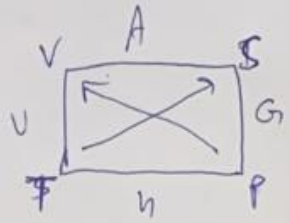
Rajiv Gandhi Institute of Petroleum Technology
(RGIPT), Jais (U.P.) -229305
(An Institute of National Importance under Ministry of Petroleum and Natural Gas, GoI)
Department of Chemical Engineering and Biochemical Engineering

Ravi

Engineering Thermodynamics (CH-161)
End Semester Question Paper
B. Tech. 1st year (Group-B)



Date of examination: 10th March 2022
Maximum marks: 100
Time: 3 Hrs

Instructions:

(1) Attempt all questions.
(2) Answer the questions precisely to the point.
(3) Follow all the examination guidelines of the institute.

Q1. Find the COP of a Carnot refrigerator operating between 40°C and 25°C. **(3 Marks)**

Q2. Compare the change in the internal energy and Gibbs free energy for an ideal gas undergoing an isothermal compression. **(4 Marks)**

Q3. A heat engine operates at a 75% of the maximum possible efficiency. The ratio of the heat source temperature to the sink temperature is 5/3. Determine the fraction of the heat supplied that is converted to work. **(5 Marks)**

Q4. One mole of CH_4 is contained in a leak proof piston-cylinder assembly at 8 bar and 1000 K. The gas undergoes isothermal expansion to 4 bar under reversible conditions. CH_4 can be considered as an ideal gas under these conditions. Determine the heat transferred during the process. **(5 Marks)**

Q5. What is the difference between the Helmholtz potential and Gibbs free energy? **(5 Marks)**

Q6. A steam boiler has a total volume of 3 m^3. The boiler initially contains 2 m^3 of saturated steam and 1 m^3 of saturated liquid at 3 MPa. Calculate the mass of vapor, mass of liquid, quality of the steam, the specific internal energy of the steam, and the specific enthalpy of the steam. **(5 Marks)**

Q7. (a) Plot the T-s diagram of the Standard Air Brayton cycle. **(2 Marks)**
(b) Plot the h-s diagram of a cycle undergoing following process, isobaric heating then isochoric compression then isobaric compression and then isochoric heat addition. **(3 Marks)**

Q8. Determine the entropy change when 1 kmol of an ideal gas with $C_P = 7R/2$ is heated from 1 bar and 300 K to 2 bar and 500 K. **(5 Marks)**

Q9. An internal combustion engine uses octane (C_8H_{18}) as fuel. The air and fuel vapor mixture enters the engine at 25°C and 0.1 MPa and the engine uses 120% of theoretical air. Suppose 75% of the fuel's carbon is converted into CO_2 and the rest is converted to CO. The combustion products leave the engine at 800K, calculate the amount of energy transferred as heat to the engine per kg of fuel. **(10 Marks)**

Compound	a	b × 10^2	c × 10^5	d × 10^8	$\Delta H^0_{f,298}(\frac{kJ}{mol})$
CO_2	19.8	7.344	-5.602	1.715	-393.8
CO	30.87	-1.285	2.789	-1.272	-110.6

H_2O	32.24	0.1924	1.055	-0.3596	-242
O_2	28.11	-3.68×10^{-4}	1.746	-1.065	0
N_2	31.15	-1.357	2.680	-1.168	0
C_8H_{18}	---	-------	------	------	-208.6

Q10. Using the method of partial derivatives, derive the following partial derivatives of the internal energy. Where all the notations have their usual meanings. **(12 Marks)**

(a) $\left(\frac{\partial u}{\partial T}\right)_\theta = C_P - \frac{T\theta\beta^2}{\kappa}$ (b) $\left(\frac{\partial u}{\partial P}\right)_\theta = \frac{C_P\kappa}{\beta} - T\theta\beta$

(c) Liquid water at 25°C is isentropically compressed such that the volume is decreased by 10%. Estimate the rise in temperature of water. Given that $\beta = 2.07 \times 10^{-4}\ K^{-1}$ and $\kappa = 4.85 \times 10^{-4}\ MPa^{-1}$ for liquid water.

Q11. Determine the efficiency of a Rankine cycle using steam as a working fluid in which the condenser pressure is 10 kPa. The boiler pressure is 2 MPa. The steam leaves the boiler as saturated steam. **(10 Marks)**

Q12. (a) Derive the energy balance equation using the 1st law of thermodynamics for a control volume. **(9 Marks)**

(b) A superheated steam enters an adiabatic nozzle operating at steady state at 4 bar and 200°C with negligible inlet velocity and exit at 2 bar with a velocity of 300 m/s. Determine the exit temperature of the steam. **(4 Marks)**

Q13. (a) Explain the working of the Otto cycle with the help of the thermodynamic diagram and derive the expression for the efficiency. **(10 Marks)**

(b) Draw a comparison between the efficiencies of the Otto cycle and the Diesel cycle. **(4 Marks)**

(c) A portion of the steam passing through a turbine is removed and fed to another turbine as shown below. Determine the power produced by this turbine. **(4 Marks)**