The Open University of Sri Lanka
Faculty of Engineering Technology

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Study Programme	:	Diploma in Technology/Bachelor of Technology (Engineering)
Name of the Examination	:	Final Examination
Course Code and Title	:	**MEX5231Applied Thermodynamics**
Academic Year	:	2013/14
Date	:	21st August 2014
Time	:	0930-1230hrs
Duration	:	3 hours

General instructions

1. Read all instructions carefully before answering the questions.
2. This question paper consists of 8 questions. All questions carry equal marks.
3. Answer any 5 questions.
4. For air C_p = 1.005 kJ/kgK, C_v = 0.718 kJ/kgK R = 0.287 kJ/kgK and γ = 1.4

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(1) (a) Show that the thermal efficiency of an ideal regenerative Brayton cycle employing a perfect heat exchanger is equal to,

$$\eta = \left[1 - \frac{T_1}{T_3}(r_p)^{\frac{\gamma-1}{\gamma}}\right]$$

where T_1 – minimum temperature of the cycle
T_3 – maximum temperature of the cycle
r_p – pressure ratio
γ – ratio of specific heat capacities of air

(b) In a gas turbine plant, air is compressed from 1.01bar and 27°C through a pressure ratio of 7:1. It is then heated to 850°C in a combustion chamber and expanded in a turbine to initial pressure. Calculate the cycle efficiency for the following conditions.

(i) A perfect heat exchanger is employed between the compressor and the combustion chamber.
(ii) A heat exchanger of effectiveness 60% is employed.
(iii) A Perfect heat exchanger and a reheater are employed. Assume that steam is to be reheated to the 850°C at the pressure of 3bar.

(2) (a) What features distinguish the simple Rankine steam cycle from Carnot cycle? What are the advantages and disadvantages of these features?

(b) In a 20MW steam power plant operating on ideal reheat cycle, steam enters the high pressure turbine at 150bar and 600°C and dryness fraction of steam at the exit of the low pressure turbine is 0.895. Assume steam is reheated to the initial temperature. The condenser is maintained that at a pressure of 0.1bar. Determine the

(i) reheat pressure
(ii) thermal efficiency neglecting feed pump work
(iii) mass flow rate of steam

(enthalpy of saturated liquid water at 0.1 bar is 192kJ/kg)

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

(b) In a 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

(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%.

(4) A refrigerating system operates with a condensing and evaporating temperatures of 30°C and -5°C respectively. The liquid temperature at the throttle valve entrance is 25°C and the vapour is 0.97 dry before leaving the evaporating coil. At the end of compression vapour is superheated. Determine the

(i) superheated temperature of vapour at the end of compression
(ii) theoretical COP of the refrigerator
(iii) mass of cooling water required per kg of refrigerant for the condenser, if the temperature rise is to be restricted to 20°C
(Specific heat capacity of water - 4.187 kJ/kgK

Properties of refrigerant is given below.

Temperature (°C)	Enthalpy(kJ/kg)		Entropy(kJ/kgK)	
	liquid	vapour	liquid	vapour
-5	158.26	1431.88	0.63	5.40
30	323.22	1465.38	1.20	4.98

Take specific heat capacity of liquid refrigerant and vapour refrigerant are 5.02 kJ/kgK and 3.35 kJ/kgK respectively.

(5) (a) An ideal gas is flowing through a nozzle such that the Mach number is 2.4 where the flow area is 25cm^2. Assuming the flow to be isentropic, determine the

(i) flow area at the location where the Mach number is 1.2.

(ii) velocity at throat if temperature at inlet is 327°C.
Take γ for gas = 1.33

(b) Steam at 22 bar and 300°C expands isentropically to a pressure of 4 bar in a convergent-divergent nozzle. Calculate the mass flow per unit exit area assuming,

(i) equilibrium flow. Take specific volume at exit condition is 0.510 m^3/kg

(ii) supersaturated flow and the process to follow the law $pv^{1.3}$ = constant. Take specific volume at inlet condition is 0.1120 m^3/kg

You may use following equations with usual notations.

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

$$\frac{T_t}{T_1} = \frac{2}{\gamma+1} \qquad \frac{P_t}{P_1} = \left(\frac{2}{\gamma+1}\right)^{\frac{\gamma}{\gamma-1}}$$

$$C_2 = \sqrt{\{2(h_1 - h_2)\}}$$

$$h_1 - h_2 = \frac{\gamma}{\gamma-1}(p_1v_1 - p_2v_2)$$

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

(6) A 3mm diameter and 5m long electric wire is tightly wrapped with a 2mm thick plastic cover whose thermal conductivity is k = 0.15W/mK. Electrical measurements indicate that a current of 10 A passes through the wire and there is a voltage drop of 8V along the wire. Insulated wire is exposed to a medium at T = 30°C with a heat transfer coefficient of h = 12W/m^2 K.

(i) Assuming steady state, one dimensional heat transfer determine the heat generated within the wire.

(ii) Estimate the temperature at the interface of the wire and the plastic cover assuming heat is generated uniformly throughout the wire and is transferred to the surrounding in the radial direction.

(iii) Determine whether doubling the thickness of the plastic cover will increase or decrease this interface temperature.

(7) (a) Define Nusselt Number (Nu), Prandtl Number (Pr) and Reynolds number (Re) with usual notations. Define each parameter.

(b) A domestic air cooler has a cooling coil with 30 parallel tubes of 0.6cm outside diameter and length 15cm, fitted into a space of 15cm high by 20cm wide. The coils are kept at a constant surface temperature of 6°C by a refrigeration circuit. The air enters at 0.4ms^{-1} and 32°C to cross the tube array. Calculate the

(i) convection heat transfer coefficient and the heat transfer rate for a single tube in the array considered in isolation and hence for the whole array

(ii) mass flow rate of air entering the cooler

(iii) temperature of the air leaving the array.

