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

Engineering Thermodynamics (CH-161)
Mid Semester Question Paper

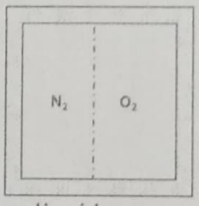
Date of examination: 10th May 2022
Maximum marks: 50
Time: 2 Hours

Instructions:

(1) Follow all the guidelines of the institute.
(2) Steam table or its photocopy (without any marking) is allowed in the examination hall.
(3) Clearly write all the assumptions made (if any) in all the questions.

Q1. If H_2 is throttled at ambient conditions, its temperature will _____? **(1 Marks)**

Q2. An insulated container contains N_2 and O_2 separated by a removable membrane as shown in the figure below. Both N_2 and O_2 have equal T, P, and n. If the membrane is removed without disturbing the system. Determine the change in the internal energy. **(2 Marks)**



Q3. A boiler pipeline carries a two-phase liquid–vapor mixture of steam at 20 bar. A small fraction of the flow in the line is diverted through a throttling device and exhausted to the atmosphere at 1 bar. The temperature of the exhaust steam is measured as 150°C. Determine the quality of the steam in the pipeline. **(4 Marks)**

Q4. 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. **(4 Marks)**

Q5. From the following differential pressure equations representing the state of the gas, identify the correct expression. **(4 Marks)**

(1) $$dP = \frac{2(\vartheta - b)}{RT} d\vartheta + \frac{(\vartheta - b)^2}{RT^2} dT$$

(2) $$dP = -\frac{RT}{(\vartheta - b)^2} d\vartheta + \frac{R}{(\vartheta - b)} dT$$

Q6. Air enters an adiabatic nozzle at 3 bar and 200°C with a velocity of 10 m/s and leaves the nozzle at 2 bar and 150°C. Calculate the exit velocity of the air. Given $C_v = 0.718$ kJ/kg K. **(5 Marks)**

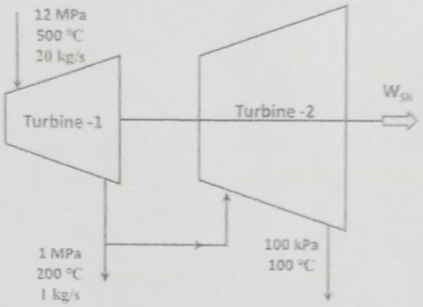
Q7. Determine the second and third viral coefficients of the van der Waal's EOS when expressed in the following viral form of EOS, **(5 Marks)**

$$Z = \frac{PV}{RT} = 1 + \frac{B}{V} + \frac{C}{V^2} + \frac{D}{V^3} + \cdots$$

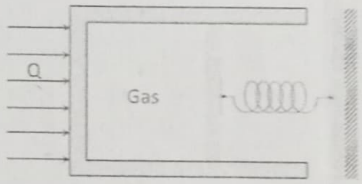
Given that the constant 'a' in the van der Waal's EOS can be taken as equal to 'RT'.

Q8. A rigid and insulated tank of 0.5 m^3 volume contains N_2 at 20 bar pressure and 400 K. N_2 is released from the tank till the final pressure inside the tank is reduced to 4 bar. Assuming that N_2 behaves as an ideal gas and the release process can be considered as reversible, calculate the mass of N_2 discharged from the tank. ($\gamma = 1.4$) **(5 Marks)**

Q9. A portion of the steam passing through a turbine is removed and fed to another turbine as shown below. Determine the combined power produced by these turbines. **(5 Marks)**



Q10. A cylinder contains ten moles of an ideal gas ($\gamma = 1.4$) at 100 kPa and 300 K as shown in the figure below. At this stage the spring just touches the piston but exerts no force on it. Energy is transferred as heat to the gas causing the piston to move. During this process the force exerted by the spring is proportional to the displacement, with the spring constant of 50 kN/m. The cross-sectional area of the spring is 0.05m^2. Calculate the temperature of the gas when the pressure reached 500 kPa, and the energy transferred as heat. **(5 Marks)**



Q11. A steam boiler uses ethane as fuel. The air and fuel vapor mixture enters the boiler at 25°C and 1 bar. The boiler uses 15% excess air and the combustion products leaving the boiler are at 1100 K. Assuming complete combustion, calculate the amount of energy transferred (in kJ/kmol of fuel) as heat to the surrounding. **(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
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_2H_6	---	-------	------	------	-84.74