UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 04 Examination in Engineering: September 2023

Module Number: ME4302 **Module Name: Applied Thermodynamics**

[3 hours]
Answer **all questions. Each question carries 10.0 marks.**

Q1. a) What is the effect of regeneration on the efficiency and network output of the gas turbine?

[3.0 Marks]

b) Air enters a compressor of a regenerative air-standard Brayton cycle with a volumetric flow rate of 60 m^3/s at 0.8 bar pressure and 280 K temperature. The compressor pressure ratio is 20 and the maximum cycle temperature is 2100 K. If the regenerator effectiveness is 85%, determine;

i. The net power developed.

[4.0 Marks]

ii. The rate of heat addition in the combustor.

[2.0 Marks]

iii. The thermal efficiency of the cycle.

[1.0 Mark]

Take the specific heat at constant pressure and specific heat ratio as 1.005 kJ/kg.K, and 1.4, respectively.

Q2. a) What are the advantages of having a reheating stage in a steam power plant?

[2.0 Marks]

b) Consider a 15MW steam power plant operating on the ideal Reheat Rankine cycle. Steam enters the high-pressure turbine at 12.5 MPa pressure and 600°C temperature. Steam exits the high-pressure turbine at a pressure of 3 MPa and is heated at constant pressure to a temperature of 500°C as it enters the low pressure turbine. The steam is condensed at a pressure of 15 kPa in the condenser. Take specific volume of saturated liquid at 12.5 MPa pressure as 0.001546 m^3/kg.

i. Sketch the layout diagram and T-s diagram for steam power plant.

[2.0 Marks]

ii. Calculate the thermal efficiency of the power plant.

[4.0 Marks]

iii. Calculate the required mass flow rate of water.

[2.0 Marks]

Q3. a) Draw the velocity compounded impulse turbine's component arrangement, velocity curve, and pressure curve.

[3.0 Marks]

b) Steam flows from the nozzles of a single-row impulse turbine with a velocity of 1200 m/s. The nozzle angle is 20 degree. The mean blade velocity is 400 m/s. The inlet and outlet angle of the blades are equal. The mass flow rate of the steam flowing through the turbine is 1000 kg/hr. Take blade velocity coefficient as 0.8. Determine,

i. Blade angles.

[2.0 Marks]

ii. Relative velocity of steam entering to the blades.

[1.0 Marks]

iii. Tangential force on the blades.

[2.0 Marks]

Iv. Power developed.

[2.0 Marks]

Q4. a) A sample of fuel has 72% of carbon, 12% of hydrogen, and 16% of oxygen composition by weight.

i. Determine the stoichiometric air-fuel ratio by mass.

[3.5 Marks]

ii. If 20% excess air is supplied, write the equation for combustion reaction.

[1.5 Marks]

b) Liquid Propane (C_3H_8) enters a combustion chamber at 25°C temperature and at a rate of 1.2 kg/min where it is mixed and burned with theoretical air that enters the combustion chamber at 12°C temperature. The combustion is completed, and the exit temperature of the combustion gas is 927°C. Determine the rate of heat transfer from the combustion chamber.

[5.0 Marks]

Q5. a) Draw the P-v diagrams for the actual and ideal cycles of the Compression Ignition Engine.

[3.0 Marks]

b) An engine working on Otto cycle has a volume of 0.45 m^3, pressure 1 bar and temperature 30°C at the beginning of compression stroke. At the end of compression stroke, the pressure is 11 bar. If 210 kJ of heat is added at constant volume, determine;

i. Efficiency of the cycle.

[5.0 Marks]

ii Mean effective pressure.

[2.0 Marks]

Take,
Specific heat at constant volume = 0.71 kJ/kg.K
Specific heat ratio = 1.4
Universal gas constant =287 J/kg.K

Table Q4: Enthalpy of formation, Enthalpy of air and combustion products at different temperatures

Substance	$\bar{h}_f^o, kJ/kmol$	$\bar{h}_{285\ K}, kJ/kmol$	$\bar{h}_{298\ K}, kJ/kmol$	$\bar{h}_{1200\ K}, kJ/kmol$
C_3H_8 (l)	-118623	-	-	-
O_2	0	8296.5	8682	38447
N_2	0	8286.5	8669	36777
H_2O (g)	-241820	-	9904	44380
CO_2	-393520	-	9364	53848