Properties of air at mean temperature (19°C)

$\rho_{air} = 1.228\ kgm^{-3}$
$\mu_{air} = 1.788 \times 10^{-5}\ kgm^{-1}s^{-1}$
$k = 2.53 \times 10^{-2}\ Wm^{-1}K^{-1}$
$C_p = 1.005\ kJ/kgK$

You may use following formula

$$Nu = 0.26Re^{0.6}Pr^{0.3}$$

(8) (a) Define Enthalpy of Combustion (ΔH_o) using H_{po} and H_{RO} , enthalpy of products and reactants at standard conditions respectively.

(b) Define Enthalpy of Formation.

(c) What is the standard enthalpy of formation of an element in its natural state?

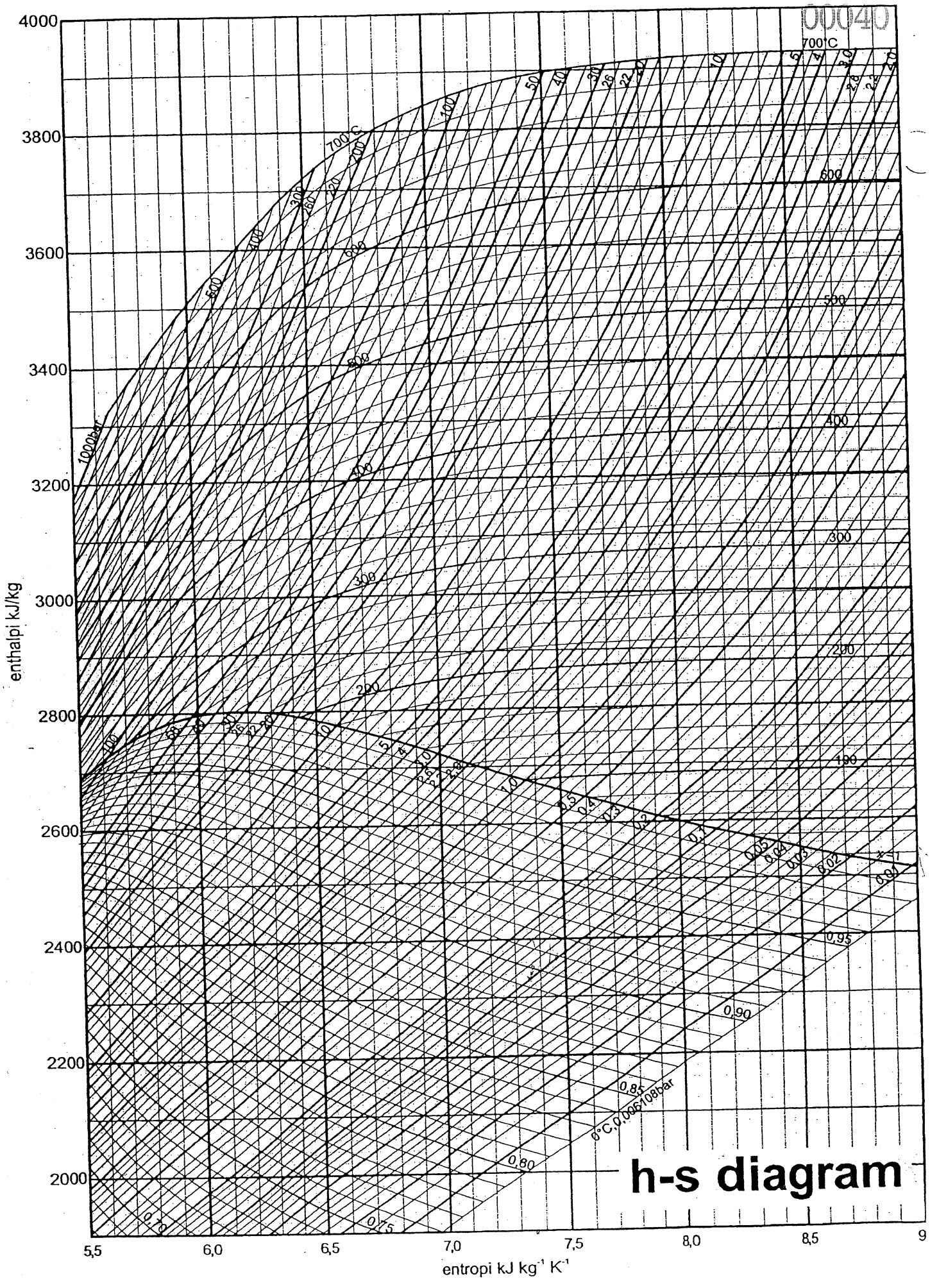
(d) Liquid octane (C_8H_{18}) enters a steady flow combustion chamber at 25°C and 1 atm at a rate of 0.25kg/min. It is burned with 50 percent excess air that also enters at 25°C and 1 atm. After combustion, the products are allowed to cool to 25°C. Assuming complete combustion and that all H_2O in the products is in liquid form,

(i) write down the combustion equation for complete combustion of liquid octane including N_2. (Atmospheric air contains 79% N_2 and 21% O_2 by volume)

(ii) determine the heat transfer rate from the combustion chamber. (Values of enthalpy of formation ($\bar{h}_f^o$) at standard conditions are given in below table)

Substance	$\bar{h}_f^o$ (kJ/kmol)
$C_8H_{18}(l)$	-249,950
O_2	0
N_2	0
$H_2O(l)$	-285,830
CO_2	-393,520

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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
700°C
1000bar
0,95
0,90
0,85
0,80
0,75
0,70
0°C,0,006108bar