MACHAKOS UNIVERSITY

University Examinations for 2019/2020Academic Year

SCHOOL OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF MECHANICAL AND MANUFACTURING ENGINEERING

FOURTH YEAR SECOND SEMESTER EXAMINATION FOR

BACHELOR OF SCIENCE IN MECHANICAL ENGINEERING

EMM 404: ENGINEERING THERMODYNAMICS III

DATE: 12/11/2020 **TIME: 8.30-10.30 AM**

INSTRUCTIONS

Answer Question One and Any Other Two Questions

QUESTION ONE (30 MARKS) (COMPULSORY)

a) List five air standard assumptions made in air standard cycles equations. (5 marks)

b) Define the following performance parameters of internal combustion engines:

i. Indicated power (1 mark)

ii. Brake power (1 mark)

iii. Mechanical efficiency (1 mark)

iv. Thermal efficiency (1 mark)

v. Mean effective pressure (1 mark)

c) Starting with the fundamental thermodynamic relations for the First law and entropy, obtain the following 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)

d) An engine working on Otto cycle has efficiency of 40% and index of adiabatic compression is 1.4. The initial pressure and temperatures are 1 bar and 27°C, respectively. Find: the compression ratio, the pressure, and volume at the end of the compression. (5 marks)

e) With the aid of p-V and T-s diagrams, briefly describe the processes involved in an air-standard diesel cycle. (5 marks)

f) A 750-kW gas turbine operates with a perfect gas on the Brayton cycle and has an inlet pressure of 1.5 bar. The combustor pressure is 10 bar and the ratio of the specific heats of the perfect gas is 1.4. Determine the cycle thermal efficiency and the rate of heat addition required. (5 marks)

QUESTION TWO (20 MARKS)

a) Deduce the expression for the thermal efficiency of the air standard Otto cycle in terms of the compression ratio. (10 marks)

b) A four cylinder four-stroke petrol engine has a compression ratio of 6. The clearance volume of each cylinder is 96×10^{-6} m^3. The rated engine speed is 2800 rpm and it is tested at this speed against a brake which has a torque arm of 0.36 m and the net brake load is found to be 160 N. The engine consumes 0.12 kg of fuel per minute, the colorific value of the fuel being 42 000 kJ/kg. if the indicated thermal efficiency is 0.48 of the ideal Otto cycle efficiency, determine:

i. The indicated power (3 marks)

ii. The indicated mean effective pressure (3 marks)

iii. Mechanical efficiency (2 marks)

iv. The indicated specific fuel consumption (2 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 (8 marks)

b) the cylinder diameter (6 marks)

c) the isothermal efficiency of the compressor. (6 marks)

Take c_p = 1.005 kJ/kg K, and γ = 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. The compressor and turbine have isentropic efficiencies of 0.9. For this unit determine:

a) The compressor power input (5 marks)

b) The rate of heat addition (5 marks)

c) The net power output (4 marks)

d) The thermal efficiency for the cycle (4 marks)

e) The work ratio (2 marks)

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 (4 marks)

   ii. The mixture strength. (4 marks)

b) Derive the Clausius-Clapeyron equation for phase change. (6 marks)

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). (6 marks)

Important Relations

Functions:

$$A = U - TS$$

$$G = H - TS$$

Differentials

$$dU = TdS - PdV$$

$$dH = TdS + VdP$$

$$dA = -PdV - SdT$$

$$dG = VdP - SdT$$

Maxwell's Relations

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

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

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

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