MACHAKOS UNIVERSITY

University Examinations 2016/2017

SCHOOL OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF MECHANICAL AND MANUFACTURING ENGINEERING

THIRD YEAR FIRST SEMESTER EXAMINATION FOR DIPLOMA IN MECHANICAL ENGINEERING

MED-PR 309: THERMODYNAMICS III

DATE:25/7/2017 **TIME: 8:30 – 10:30 AM**

INSTRUCTIONS

Answer Question one and any other Two questions.

SECTION A (COMPULSORY)

QUESTION ONE (30 MARKS)

a) Outline the necessary conditions that must be met for minimum work input of a multi-stage compressor. (2 marks)

b) State **three** factors that heat transfer by conduction depends on. (3 marks)

c) In terms of construction and operation, distinguish between impulse and reaction turbines. (4 marks)

d) Name the types and explain the principles of operation of recuperative heat exchangers. (6 marks)

e) An open gas turbine unit has a pressure ratio of 6/1 and a maximum cycle temperature of 600^0C.The isentropic efficiencies of the compressor and turbine are respectively 0.82 and 0.85.Air enters the compressor at 15^0C at a rate of 15Kg/s.

Take; C_P = 1.005KJ/KgK and γ = 1.4 for the compression process

C_P = 1.11KJ/KgK and γ = 1.333 for the expansion and combustion process.

Draw the plant and T-S diagrams and Calculate**;**

i The power output of an electric generator geared to the turbine

ii Thermal efficiency

iii Work ratio. (15 marks)

SECTION B: (ATTEMPT ANY TWO QUESTIONS IN THIS SECTION)

QUESTION TWO (20 MARKS)

a) Show that the heat transferred Q, through a single flat wall is given as;

$$Q = KA \frac{(T_1 - T_2)}{X}$$

Where; K = thermal conductivity of material

A = area

T_1 = inlet temperature

T_2 = outlet temperature

X = wall thickness (5 marks)

b) A furnace wall consists of 125 mm wide refractory brick and 125 mm wide insulating firebrick separated by an air gap. The outside wall is covered with a 12 mm thick plaster. The inner surface of the wall is at 1100^0C and the room temperature is 25^0C.The heat transfer coefficient from the outside wall surface to the air in the room is 17 W/m^2K, and the resistance to heat flow of the air gap is 0.16K/W. The thermal conductivity of refractory brick, insulating firebrick and plaster are 1.6, 0.3 and 0.14W/mK respectively. Calculate;

i The rate at which heat is lost per unit area of the wall surface

ii Each interface temperature and the temperature of the outside surface of the wall. (15 marks)

QUESTION THREE (20 MARKS)

a) Show that the heat transfer Q for a parallel flow heat exchanger is given by;

$$Q = \frac{U A (\Theta_1 - \Theta_2)}{\ln \left[\frac{\Theta_1}{\Theta_2} \right]}$$

where Θ_1 = temperature difference at inlet

Θ_2 = temperature difference at outlet

U = the overall heat transfer coefficient

A = mean surface area of the tube (12 marks)

b) Oil enters the tube of a double pipe heat exchanger at 100^0C and leaves at 50^0C.The oil is cooled by a counter – current flow of water available at 15^0C.The water and oil flow rates are respectively 3.5 Kg/s and 10.5 Kg/s. The overall heat transfer coeffient is 1640 W/m^2K and the tube has a mean diameter of 12.5 mm.Take specific heat capacity of oil as 2.2 KJ/KgK and that of water as 4.2 KJ/KgK. Determine the length of tube required. (8 marks)

QUESTION FOUR (20 MARKS)

a) A two- stage reciprocating air compressor with complete cooling between stages has inlet and discharge pressure, P_1 and P_2 respectively. Show that the interstage pressure P_i, for minimum work can be expressed as;

$$P_i = \sqrt{P_1 P_2}$$ (7 marks)

b) A single – acting air compressor is required to deliver at 70 bars from an induction pressure of 1 bar at a rate of 2.4 m^3/min, measured at free air condition of 1.013 bar and 15^0C.The compression is carried out in two stages with ideal intermediate pressure and complete intercooling. The clearance volume is 3% of the swept volume in each cylinder and the compressor speed is 750 rev/min.The index of compression and expansion for both cylinders is 1.25,and the temperature at the end of induction in each cylinder is 32^0C.If the mechanical efficiency of the compressor is 85%,draw the indicator diagram and determine the;

i Indicated power

ii Swept volume in low pressure cylinder

iii Power output required from a motor. (13 marks)

Take R = 287J/KgK

QUESTION FIVE (20 MARKS)

In a gas turbine generating set, two stages of compression are used with an intercooler between stages. The high - pressure turbine drives the high - pressure compressor and the low - pressure turbine drives the low – pressure compressor and the alternator. The exhaust gasses from the low – pressure turbine passes through a heat exchanger which transfers heat to the air leaving the high – pressure compressor. There is a reheat combustion chamber between turbine stages which raises the gas temperature to 600^0C, which is also the gas temperature at entry to the high – pressure turbine. The overall pressure ratio is 10/1,each compressor have the same pressure ratio and the air temperature to the unit is 20^0C.The isentropic efficiency of 0.8 for both compressors and 0.85 for both turbines stages may be assumed, and that 2% of the work of each turbine is used in overcoming friction. The heat exchanger thermal ratio is 0.7 and the mass flow rate of air is 115 Kg/s.If intercooling is complete and neglecting all losses in pressure and changes in velocity, draw the plant and T-S diagrams and determine;

a) The power output (16 marks)

b) The overall thermal efficiency of the plant (4 marks)

Take CP and ϒ as 1.005KJ/KgK and 1.4 for all compression processes

C_P and ϒ as 1.15KJ/KgK and 1.333 for all combustion and expansion processes