MACHAKOS UNIVERSITY

University Examinations for 2020/2021 Academic Year

SCHOOL OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF MECHANICAL AND MANUFACTURING ENGINEERING

FOURTH YEAR SPECIAL/SUPPLIMENTARY EXAMINATION FOR

BACHELOR OF SCIENCE (MECHANICAL ENGINEERING)

EMM 404: ENGINEERING THERMODYNAMICS III

DATE: 22/3/2021 **TIME: 2.00-4.00 PM**

INSTRUCTIONS

Answer Question One and Any Other Two Questions

QUESTION ONE (30 MARKS) (COMPULSORY)

a) Briefly define the following terms as applied in reciprocating compressors:

i. Compression ratio

ii. Swept volume

iii. Clearance volume

iv. Compressor capacity

v. Free air delivery (5 marks)

b) Represent the processes making up the diesel cycle on P-v and T-s diagrams. (5 marks)

c) An internal combustion four-cylinder engine has a bore of 7.2 cm, a stroke of 7.8 cm, and a clearance length of 1 cm, determine the compression ratio and engine displacement (5 marks)

d) The percentage composition of a sample of coal is found by mass analysis as: C 90%, H_2 4%, O_2 1.5%, N_2 1.3%, S 0.8% and the remaining is ash.

Calculate the theoretical mass of air for complete combustion of 1 kg of coal. Take air to consist of 23% O_2 by mass. (5 marks)

e) State FIVE assumptions made in the analysis of the thermal efficiency of an ideal gas turbine plant. (5 marks)

f) Starting with the fundamental thermodynamic relations for the First law and entropy with specific reference to internal energy, obtain the Maxwell's relation.

$$\left(\frac{\partial T}{\partial V}\right)_S = -\left(\frac{\partial P}{\partial S}\right)_V$$

Where; T – temperature

V – volume

P – pressure

S – entropy (5 marks)

QUESTION TWO (20 MARKS)

a) Deduce the expression for the thermal efficiency of the air standard Diesel cycle in terms of the compression and cut-off ratios. (10 marks)

b) An air- standard Diesel cycle has a compression ratio of 16 and a cut-off ratio of 2. At the beginning of the compression process, air is at 95 kPa and 27 °C. Determine:

- The temperature after the heat-addition process
- The thermal efficiency
- The mean effective pressure (10 marks)

Take $\gamma = 1.4$

QUESTION THREE (20 MARKS)

A single acting, single stage air compressor is required to deal with 8 m^3 of air per minute measured at 1.013 bar and 25°C. The conditions at the beginning of compression are 0.96 bar and 28 °C and the delivery pressure is 5 bar. The compressor clearance volume is 6% of the swept volume and the operating speed is 360 rev/min. The stroke is 1.2 times the cylinder diameter. The index of compression and expansion is 1.32.

Calculate;

a) the power required

b) the cylinder diameter

c) the isothermal efficiency of the compressor.

Take $c_p = 1.005$ kJ/kg K, and $\gamma = 1.4$

QUESTION FOUR (20 MARKS)

A gas turbine unit takes in air at 20°C and 100 kPa and operates with a pressure ratio of 18:1. The maximum combustor temperature is 2800 K at a mass flow rate of 8.8 kg/s. Assuming ideal compression and expansion processes, determine;

a) The compressor power input

b) The rate of heat addition

c) The net power output

d) The thermal efficiency for the cycle

e) The work ratio

Take: $c_p = 1.005$ kJ/kg K, and $\gamma = 1.4$

QUESTION FIVE (20 MARKS)

a) The ultimate analysis of a sample of petrol was 85% C and 15% H. The analysis of the dry products gave 12% CO_2 and some O_2. Determine;

  i. The air/fuel ratio supplied to the engine

  ii. The mixture strength.

b) Derive the Clausius-Clapeyron equation for phase change.

c) With the help of the Maxwell's relations and expression for Gibb's free energy, show that for an ideal gas the enthalpy (H) is independent of pressure (P).

<u>Important Relations</u>

Functions:

$$A = U - TS$$

$$G = H - TS$$

Differentials

$$dU = TdS - PdV$$

$$dH = TdS + VdP$$

$$dA = -PdV - SdT$$

$$dG = VdP - SdT$$

Maxwell's Relations

$$\left(\frac{\partial T}{\partial V}\right)_S = -\left(\frac{\partial P}{\partial S}\right)_V$$

$$\left(\frac{\partial T}{\partial P}\right)_S = \left(\frac{\partial V}{\partial S}\right)_P$$

$$\left(\frac{\partial P}{\partial T}\right)_V = \left(\frac{\partial S}{\partial V}\right)_T$$

$$\left(\frac{\partial V}{\partial T}\right)_P = -\left(\frac{\partial S}{\partial P}\right)_T$$