The Open University of Sri Lanka
Faculty of Engineering Technology

00027

Study Programme	:	Diploma in Technology/Bachelor of Technology (Engineering)
Name of the Examination	:	Final Examination
Course Code and Title	:	**MEX5231Applied Thermodynamics**
Academic Year	:	2012/13
Date	:	8thAugust 2013
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.

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(1) (a) Compare the effect of reheating, regeneration and intercooling on the performance of gas turbine cycle.

(06 marks)

(b) A gas turbine takes in air at a temperature T_1 and compresses it through a pressure ratio r_p in two stages with perfect intercooling. After compression heat is added and the air enters the turbine at a temperature T_5. If an ideal regenerator is employed in this cycle, show that the thermal efficiency of the cycle is equal to

$$\eta = 1 - \frac{2T_1}{T_5}\frac{\left[(r_p)^{\frac{\gamma-1}{2\gamma}} - 1\right]}{\left[1 - (r_p)^{\frac{1-\gamma}{\gamma}}\right]}$$

where γ – ratio of specific heat capacities of air

(14 marks)

(2) 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 the open heater at 9bar, and the saturated liquid from the condenser is pumped into the feed water heater by a feed pump. Saturated liquid that was coming from the open heater is pumped into the boiler by a second feed pump. The energy transferred as heat from the heater to atmosphere is negligible. Saturated liquid enthalpy of steam at 0.07bar and 9bar are 163kJ/kgK and 743kJ/kgK respectively.

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

(a) The mass of bled steam per kg of steam generated
(b) The rate of steam generation
(c) The net power developed and
(d) The thermal efficiency of the plant.

(05 x 4 marks)

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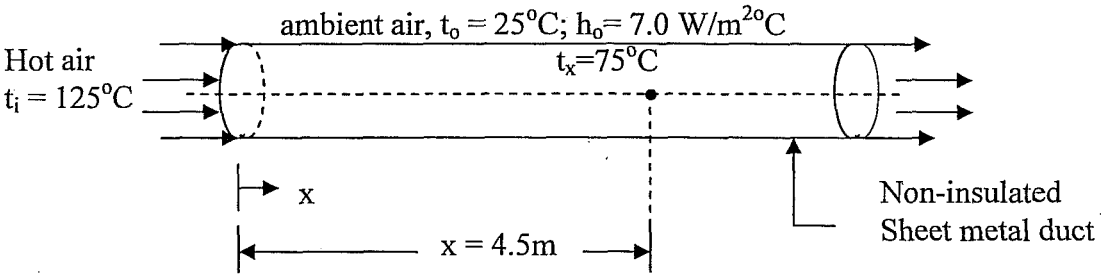
(3) As shown in the figure below 0.08 kg/s of hot air flows through an non-insulated sheet metal duct of 180mm diameter. The air enters the duct at a temperature of 125°C and after a distance of 4.5m gets cooled to a temperature of 75°C. If the heat transfer coefficient between the outer surface of the duct and ambient air at 25°C is 7.0W/m^2°C. Calculate the following.

(i) Heat lost from the duct over its 4.5m length.
(ii) Heat flux at a length of 4.5m
(iii) Duct surface temperature at a length of 4.5m.



Thermo-physical properties of air at 100°C are :

$\rho = 0.972 kg/m^3$	Cp = 1.009 kJ/kg°C
K = 0.03127W/m°C	$\nu = 22.1 \times 10^{-6} m^2/s$
$\mu = 22.14 \times 10^{-6}$ kg/ms	Pr= 0.69

You may use following equation

$$Nu = 0.023(Re)^{0.8}(pr)^{0.333}$$ for turbulent flow

(20 marks)

(4) The velocity of steam leaving the nozzles of an impulse turbine is 1000m/s and the nozzle angle is 20°. The blade velocity is 300m/s and the blade velocity coefficient is 0.7. Calculate for a mass flow of 1kg/s and symmetrical blading,

(i) blade inlet angle
(ii) the driving force on the wheel
(iii) axial thrust
(iv) diagram power
(v) diagram efficiency.

(04 x 5 marks)

(5) (a) Define Coefficient of Performance (COP) for a refrigerator and a heat pump.

(04 marks)

(b) A one tonne refrigerator operating on vapour compression cycle works within the temperature limits of 261K and 295K. Refrigerant leaves the compressor dry and saturated.

Calculate the COP under following conditions,

(i) no under cooling
(ii) undercooling of 20°C.

(10 marks)

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

(06 marks)

Properties of refrigerant is given below.

Saturation temp(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	

(6) 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,

(i) exit area
(ii) pressure, temperature and velocity at the throat and exit
(iii) mass flow rate.

Take $\gamma = 1.4$

You may use following equations.

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

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

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

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

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

Where subscripts 0,1,2 denote the inlet, throat and exit areas respectively.

