UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 1 Examination in Engineering: August 2015

Module Number: ME1202 **Module Name: Fundamentals of Engineering Thermodynamics**

[Three Hours]

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

All assumptions must be stated clearly. Sketches and diagrams are to be provided where required. Symbols stated herein denote standard parameters. Tables of thermodynamics and transport properties of fluids will be provided.

Q1. a) Briefly explain following terms in Thermodynamics

i) Open and closed systems
ii) Internal energy of a substance
iii) Heat and work
iv) Specific heats of a substance

[04 Marks]

b) Steam enters a turbine operating at steady state with a mass flow rate of 4600 kgh^{-1}. The turbine develops a power output of 1000 kW. At the inlet, the pressure is 60 bar, the temperature is 400 °C, and the velocity is 10 ms^{-1}. At the exit, the pressure is 0.1 bar, the dryness fraction (quality) is 0.9, and the velocity is 50 ms^{-1}. Apply your knowledge of the 1st Law of Thermodynamics and calculate the rate of heat transfer between the turbine and surroundings, in kW.

[06 Marks]

Q2. Steam enters a nozzle operating at steady state with inlet pressure at 40 bar, inlet temperature at 400 °C and velocity at 10 ms^{-1}. The nozzle is insulated. The steam exits the nozzle at a pressure of 15 bar and velocity of 665 ms^{-1}. The mass flow rate of the steam is 2 kgs^{-1}.

a) Estimate the specific enthalpy, temperature and specific volume of the exit stream.

[07 Marks]

b) Determine the exit area of the nozzle in m^2.

[03 Marks]

Q3. a) Show that the boundary work (W_b) for a gas undergoing a polytropic process from an initial state 1 to a final state 2, can be expressed as,

$$W_b = \frac{P_2V_2 - P_1V_1}{1-n}$$

[03 Marks]

Q3 is continued to next page....

b) When $n \neq 1$, show that the boundary work (W_b) for an ideal gas undergoing a polytropic process can be expressed as,

$$W_b = \frac{[mR_i(T_2 - T_1)]}{1-n}$$

(m - Mass of the ideal gas, R_i - Specific gas constant)

[01Mark]

c) When $n = 1$, show that the boundary work (W_b) can be expressed as,

$$W_b = P_1 V_1 \ln\left(\frac{V_2}{V_1}\right)$$

[01 Mark]

d) A piston - cylinder device initially contains 0.4 m^3 of air at 100 kPa and 80 °C. The air undergoes a reversible isothermal compression process. The volume of air after isothermal compression is 0.1 m^3. Calculate the work done during the process. Consider air to act as an ideal gas.

[05 Marks]

Q4. a) Briefly explain the reversed Carnot cycle for a heat engine.

[02 Marks]

b) Write down an expression for the Coefficient of Performance (COP) of a Heat Pump that operates on the reversed Carnot cycle in terms of temperature values of high temperature reservoir and low temperature reservoir.

[02 Marks]

c) A domestic heat pump is used to heat a house during the winter (Figure Q4). The motor that drives it, is rated as 2.5 kW. It is estimated that the house kept at 20 °C will lose 14 kW when the outside temperature is -5 °C. Is the rated motor sufficient for an ideal heat pump? Suppose the actual heat pump has only one third the Coefficient of Performance as the ideal one. How much heating power could it supply?

[06 Marks]

Q5. a) Show that when a perfect gas changes from a state (P_1, V_1, T_1) to another state (P_2, V_2, T_2) the change in entropy per unit mass is given by ,

$$S_2 - S_1 = C_V \log_e \frac{T_2}{T_1} + R \log_e \frac{V_2}{V_1}$$

[02 Marks]

b) Further deduce the following equation to express the entropy in terms of pressure and temperature, using the above equation in part (a).

$$S_2 - S_1 = C_p \log_e \frac{T_2}{T_1} + R \log_e \frac{P_1}{P_2}$$

[01 Mark]

Q5. is continued to next page....

c) 3 kg of air at 150 kPa pressure and 360K temperature is compressed polytropically to pressure 750 kPa according to the law $PV^{1.2}$ = constant. Subsequently the air is cooled to initial temperature at constant pressure. This is followed by expansion at constant temperature till the original pressure of 150 kPa is reached.

i) Sketch the cycle on $P-V$ and $T-S$ diagrams.

[02 Marks]

ii) Determine the work done, heat transfer and change of entropy for each process.

[05 Marks]

Assume C_p =1.005 kJkg^{-1} K^{-1}, C_V =0.718 kJkg^{-1} K^{-1} and R=0.287 kJkg^{-1} K^{-1}.

Q6. a) A steam power plant is operated between a boiler pressure of 4 MPa and a temperature of 300 °C and a condenser pressure of 50 kPa. Determine the thermal efficiency of the cycle and the work ratio, assuming the cycle to be

i) a Carnot cycle

[04 Marks]

ii) a simple ideal Rankine cycle

[04 Marks]

b) Explain how the actual vapor power cycle diverges from the ideal one using a $T-S$ diagram.

[02 Marks]

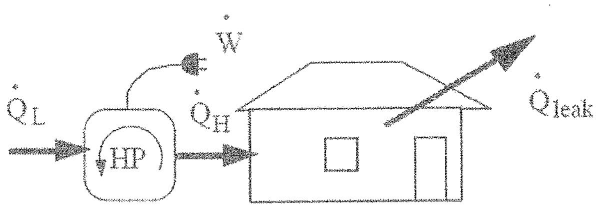

Figure Q4. Operation of Domestic Heat Pump