



MACHAKOS UNIVERSITY

University Examinations 2018/2019

SCHOOL OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF MECHANICAL AND MANUFACTURING ENGINEERING

THIRD YEAR SPECIAL/SUPPLEMENTARY EXAMINATION FOR

DIPLOMA IN MECHANICAL ENGINEERING

MED – PR 308: THERMODYNAMICS III

DATE: 22/7/2019

TIME: 2.00-4.00 PM

INSTRUCTIONS:

Answer Question One (Compulsory) and Any Other Two Questions

QUESTION ONE

- 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°C. The isentropic efficiencies of the compressor and turbine are respectively 0.82 and 0.85. Air enters the compressor at 15°C at a rate of 15 Kg/s.
 - a. Take; $C_p = 1.005 \text{ KJ/KgK}$ and $\gamma = 1.4$ for the compression process
 - i. $C_p = 1.11 \text{ KJ/KgK}$ and $\gamma = 1.333$ 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)

QUESTION TWO

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

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

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°C and the room temperature is 25°C . The heat transfer coefficient from the outside wall surface to the air in the room is $17 \text{ W/m}^2\text{K}$, and the resistance to heat flow of the air gap is 0.16 K/W . The thermal conductivity of refractory brick, insulating firebrick and plaster are 1.6, 0.3 and 0.14 W/mK respectively. Calculate;

- The rate at which heat is lost per unit area of the wall surface
- Each interface temperature and the temperature of the outside surface of the wall.

(15 marks)

QUESTION THREE

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

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

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°C and leaves at 50°C . The oil is cooled by a counter – current flow of water available at 15°C . The water and oil flow rates are respectively 3.5 Kg/s and 10.5 Kg/s . The overall heat transfer coefficient is $1640 \text{ W/m}^2\text{K}$ 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

- 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;

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

- b) A single – acting air compressor is required to deliver at 70 bars from an induction pressure of 1 bar at a rate of $2.4 \text{ m}^3/\text{min}$, measured at free air condition of 1.013 bar and 15°C . 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°C . If the mechanical efficiency of the compressor is 85%, draw the indicator diagram and determine the;
- Indicated power
 - Swept volume in low pressure cylinder
 - Power output required from a motor. (13 marks)
 - Take $R = 287 \text{ J/KgK}$

QUESTION FIVE

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°C , 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°C . 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 C_p and γ as 1.005 KJ/KgK and 1.4 for all compression processes

C_p and γ as 1.15 KJ/KgK and 1.333 for all combustion and expansion processes