King Saud University
College of Engineering
Mechanical Engineering Dept.

ME 372
Thermodynamics II
Time Allowed: 3.00 hrs
Final Exam, 1st semester
1429/1430

Final-Term Exam (13-2-1430)

- **Thermodynamics table are allowed.**
- **Solve questions 1, 2, 3 and 4 then choose only one question either number 5 or 6.**

Question (1): [20 points]

(1.1) Room contains air (ideal gas) at 25°C and 100 kPa at a relative humidity of 80%. Determine: (10 points)

(a) The partial pressure of dry air.
(b) The specific humidity.
(c) The enthalpy per unit mass of the dry air. (C_p = 1.005 kJ/kg °C).

(1.2) Steam is the working fluid in an ideal Rankine cycle. Saturated vapor enters the turbine at 8.0 MPa and saturated liquid exits the condenser at a pressure of 0.01 MPa. The net power output of the cycle is 100 MW. Determine for the cycle (10 points)

(a) The thermal efficiency,
(b) The mass flow rate of the steam, in kg/h,
(c) The rate of heat transfer into the working fluid as it passes through the boiler, in MW,

Question (2): [20 points]

Methane gas (CH_4) at 400 K and 1 atm enters a combustion chamber, where it is mixed with air entering at 500 K and 1 atm. The products of combustion exit at 1700 K and 1 atm. The molar analysis of the products on a dry basis is 9.7% CO_2, 0.5% CO, 2.95% O_2 and 86.85% N_2. For operation at steady state, determine:

(a) The air–fuel ratio.
(b) The percent theoretical air,
(c) The rate of heat transfer from the combustion chamber in kJ per kmol of fuel.

Neglect kinetic and potential energy effects. The average value for the specific heat of methane between 298 and 400 K is 38 kJ/kmol K. Assume the water in the product is in the vapor form.

Question (3): [20 points]

Steam enters an adiabatic turbine at 6 MPa, 600°C, and 140 m/s and leaves at 50 kPa, 100°C and 80 m/s. If the power output of the turbine is 5 MW. Assuming the surroundings to be at 25°C, determine:

(a) The mass flow rate of the steam in kg/s,
(b) The entropy generation in kW/K,
(c) The reversible output power of the turbine in kW,
(d) The exergy destroyed within the turbine in kW,
(e) The second law efficiency of the turbine, and
(f) Draw the T-S and P-v diagrams of the process showing the inlet and exit states with respect to saturation lines.

Question (4): [20 points]

Use the ideal gas cycle with constant volume combustion to describe the operation of an SI engine with a compression ratio of 8. Assume a pressure of 100 kPa and a temperature of 298 K at the beginning of the compression process. Assume $m_f/m = 0.05$, $k = C_p/C_v = 1.3$, $C_v = 0.946$ kJ/kg K, and $Q_{LHV} = 44$ MJ/kg. Determine:

(a) The pressure and temperature at each point of the cycle.
(b) Draw the P-v diagram showing all states.
(c) The fuel conversion efficiency (thermal efficiency) of the cycle.
(d) The imep for this engine under these operating conditions.

Choose only one from the following questions:

Question (5): [20 points]

(5.1) Determine the change in the entropy of Helium, in kJ/kg K, as it undergoes a change of state from 100 kPa and 20 °C to 600 kPa and 300 °C using the equation of state $P(v - a) = RT$ where $a = 0.10$ m^3/kg, and compare the result to the value obtained by using the ideal gas equation of state. (10 points)

(5.2) Temperature and pressure may be defined as:

$$\mathbf{T} = \left(\frac{\partial \mathbf{u}}{\partial \mathbf{s}}\right)_{\mathbf{v}} \quad \textbf{and} \quad \mathbf{P} = -\left(\frac{\partial \mathbf{u}}{\partial \mathbf{v}}\right)_{\mathbf{s}}.$$

Using these definitions, prove that for a simple compressible substance:

$$\frac{\mathbf{P}}{\mathbf{T}} = \left(\frac{\partial \mathbf{s}}{\partial \mathbf{v}}\right)_{\mathbf{u}}$$ (5 points)

(5.3) Steam is throttled from 4.5 MPa and 300 ^{o}C to 2.5 MPa. Estimate the temperature change of the steam during this process and the average Joule-Thomson coefficient. (5 points)

Question (6): [20 points]

In a single acting, two-stage reciprocating compressor 300 kg of air per hr are compressed from 1.0103 bar and 17°C through a pressure ratio of 9 to 1. Both stages have the same pressure ratio and the law of compression and expansion in both stages is $PV^{1.3}$ = constant. The clearance volumes of both stages are 4% of their respective swept volumes and the compressor runs at 400 rev/min. If intercooling is complete, determine:

(a) The indicated power.
(b) The volumetric efficiency of each stage.
(c) The cylinder swept volume required for each stage.