THE OPEN UNIVERSITY OF SRI LANKA
FACULTY OF ENGINEERING TECHNOLOGY
BACHELOR OF TECHNOLOGY – LEVEL 05
FINAL EXAMINATION– 2008/2009

MEX5231 – APPLIED THERMODYNAMICS

DATE : 24th MARCH 2009
TIME : 1400 HRS. – 1700 HRS.
DURATION : THREE HOURS

ANSWER FIVE QUESTIONS ONLY. ALL QUESTIONS CARRY EQUAL MARKS.

Density of water = 1000kg/m^3. Acceleration due to gravity = 9.81m/s^2

1. A refrigerating system operates with a condensing and evaporating temperatures of 30°C and -5°C respectively. The corresponding pressures are 1.2MPa and 0.35MPa. The temperature of the refrigerant at the throttle valve entrance is 25°C and the vapour is 0.97 dry before leaving the evaporator. Determine,
   (i). the condition of the refrigerant entering the evaporator
   (ii). the coefficient of performance
   (iii). the mass of cooling water used per kg of refrigerant for the condenser, if the temperature rise is to be restricted to 20°C

   The properties of refrigerant

P (MPa)	T °C	h_f (kJ/kg)	h_g (kJ/kg)	s_f (kJ/kg.K)	s_g (kJ/kg.K)
0.35	-5	157.31	1436.7	0.6266	5.3977
1.0	25	298.25	1463.8	1.1210	5.0293
1.2	30	322.42	1466.3	1.2005	4.9738
1.2	40	-	1495.4	-	5.0564
1.2	50	-	1525.1	-	5.1497
1.2	60	-	1553.3	-	5.2357
1.2	70	-	1580.5	-	5.3159

   For water C_p = 4.2 kJ/kg.K

2. In a stage of an impulse turbine provided with a single row wheel, the nozzles are inclined at 20° to the plane of the wheel. The blade rotor with diameter 955mm rotates with a speed 3000rev/min. Determine,
   (i). suitable inlet and outlet angle for the moving blade so that there is no axial thrust on the blade. It may be assumed that friction in blade passage is 19% of the kinetic energy corresponding to relative velocity at inlet to blades.
   (ii). power developed by blading for a steam flow of 1kg/s.
   (iii). kinetic energy of steam finally leaving the stage.

3. In a single heater regenerative cycle the steam enters the turbine at 30bar, 400 °C and the exhaust pressure is 0.10bar. The feed water heater operates at 5bar. Determine,

   (i). the efficiency of the cycle.
   (ii).the increase in mean temperature of heat addition, efficiency and steam flow rate when compared with a Rankine cycle(without regeneration).

4. The following observations were made at a trial o a gas turbine set having a heat exchanger and running the at the design speed:

Isentropic efficiency of the compressor	=	80%
Isentropic efficiency of the turbine	=	85%
Combustion efficiency	=	95%
Pressure ratio	=	5:1
Mass flow of air	=	20kg/s
Heat exchanger effectiveness	=	80%
Maximum cycle temperature	=	725°C

   The ambient temperature and pressure of air are 15°C and 1bar respectively.
   Determine,
   (i). the power output
   (ii).thermal efficiency of the cycle
   (iii). specific fuel consumption
   Assume that there are no pressure losses in heat exchanger and combustion chamber. Take Calorific Value of fuel as 43500kJ/kg, C_p=1.05kJ/kg.K and γ = 1.4.

5. In a gas engine producer plant the volumetric analysis of the produced gas and of the engine exhaust gas were as follows:

Substance	CO%	H_2%	CH_4%	C_2H_4%	CO_2%	O_2%	N_2%
Producer gas	20.5	12.5	3	0.5	7.5	0.2	55.8
Exhaust gas	-	-	-	-	10.7	8.3	81

   Find the chemically correct volumetric analysis of the producer gas and the percentage of excess air supplied to the gas engine.

6. Starting from the basic equation with usual notation, $V_t = \sqrt{2000 \times (h_1 - h_2)}$ and assuming frictionless adiabatic flow through a convergent divergent nozzle, show that the velocity of steam at throat for maximum discharge is given by

$$V_t = \sqrt{2000 \times \frac{n}{n+1} P_1 v_1}$$

   Where n - the index of expansion
   P_1 - Initial pressure of steam in kPa
   v_1 – Initial specific volume of steam in m^3/kg

   40kg of steam per minute is discharged from a convergent divergent nozzle. The Pressure and Temperature of the steam supplied to the nozzle is 10 bar and 200°C respectively. Determine the velocity of the throat and the throat area. Index for the expansion can be considered as 1.3.

7. Show that the amount of heat transfer through a hollow sphere of internal radius r_1, external radius r_2 and inner temperature t_1,outer temperature t_2, is given by $Q = \dfrac{(t_1 - t_2)}{\left(\dfrac{r_2 - r_1}{4\pi k r_1 r_2}\right)}$

A hollow sphere of inside radius 40mm and outside radius 60mm is electrically heated at the inner surface at constant rate $10^5 W/m^2$. At the outer surface it dissipates heat by convection into a fluid at a temperature of 100°C and a heat transfer coefficient of 450W/ m^2.K. The thermal conductivity of the solid is 20 W/ m.K. Calculate the inner and outer surface temperatures of the sphere.

8. A 150mm outer diameter steel pipe lies 2m vertically and 8m horizontally in a large room with an ambient temperature of 30°C. If the pipe surface is at 250°C and the emissivity of steel is 0.60, calculate the total rate of heat loss from the pipe to the atmosphere. Properties of air at 140°C are ρ=0.854kg/m^3, Cp = 1.01kJ/kg K, $\upsilon = 27.8*10^{-6} m^2/s$ and k = 0.035W/mK, Pr = 0.684.

The following relationships are given with usual notation.

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

$$Gr_d = \frac{g\beta\theta D^3}{\nu^2}$$

For Turbulent flow

$$Nu = 0.13(\mathrm{Gr} \times \mathrm{Pr})^{\frac{1}{3}}$$

For Laminar flow

$$Nu = 0.53(\mathrm{Gr} \times \mathrm{Pr})^{\frac{1}{4}}$$