MACHAKOS UNIVERSITY

University Examinations for 2020/2021 Academic Year

SCHOOL OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF MECHANICAL AND MANUFACTURING ENGINEERING

THIRD YEAR FIRST SEMESTER EXAMINATION FOR

BACHELOR OF SCIENCE (MECHANICAL ENGINEERING)

EMM 307: ENGINEERING THERMODYNAMICS II

DATE: 17/8/2021 **TIME: 8:30 – 10:30 AM**

INSTRUCTIONS

Answer question ONE and any other two questions.

Provided:

Thermodynamic and Transport Properties of Fluids, SI Units - by Rogers G.F.C and Mayhew Y.R

QUESTION ONE (30 MARKS)

a) With the aid of a T-s diagram, give a brief description of the Carnot cycle. (5 marks)

b) Briefly explain five assumptions made for a cycle to be an air-standard cycle. (5 marks)

c) A steam power plant operating in a simple Rankine cycle has saturated vapor at 3.5 MPa leaving the boiler. The turbine exhausts to the condenser operating at 10 kPa. Given that the turbine expansion is isentropic, find the specific turbine work output and the heat transferred in the condenser. (5 marks)

d) A gasoline engine has a volumetric compression ratio of 10. The state of the charge before compression is 27 °C and 101 kPa, and the peak cycle temperature is 1750 K. Assuming that the engine operates in the Otto air-standard cycle, find the cycle network and the cycle efficiency. Take $\gamma = 1.4$ and $c_v = 0.718$ kJ/kg K. (5 marks)

e) A gas mixture consists of 2 kg of O_2, 3.5 kg of N_2, 9 kg of CH_4, and 0.5 kg of water vapor. For this gas mixture determine: the mole fraction of each component, and the average molar mass of the mixture. (5 marks)

f) At the beginning of the compression process of an air-standard dual combustion cycle with a compression ratio of 16, the temperature and pressure are 300 K and 100 kPa respectively. The pressure ratio for the constant volume part of the heat addition process is 1.4:1, and the volume ratio for the constant pressure part of the heat addition process is 2:1. Determine the total heat added. Take $\gamma = 1.4$ and $c_p = 1.005$ kJ/kgK. (5 marks)

QUESTION TWO (20 MARKS)

a) State four advantages of superheating steam in a Rankine cycle. (4 marks)

b) In a particular reheat-cycle power plant, steam enters the high-pressure turbine at 6 MPa, 400 °C and expands to 0.6 MPa, after which it is reheated to 400 °C. The steam is then expanded through the low-pressure turbine to 0.8 kPa. The condensate leaves the condenser as saturated liquid, and is pumped to 6 MPa, and then returned to the steam generator. Each turbine is adiabatic with an isentropic efficiency of 90% and the pump is isentropic. If the total power output of the plant is 10 MW, determine:

i. The mass flow rate of steam

ii. The pump power input

iii. The thermal efficiency of the power plant

iv. The specific steam consumption, kg/kWh. (16 marks)

QUESTION THREE (20 MARKS)

a) Derive the expression for the thermal efficiency of the air-standard Diesel engine cycle in terms of the compression and cut-off ratios. (8 marks)

b) An engine operates on an ideal diesel cycle with air as the working substance. The temperature and pressure of the air at the beginning of the compression process are 25 °C and 1.01 bar respectively. The compression ratio is 18 and the cut-off ratio is 2.5. Determine:

i. The air standard efficiency of the cycle

ii. The mean effective pressure.

Take $\gamma = 1.4$ and $c_p = 1.005$ kJ/kgK. (12 marks)

QUESTION FOUR (20 MARKS)

In a gas turbine power plant working on the Brayton cycle, the air at inlet is at a temperature and pressure of 27 °C and 0.1 MPa respectively. The pressure ratio is 7 and the maximum cycle temperature is 750 °C. The mass flow rate is 115 kg/s and the isentropic efficiency of the turbine and compressor are each 80 per cent. Using well labelled P-v and T-s diagrams, find:

a) The required compressor power input

b) The back work ratio

c) The net power output

d) The cycle efficiency.

QUESTION FIVE (20 MARKS)

a) Define the following terms as used in fuels and combustion:

i. Air-fuel ratio

ii. Equivalence ratio

iii. Lean mixture

iv. Rich mixture (4 marks)

b) Propane, C_3H_8, is burned with dry air. The molar analysis of the on a dry basis is CO_2, 9.4%; CO, 0.8%; O_2, 3.4%; and N_2, 86.4%. Determine:

i. The air-fuel ratio on both a molar and a mass basis

ii. The percent theoretical air

iii. The molar analysis of the products on a wet basis

iv. The dew point temperature products, in °C, if the products are cooled at 101325 Pa.

v. The amount of water vapour condensed in kg per kg of fuel consumed, if the products are cooled to 28 °C at 101325 Pa. (16 marks)