MANICALAND STATE UNIVERSITY OF APPLIED SCIENCES

FACULTY OF ENGINEERING

Chemical and Processing Engineering Department

CHEMICAL ENGINEERING THERMODYNAMICS II

CODE: HCHE 214

SESSIONAL EXAMINATIONS
APRIL 2021

DURATION: 3 HOURS

EXAMINER: K. NYENYAYI (MR)

INSTRUCTIONS

1. Answer ***any four questions*.**
2. Each question carries 25 marks.
3. Total marks 100.

ADDITIONAL MATERIALS

Calculators, Steam tables.

This question paper consists of 5 printed pages

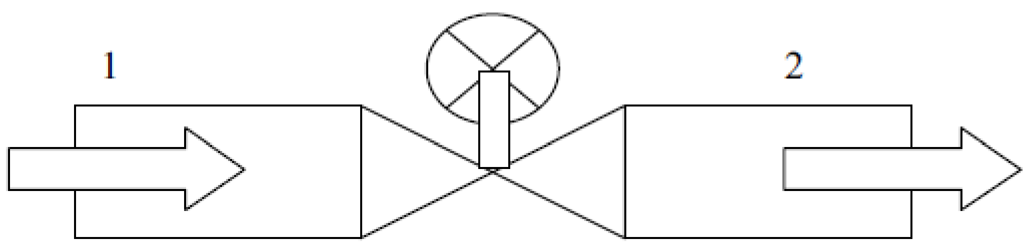
QUESTION ONE

a) With aid of P - V diagrams, define terms *cyclic process, heat engine* and *heat pump*. [7]

b) Determine using Steam tables, the volume occupied by 2 kg of steam at 500 kPa, under the following conditions and specify the state of the steam.

i. Pure liquid state.
ii. When it is a pure vapour state.
iii. 20% moisture content.
iv. 20% dry [8]

c) Consider flow of fluid through a small valve as shown;



i. Describe *throttling process.* [3]

ii. Applying Steady Flow Energy Equation (SFEE) below

$$Q - W = (\Delta H + \Delta KE + \Delta PE)$$

and making necessary assumptions, show that for the control valve above, the enthalpy of the fluid remains constant. [7]

QUESTION TWO

a) With the aid of a clearly labelled block diagram and P-V or T-S diagrams, describe the process of steam production in chemical industry. Your description should include the following aspects:

- The ideal Carnot cycle
- Impracticalities of the Carnot cycle
- The ideal Rankine cycle [20]

b) Calculate efficiency of Carnot cycle for a system with hot reservoir temperature (T_h) of 500 K and cold reservoir temperature (T_c) of 350 K. [5]

QUESTION THREE

a) A steam turbine operates adiabatically at a power level of 3500 kW. Steam enters the turbine at 3000 kPa and 773.15 K and exhausts the turbine at as saturated vapour at 20 kPa.

i. What is the steam rate through the turbine?

ii. What is the turbine efficiency? [10]

b) An adiabatic compressor has been designed to continuously compress 1kg/s of saturated vapour steam from 100 kPa to 10 000 kPa and 1100 ^{0}C.

i. Estimate the power requirement of this compressor in kW.

ii. Determine the efficiency of the compressor. [10]

c) Using examples, distinguish between *internal* and *external combustion engines.*

[5]

QUESTION FOUR

a) What is Theoretical Flame Temperature (TFT) ? [2]

b) Define the terms Gross Calorific Value (GCV) and Net (lower) Calorific Value (NCV). Give a mathematical relationship between the two. [5]

c) A medium sized boiler has the following specifications. Determine the boiler efficiency based on the net calorific value of the fuel.

- Steam output 31.6 kgs^{-1}
- Steam pressure 6 MPa
- Steam temperature 500°C
- Boiler Feed Water (BFW) temperature 100°C
- Fuel (Nat. Gas) -96.5 v/v% CH_4, 0.5v/v% C_2H_6, remainder non-combustible
- GCV = 38,700 kJm^{-3} at 25°C
- Fuel consumption 2.9 m^3s^{-1}

$$Boiler efficiency\ (\eta) = \frac{Energy\ Output\ to\ water}{Energy\ Input\ from\ fuel}$$ [18]

QUESTION FIVE

a) Describe liquefaction process and outline how the process can be achieved.

[5]

b) With aid of diagram, outline the Linde Liquefaction process.

[17]

c) Give any 3 industrial applications of liquefaction process.

[3]

Process	Constant Volume	Constant Pressure	Constant Temperature	Polytropic	Reversible Adiabatic or Isentropic
Law	$\frac{P}{T} = \text{const}$	$\frac{V}{T} = \text{const}$	PV = const	$PV^n = \text{const}$	$PV^\gamma = \text{const}$
P, V, T. Relation	$\frac{P_1}{T_1} = \frac{P_2}{T_2}$	$\frac{V_1}{T_1} = \frac{V_2}{T_2}$	$P_1V_1 = P_2V_2$	$P_1V_1^n = P_2V_2^n$ $\frac{P_1}{P_2} = \left(\frac{V_2}{V_1}\right)^n$ $= \left(\frac{T_1}{T_2}\right)^{\frac{n}{n-1}}$	$P_1V_1^\gamma = P_2V_2^\gamma$ $\frac{P_1}{P_2} = \left[\frac{V_2}{V_1}\right]^\gamma$ $= \left[\frac{T_1}{T_2}\right]^{\frac{\gamma}{\gamma-1}}$
Change in Internal Energy ΔU	$mC_v(T_2-T_1)$	$mC_v(T_2-T_1)$	0	$mC_v(T_2-T_1)$	$mC_v(T_2-T_1)$
Work Transfer W=∫ pdv	0	$P(V_2-V_1)$ Or $mR(T_2-T_1)$	$PV \ln\frac{V_2}{V_1}$ Or $mRT \ln\frac{V_2}{V_1}$	$\frac{P_1V_1 - P_2V_2}{(n-1)}$ $\frac{mR(T_1 - T_2}{(n-1)}$	$\frac{P_1V_1 - P_2V_2}{(\gamma-1)}$ $\frac{mR(T_1 - T_2}{(\gamma-1)}$ $mC_v(T_1-T_2)$
Heat Transfer Q	$mC_v(T_1-T_2)$	$mC_p(T_1-T_2$	$PV \ln\frac{V_2}{V_1}$ Or $mRT \ln\frac{V_2}{V_1}$	$W + (U_2 - U_1)$	0
Change in Entropy ΔS=S₂–S₁	$mC_v\ln\frac{T_2}{T_1}$ or $mC_v\ln\frac{P_2}{P_1}$	$mC_p\ln\frac{T_2}{T_1}$ or $mC_p\ln\frac{V_2}{V_1}$	$mR\ln\frac{V_2}{V_1}$ or $mR\ln\frac{P_1}{P_2}$	$m\left[R\ln\frac{V_2}{V1} + C_v\ln\frac{T_2}{T_1}\right]$ $m\left[R\ln\frac{P_1}{P_2} + C_p\ln\frac{T_2}{T_1}\right]$ $m\left[C_p\ln\frac{V_2}{V_1} + C_v\ln\frac{P_2}{P_1}\right]$	0

Table 1: List of Perfect Gas Relations