(20 marks)

(7) (a) (i) State three criteria use to define a "black surface".

(04 marks)

(ii) What is emissivity? Give the range of values for the emissivity of a surface.

(04 marks)

(b) A steam pipe of outside diameter 14cm passes through a large room where the temperature of the surroundings is 303K. The pipe surface temperature is 650K and the emissivity is 0.80.

(i) Calculate the surface emissive power of the pipe.
(ii) Estimate the rate of heat loss per unit length of the pipe due to radiation and convection.

- Heat transfer coefficient by natural convection is $15 W/m^2K$.
- Stefan Boltzmann constant $\sigma = 5.67 \times 10^{-8} W/m^2K^4$

(12 marks)

(8) (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.

(04 marks)

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

(04 marks)

(c) Define internal energy of combustion of fuel.

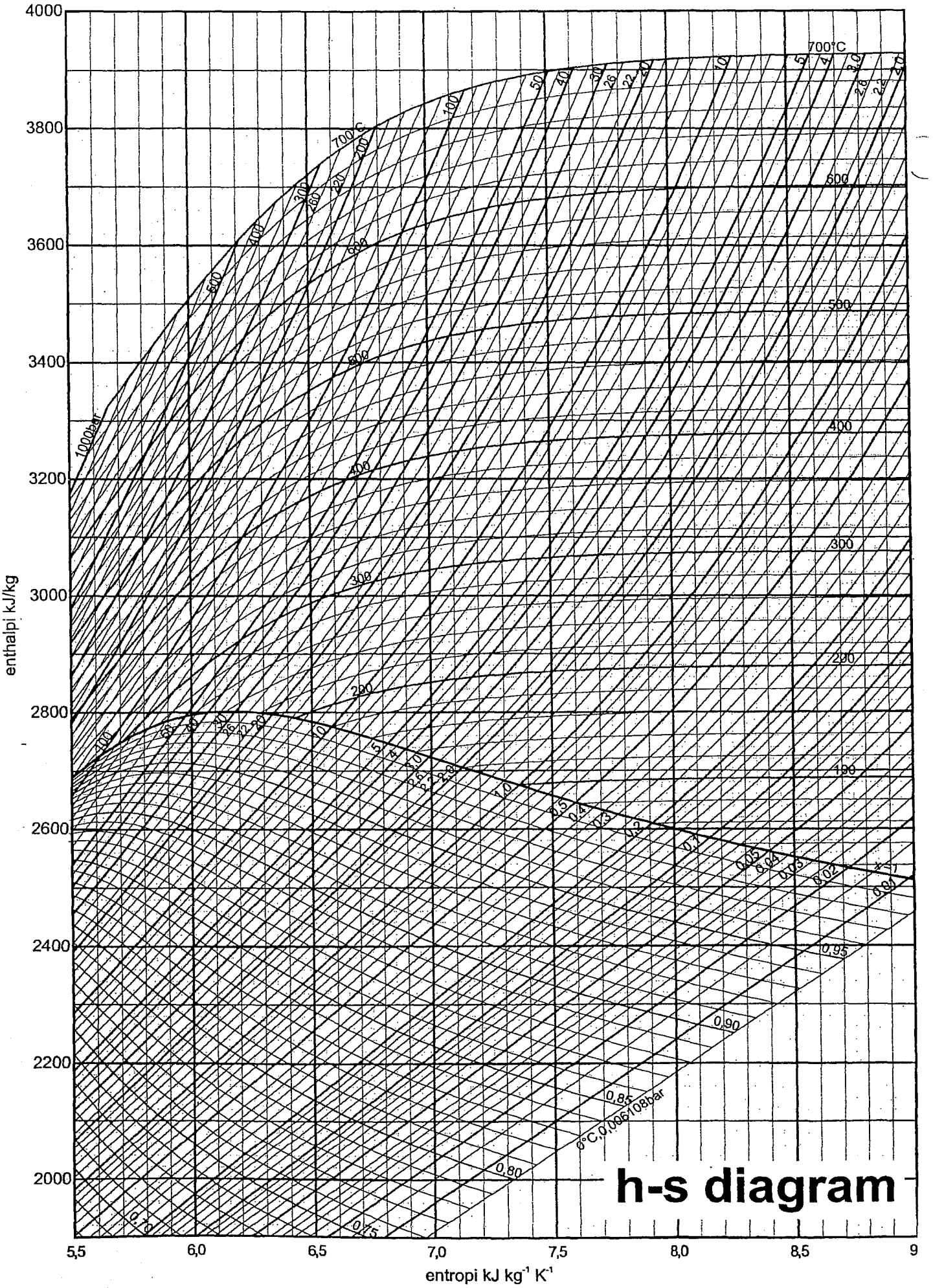
(04 marks)

(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

(08 marks)


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°C,0,006108bar