THE OPEN UNIVERSITY OF SRI LANKA
FACULTY OF ENGINEERING TECHNOLOGY
BACHELOR OF TECHNOLOGY (ENGINEERING)- LEVEL 05
FINAL EXAMINATION- 2010/2011

MEX5231 – APPLIED THERMODYNAMICS

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The Open University of Sri Lanka

DATE : 4th APRIL 2011
TIME : 1400 HRS. – 1700 HRS.
DURATION : THREE HOURS

ANSWER FIVE QUESTIONS ONLY. ALL QUESTIONS CARRY EQUAL MARKS.

(1) (i) Describe simple vapour compression refrigeration cycle giving clearly its flow diagram.

(ii) A simple vapour compression plant produces 5 TR. The specific enthalpy values are given below.

Inlet to compressor - 183.19 kJ/kg
Exit from the compressor - 209.41 kJ/kg
Exit from the condenser - 74.59 kJ/kg

Estimate,

a) refrigerant flow rate.
b) COP.
c) power required to drive the compressor.
d) rate of heat rejection to the condenser.

1TR = 14000 kJ/h

(2) A gas turbine plant operates on the brayton cycle with a regenerator of 100% effectiveness.

(i) Derive an expression for net work output in terms of pressure ratio r_p, maximum temperature T_{max}, and minimum temperature T_{min} of the cycle.

(ii) Hence obtain the following expressions.

(a) Optimum pressure ratio for maximum work output

$$r_p = \left[\frac{T_{max}}{T_{min}}\right]^{\frac{\gamma}{2(\gamma-1)}}$$

(b) Maximum work output

$$W_{max} = C_p\left[\sqrt{T_{max}} - \sqrt{T_{min}}\right]^2$$

(c) Maximum efficiency

$$\eta_{max} = 1 - \left[\frac{\sqrt{T_{min}}}{\sqrt{T_{max}}}\right]$$

(3) In a two stage turbine, superheat steam at 550°C expands isentropically until vapour becomes dry saturated. Steam is then reheated to 400°C and is expanded in a low pressure turbine so that final temperature is 40°C. If the moisture content at the exit of low pressure turbine is 14.67%. Determine,

(i) reheat pressure
(ii) pressure of steam at inlet to the high pressure turbine.
(iii) net work output per kg and
(iv) cycle efficiency.

Assume all process to be ideal. Take saturated liquid enthalpy and entropy at 40° C are 167 kJ/kg and 0.572 kJ/kg respectively. Entropy of saturated vapour at 40° C is 8.256 kJ/kgK.

(4) In an impulse turbine (with a single raw wheel) the mean diameter of the blades is 0.8 m and the speed is 2800 rpm. The nozzle angle is 18°, the ratio of blade speed to steam speed is 0.4 and the ratio of relative velocity at outlet from the blades to that at inlet is 0.85. The outlet angle of the blade is to be made 4° less than the inlet angle. The steam flow rate is 8 kg/s. Draw the velocity diagram for the blades and determine the following.

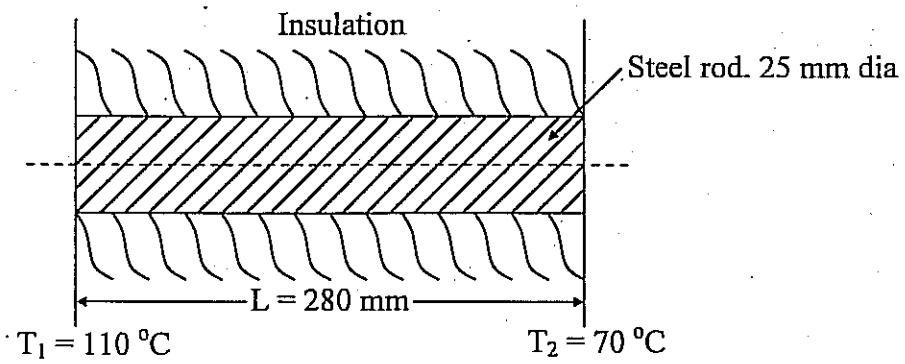
(i) tangential thrust on the blades
(ii) axial thrust on the blades
(iii) resultant thrust on the blades
(iv) power developed in the blades
(v) blading efficiency

(5) As shown in the figure given below two large steel plates at temperature of 110°C and 70°C are separated by a steel rod 280mm long and 25mm in diameter. The rod is welded to each plate. The space between the plates is filled with insulation which also insulates the circumference of the rod. Because of a voltage difference between the two plates an electric current flows through the rod, dissipating electrical energy at a rate of 160W. Find
(i) heat generated per unit volume per unit time.
(ii) the maximum temperature in the rod

Take thermal conductivity of the rod as 4.7 W/mK

The temperature distribution is given by;

$$\frac{dT}{dx} = -\frac{Q_G}{k}x + C_1$$



(6) The percentage composition by mass of a solid fuel used in a boiler is given by

C – 90 %
H2 – 3.2 %
O - 2.9 %
N - 1.4 % and
S - 1.5 %
And the remainder being ash.

(i) Find theoretical air fuel ratio.

(ii) If 50% excess air is supplied in actual combustion, determine the mass analysis of dry products per kg of fuel.

