 kJ/kgK and 0.733 kJ/kgK respectively.

5 a Derive an expressions given below for the critical pressure (p*) and critical temperature (T*) for a gas flow in a nozzle.

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

$$\frac{T^*}{T_o} = \frac{2}{\gamma + 1}$$

Where T_o is the isentropic stagnation temperature and P_o is the isentropic stagnation pressure. (10 marks)

b Helium at 950 kPa and 500 K expands isentropically in a convergent divergent nozzle to a pressure of 100 kPa.

If the inlet velocity is negligible find the

i critical pressure, Critical temperature and critical velocity (06 marks)

ii throat area of the nozzle (02 marks)

iii Mach no at exit. (02 marks)

6 a How does radiation heat transfer take place? (04 marks)

b

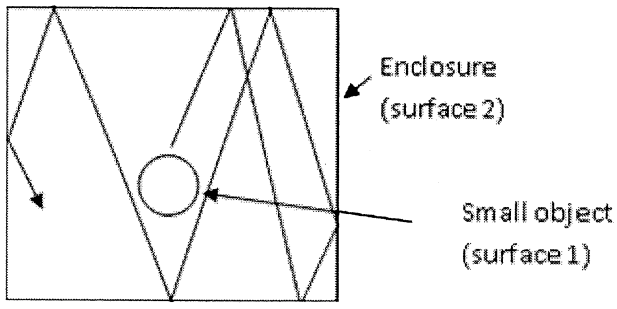


Figure Q6

As shown in figure Q6 small object is kept in a large enclosed area. Write down an expression for the net exchange of radiation between two surfaces (02 marks)

c A pig is in a barn. The body surface area of the pig is 2.5 m^2. The barn is 12 m by 6 m with 2 m high walls.
The emissivity of the skin of the pig can be assumed to be 0.9.
Take shape factor from object to wall ($F_{object\text{-}wall}$; $F_{1\text{-}2}$) is 1

i Find the shape factor from barn to the pig ($F_{2\text{-}1}$). (06 marks)

ii If the pig's skin temperature is 42°C and average temperature of the surroundings (including barn walls) is 28°C, determine the rate of heat loss by radiation from the pig. (08 marks)

7 a Define Nusselt Number (N_u) and Prandtl Number (P_r) with usual notations and identify each term. (06 marks)

b A metal plate 0.6 m in height forms the vertical wall of an oven and is at a temperature of 200°C. Within the oven air is at a temperature of 90°C and the atmospheric pressure.

Assume following data:
Thermal conductivity air close to oven = 33×10^{-6} kW/mK
Viscosity of air = 0.232×10^{-4} kg/ms
Specific heat capacity of air = 1.005 kJ/kgK
Coefficient of cubic expansion of air = 2.5×10^{-3} K^{-1}
Atmospheric pressure = 1.01325×10^5 N/m^2

For free convection the heat transfer coefficient (h) is given by,

$$h = \frac{k}{l} C(p_r G_r)^m$$

where Grashof Number (Gr) with usual notations is given by

$$G_r = \frac{\beta \theta l^3}{\vartheta^2}$$

C and *m* are constants that are found using experimental data and given in the table Q7

Object	Flow type	C	m
vertical plates and cylinders	Laminar	0.59	1/4
	Turbulent flow	0.13	1/3
Horizontal cylinder	Laminar	0.53	¼
	Turbulent	0.13	1/3

Table Q7 - C and m values for cylinders and plates

i Determine whether the flow is laminar or turbulent. (04 marks)
ii Find the mean convection heat transfer coefficient. (08 marks)
ii Calculate the heat loss rate from a unit area of the wall. (02 marks)

