UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 4 Examination in Engineering: December 2016

Module Number: ME4301 **Module Name: Applied Thermodynamics**

[Three Hours]

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

Q1. a) Why the Rankine cycle is considered as the basic cycle for a steam power plant over the Carnot cycle?

[2.0 Marks]

b) How does the operating pressure of a boiler affects the efficiency of the Rankine cycle?

[2.0 Marks]

c) Explain the "Regenerative Rankine cycle" with the help of a neat sketch. Derive an expression for thermal efficiency of a Regenerative Rankine cycle with a direct-contact feed water heater.

[4.0 Marks]

d) In a single-heater regenerative cycle, steam enters the turbine at 30 bar, 400 °C and the exhaust pressure is 0.01 bar. The feed water heater is a direct contact type which operates at 5 bar. Find the efficiency of the cycle, which neglecting the pump work.

[4.0 Marks]

Q2. a) Discuss the influence of reheating, regeneration and intercooling on the performance of a gas turbine cycle.

[4.0 Marks]

b) Consider a gas turbine cycle working on the Brayton cycle and provided with intercooling, regeneration and reheating. Air enters the low pressure compressor at 1 bar, 290 K, After compression to 4 bar, air is cooled down to 295 K. After subsequent compression to 8 bar in the high pressure compressor, the air passes through a regenerator which has an effectiveness of 80%. Next, the air is sent to a combustion chamber where it is heated up to 1250 K. Then the heated air enters the high pressure turbine and expands to 4 bar. The air is reheated thereafter up to 1200 K, before being expanded to 1 bar in the low pressure turbine. The exhaust from the turbine is passed through a regenerator before being discharged out of the cycle. Determine the thermal efficiency.

Use,

C_p =1.005 kJ/kg/K (assumed constant throughout the cycle)

$$effectiveness\ of\ a\ regenerator\ is\ given\ by: = \frac{Actual\ heat\ received\ by\ compressed\ air}{Maximum\ possible\ heat\ which\ could\ be\ transferred\ from\ gasses}$$

[8.0 Marks]

Q3. a) State the difference between the impulse and reaction turbines.

[2.0 Marks]

b) Using suitable sketches, briefly explain velocity and pressure compounding of a multi-stage impulse turbine.

[4.0 Marks]

c) In a two-row velocity-compounded impulse stage of a turbine, following data have been recorded.

Nozzle angle: 17^0
Blade speed: 125 m/s
Exit angle of the first row of moving blades: 22^0
Exit angle of the fixed blades: 26^0
Exit angle of the second row of moving blades: 30^0

Take the blade velocity coefficient for each row of blades as 0.9 and assume that the direction of the steam leaving this stage is along with the turbine axis. Draw the velocity diagram and answer the following questions.

I) The absolute velocity of the steam leaving this stage.

[3.0 Marks]

II) The diagram efficiency.

[3.0 Marks]

Q4. a) Using a suitable graph, briefly describe the condition for the minimum work of a reciprocating compressor.

[2.0 Marks]

b) A single stage, double acting compressor with one cylinder is required to deliver 14 m^3 of air per minute measured at 1.013 bar and 15 ^{0}C. The delivery pressure is 7 bar and the rotational speed of the compressor is 300 rev/min. Take the clearance volume as 5% of the swept volume and the compression and re-expansion index n as 1.3. Calculate the swept volume of the cylinder of the compressor, the delivery air temperature and the indicated power of the compressor.

[4.0 Marks]

c) What is meant by the volumetric efficiency of a compressor? Using a suitable graph describe the effect of increasing the delivery pressure for the volumetric efficiency of a compressor.

[6.0 Marks]

Q5. a) Define the terms weak (lean) mixture, rich mixture and stoichiometric mixture for an air-fuel mixture.

[1.5 Marks]

b) Define the higher calorific value and lower calorific value of a given fuel.

[2.5 Marks]

..... *Question Q5. is continued on Page 3*

Question Q5. is continued from Page 2 ....

c) A hydrocarbon fuel having an unknown composition is burned with air which has resulted in the following dry product analysis,
$CO_2 = 7.26\%;\ CO = 2.42\%;\ O_2 = 7.5\%$

I) Determine the empirical formula of the fuel.

[4.0 Marks]

II) Calculate the percentage of theoretical air used.

[4.0 Marks]