(7) Feed water of a steam power plant is flowing through a tube of 5cm internal diameter with negligible thickness. The inside wall temperature of the tube is 170°C throughout the length. Flow rate of feed water is 180 kg/min. The inlet temperature of the feed water is 30°C and it will be heated to 150°C.

Determine

(i) Surface convection heat transfer coefficient

(ii) Length of the duct.

The following data for water is given at mean temperature of 108 °C.

$Pr = 1.61$, $\mu = 260 \times 10^{-6}$ *kg/ms*, $c_p = 4.226$*kJ/kgK*, $k = 683 \times 10^{-3}$ *W/mK*

The following relationship between dimensionless numbers can be used.

$$N_u = 0.023(R_e)^{0.8}(P_r)^{0.3}$$

(8) (i) What is the function of a nozzle?

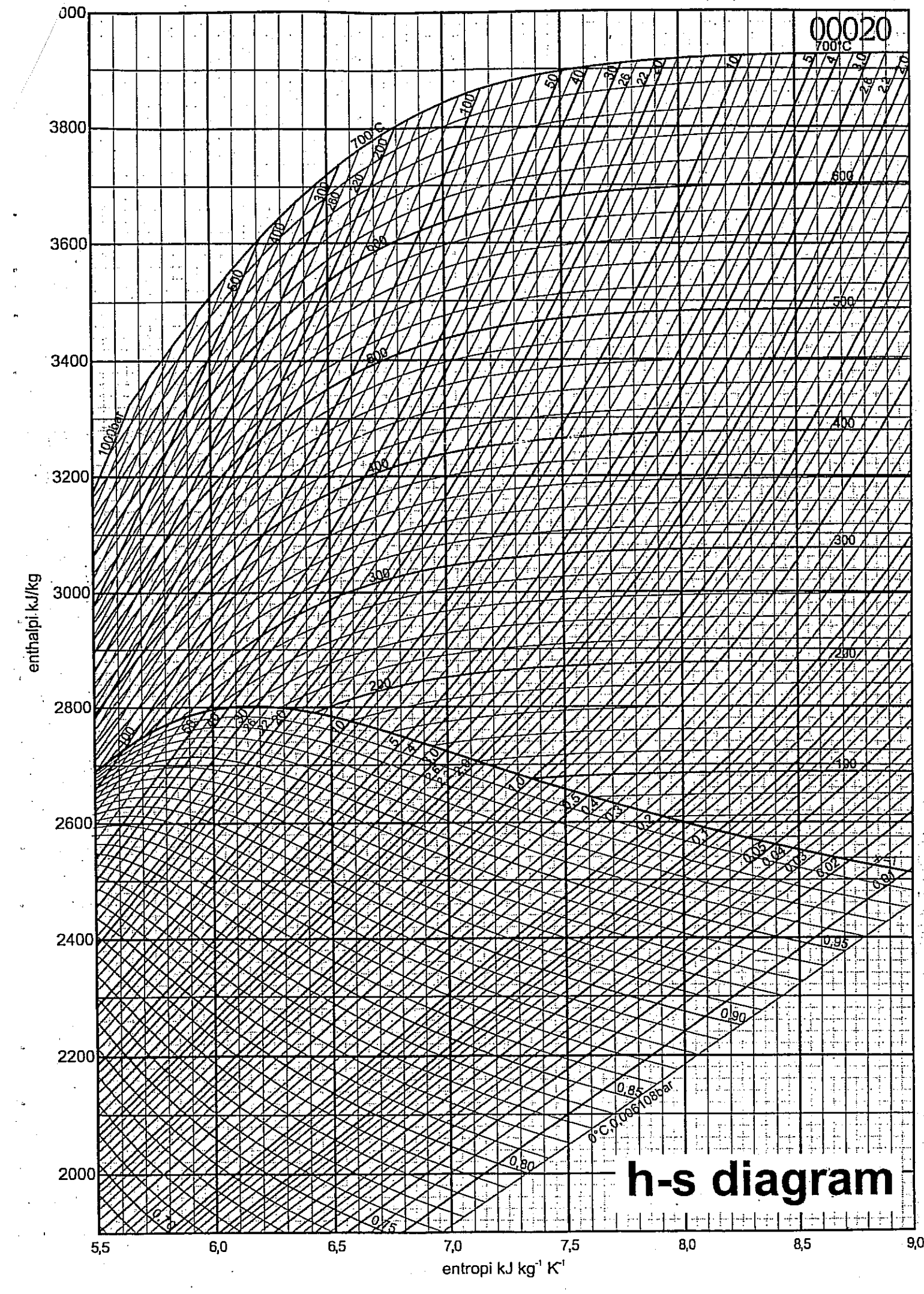
(ii) Explain the term critical pressure as applied to steam turbines.

(iii) Air at a pressure of 20 bar and at a temperature of 27°C is supplied to a convergent divergent nozzle having a throat diameter of 1.25 cm and discharging to atmosphere. Take $\gamma = 1.4$ for air. Find the weight of air discharged per minute. You may use following equations with usual notations

$$\frac{p_t}{P_1} = \left[\frac{2}{\gamma + 1}\right]^{\frac{\gamma}{\gamma - 1}}$$

$$V_t = \sqrt{\gamma R T_t}$$

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00020
700°C
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
9,0
100bar
0,80
0,85
0,90
0,95
0°C,0,006108bar