UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 4 Examination in Engineering: November 2017

Module Number: ME 4301 **Module Name: Applied Thermodynamics**

[Three Hours]

[Answer all questions, each question carries **ten** marks]

Draw neat sketches to justify your answers, where necessary. Use the provided steam property table.

Q1. A steam power plant operates on an ideal regenerative Rankine cycle with two open feed water heaters. Steam enters the turbine at 10 MPa and 600 °C, and exhausts to the condenser at 5 kPa. Water leaves both feed water heaters as a saturated liquid. The mass flow rate of steam through the boiler is 22 kg/s.

a) State the assumptions.

[1.0 Mark]

b) Show the cycle on T-s diagram.

[2.0 Marks]

c) Determine the net power output of the plant.

[4.0 Marks]

d) Calculate the thermal efficiency of the cycle.

[3.0 Marks]

Q2. An air-standard Brayton cycle operates with a compression ratio of five. The actual expansion and compression efficiencies of the gas process are 0.88 and 0.82, respectively. The maximum and minimum temperatures are 790 °C and 16 °C.

For air: Cp= 1.005 kJ/kg.K, R= 0.287 kJ/kg.K, and k = 1.4

a) Determine the compression work and the expansion work.

[3.0 Marks]

b) Calculate the "ratio of compression to expansion work" and the actual and theoretical thermal efficiencies.

[2.0 Marks]

c) If the power output of the plant is 8 MW, determine the mass flow rate in kg/min.

[3.0 Marks]

d) Plot the regenerative Brayton cycle efficiency as a function of the pressure ratio and the minimum to maximum temperature ratio.

[2.0 Marks]

Q3. a) Using a P-V diagram, explain the effect of intercooling on the compressor work.

[1.0 Mark]

b) Provide theoretical and practical P-V diagrams for air standard Otto and Diesel cycles.

[2.0 Marks]

c) A single-acting, two-stage reciprocating air compressor is used to compress 4.5 kg of air per minute from 1.013 bar and 15 °C. Both stages have the same pressure ratio of 9 to 1, and the law of compression and expansion is $PV^{1.3}$= constant. If intercooling is complete, calculate the required indicated power and the cylinder swept volumes. Assume that the clearance volumes of both stages are 5% of their respective swept volumes and that the compressor runs at 300 rev / min.

[4.0 Marks]

d) In a dual combustion cycle, the compression starts from 1 bar and 20°C. The compression ratio is 18/1 and the cut-off ratio is 1.15. The maximum cycle temperature is 1360 K. The total heat input is 1 kJ per cycle. Calculate the following.

i) The thermal efficiency of the cycle.

[1.0 Mark]

ii) The total work output per cycle.

[2.0 Marks]

Q4. a) What are the types of compounding techniques available for turbines?

[2.0 Marks]

b) Select one compounding method and explain the pressure and velocity variation.

[2.0 Marks]

c) In a first stage two-row velocity-compounded impulse turbine, the steam velocity at inlet is 600 m/s, the mean blade velocity is 120 m/s, and the blade velocity coefficient for all blades is 0.9. The nozzle angle is 16° and the exit angles for the first row of moving blades, the fixed blades, and the second row of moving blades, are 18°, 21°, and 35° respectively, Calculate the following,

i. The blade inlet angles for each row.

[2.0 Marks]

ii. The driving force for each row of moving blades and the axial thrust on the wheel, for a mass flow rate of 1 kg/s.

[2.0 Marks]

iii. The diagram power for kilogram per second of steam flow, and the diagram efficiency for the wheel.

[1.0 Mark]

iv. The maximum possible diagram efficiency for the given steam inlet velocity and nozzle angle.

[1.0 Mark]

Q5.

a) A well-insulated, shell-and-tube heat exchanger is used to heat water (Cp = 4.18 kJ/kg.K) in the tubes from 20 °C to 70 °C at a rate of 4.5 kg/s. Heat is supplied by hot oil (Cp = 2.3 kJ/kg.K), that enters the shell side at 170 °C at a rate of 10 kg/s. Disregarding any heat loss from the heat exchanger,

i. Determine the exit temperature of the oil

[2.5 Marks]

ii. Calculate the rate of entropy generation in the heat exchanger.

[2.5 Marks]

b) Based on your knowledge in "Basics of Combustion" describes the difficulties that you are encountering in designing an internal combustion engine for automotive applications.

[5.0 Marks]