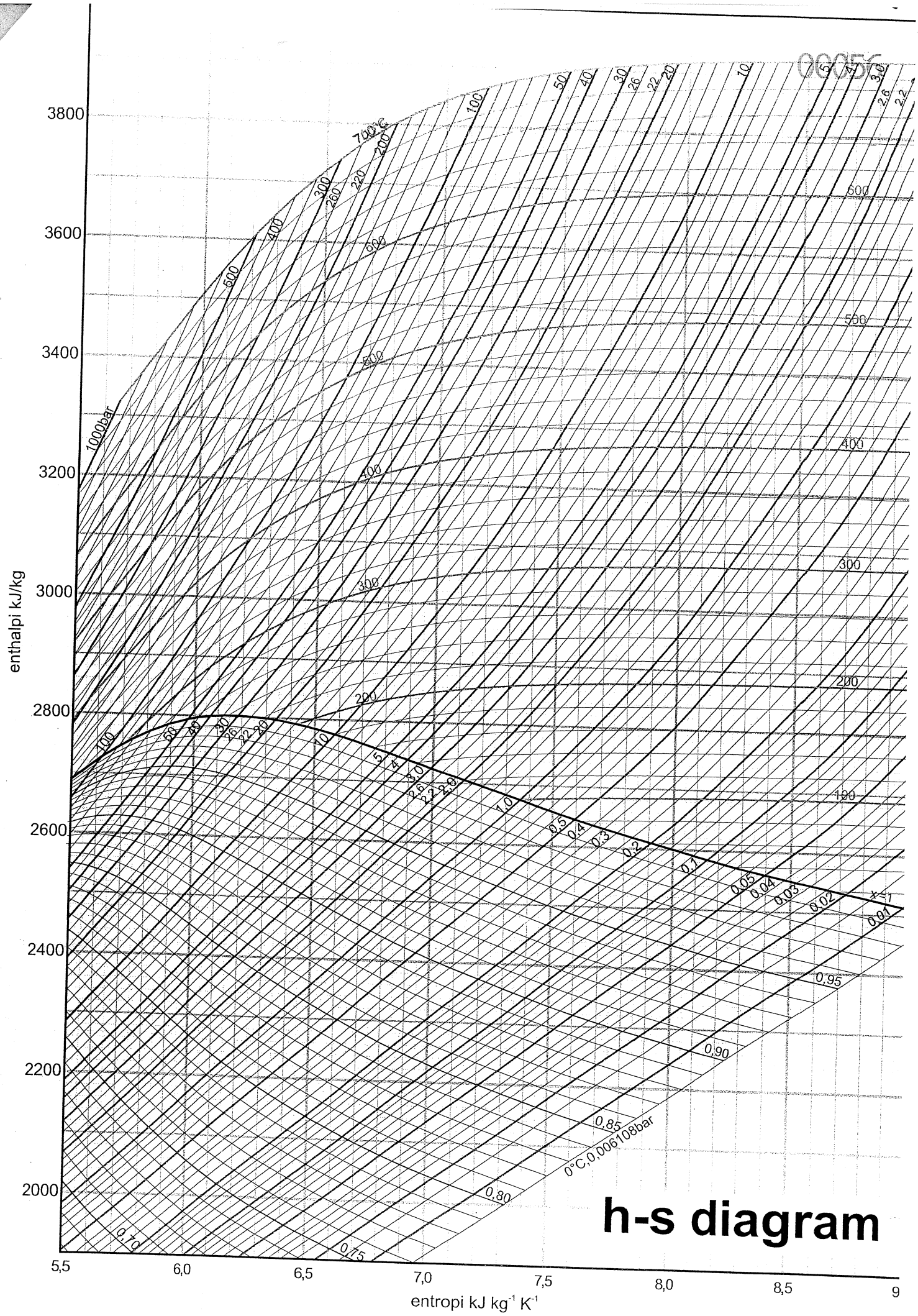
8 a A mixture of 80% methane (CH_4) and 20% hydrogen (by volume) is burnt in air at atmospheric pressure.
Determine the
i stoichiometric air to fuel ratio by volume (04 marks)
ii air to fuel ratio by volume if 20% excess air is supplied (04 marks)
iii wet volumetric composition of the products if 20% excess air is supplied. (04 marks)

b i Define enthalpy of combustion (04 marks)
ii Calculate the enthalpy of combustion for gaseous propane (C_3H_8) at 25°C, 1atm with liquid water in the products. Enthalpy of formation values are given in table Q8 (04 marks)

Substance	$\bar{h}_f^o$ (kJ/mol)
$C_8H_{18}(g)$	-103.8
$H_2O(l)$	-285.8
CO_2	-393.5

Table Q8

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h-s diagram
enthalpi kJ/kg
entropi kJ kg⁻¹ K⁻¹
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
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