National University of Computer & Emerging Sciences, Lahore
Department of Electrical Engineering
(FALL 2024)

ME2002 – Applied Thermodynamics
Assignment # 3 on CLO # 03 (Total Marks = 30)

Notes:

1. **Submit the hardcopy at the very start of the lecture. Use A4 sheets for the answers.**
2. **No late submissions.**
3. **Any help from the internet, solution manuals, or any other source is strictly prohibited. Violation may lead to serious consequences.**
4. **Draw the diagrams where necessary.**

Date of Submission: Friday 6th December 2024

Problem # 01: A heat engine receives 6 kW from a 250^0C source and rejects heat at 30^0C. Examine each of three cases with respect to the inequality of Clausius. **[10 Marks]**

a. W. = 6 kW
b. W. = 0 kW
c. Carnot cycle

Problem # 02: In a Carnot engine with ammonia as the working fluid, the high temperature is 60°C and as Q_H is received, the ammonia changes from saturated liquid to saturated vapor. The ammonia pressure at the low temperature is 190 kPa. Find T_L, the cycle thermal efficiency, the heat added per kilogram, and the entropy, *s*, at the beginning of the heat rejection process. **[10 Marks]**

Problem # 03: Water is used as the working fluid in a Carnot cycle heat engine, where it changes from saturated liquid to saturated vapor at 200°C as heat is added. Heat is rejected in a constant pressure process (also constant T) at 20 kPa. The heat engine powers a Carnot cycle refrigerator that operates between –15°C and +20°C. Find the heat added to the water per kg water. How much heat should be added to the water in the heat engine so the refrigerator can remove 1 kJ from the cold space? **[10 Marks]**

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ME2002 – APPLIED THERMODYNAMICS

Assignment # 3 on CLO # 03

Name:	**Roll Number:**
Date of Submission: 6th December 2024	**Section:**

Instructor: Dr. Huzaifa Rauf

Instructions:

1. Assignment must be handed over to the instructor at the very start of the class.
2. Late submission will not be accepted.
3. Only submit your own work. Do not copy from others. Plagiarism will be dealt with seriously and it will be treated according to the University disciplinary rules.
4. Submit assignment on **A4 size paper**.
5. Use blue or black ink only. Figures may be in color.
6. Handwriting must be legible. Otherwise, your assignment may be returned ungraded.

Problems ↓ [Marks]	Score	CLO # 03				
		Exemplary (5)	Proficient (4)	Developing (3)	Beginning (2)	Novice (1)
P1 [10]						
P2 [10]						
P3 [10]						
Total [30]						

Oath: *I have solved all the questions by myself and taken no help from the internet, solution manuals, colleagues, or any other unfair means. It is my work only.*

Signature:________________________

Attach this sheet to the front of submitted work.

Q. No. 1

$\cancel{\dot{Q}_H = 6kW}$

$T_H = 250°C = 523\ K$ $T_L = 30°C = 303K$

The inequality of Clausius is as follows:-

$$\oint \frac{\delta Q}{T} \leq 0$$

(a)

$\dot{W} = 6\ kW$

$$\Rightarrow \oint \frac{\delta \dot{Q}}{T} = \frac{\dot{Q}_H}{T_H} - \frac{\dot{Q}_L}{T_L}$$

$$= \frac{6k}{523} - \frac{0}{303}$$

$$= 11.472\ kW/K > 0$$

Hence, the inequality of Clausius is invalid here.

As $\dot{W} = \dot{Q}_H - \dot{Q}_L$
For $\dot{W} = 6kW$
Put $\dot{Q}_L = 0$
Hence,
$\dot{W} = \dot{Q}_H = 6kW$

(b)

$\dot{W} = 0kW$

$$\Rightarrow \oint \frac{\delta \dot{Q}}{T} = \frac{\dot{Q}_H}{T_H} - \frac{\dot{Q}_L}{T_L}$$

$$= \frac{6k}{523} - \frac{6k}{303}$$

$$= -8.329\ kW/K < 0$$

Hence, the inequality of Clausius is valid here.

As $\dot{W} = \dot{Q}_H - \dot{Q}_L$
For $\dot{W} = 0$.
Put $\dot{Q}_H = \dot{Q}_L = 6k$

(c)

Carnot Cycle

$$\Rightarrow \oint \frac{\delta \dot{Q}}{T} = \frac{\dot{Q}_H}{T_H} - \frac{\dot{Q}_L}{T_L} = 0$$

$$\frac{6k}{523} = \frac{\dot{Q}_L}{303}$$

$$\dot{Q}_L = 3.476\ kW$$

As $\dot{W} = \dot{Q}_H - \dot{Q}_L = 6k - 3.476k$

$= 2.524\ kW$

Q. No. 2

$T_H = 60^\circ C = 333 K$ $\qquad$ $P_L = 190$ kPa

As saturated ammonia,
from Table B.2.1,
AT $T = 60^\circ C$, $\quad s_1 = s_f = 1.6652$ kJ/kg·K $\qquad$ (saturation entropy)

$\quad$, $s_2 = s_g = 4.6577$ kJ/kgK $\qquad$ (evaporation entropy)

As $\displaystyle\int_1^2 \frac{\delta Q}{T} = s_2 - s_1$

Rearranging $Q_H = T(s_2 - s_1)$

$= (333)(4.6577 - 1.6652)$

$\boxed{Q_H = 996.5025 \text{ kJ/kg}}$

From Table B2.1,
AT $P = 190$ kPa, $\boxed{T_L = -20^\circ C} = 253 K$

As $\eta = 1 - \dfrac{T_L}{T_H} = 1 - \dfrac{253}{333}$

$\boxed{\eta = 0.24}$

$= 24\%$

At the beginning, $T = 60^\circ C$
From table B2.1, $\boxed{s = s_f = 1.6652}$ kJ/kgK

Q. No. 3

Heat Engine: $T_H = 200°C = 473\,K$

$P_L = 20\ kPa$

Refrigrator: $T_H = 20°C = 293\,K$

$T_L = -15°C = 258\,K$

$Q_L = 1\,kJ$

Heat Engine

As saturated water from table B1.1,

AT $T = 200°C$, $s_1 = s_f = 2.3308\ kJ/kgK$

$s_2 = s_g = 6.4322\ kJ/kgK$

As $\int_1^2 \frac{\delta Q}{T} = s_2 - s_1$

Rearranging $Q_H = T(s_2 - s_1)$

$= (473)(6.4322 - 2.3308)$

$\boxed{Q_H = 1939.9622\ kJ/kg}$

From table B1.2, At $P = 20\,kPa$, $T_L = 60.06°C = 333.06\,K$

As $\eta = 1 - \frac{T_L}{T_H} = 1 - \frac{333.06}{473} = 0.296 = 29.6\%$ — ①

Refrigerator

As COP: $\beta = \frac{T_L}{T_H - T_L}$ & $= \frac{258}{293 - 258} = 7.371$

As work done $W = \frac{Q_L}{\beta} = \frac{1k}{7.371} = 0.136\ kJ$ — ②

Using ① & ②,

As $\eta = \frac{W}{Q_H}$

$\Rightarrow Q_H = \frac{W}{\eta} = \frac{0.136}{0.296} = 0.459\,kJ$

$\boxed{Q_H = 0.459\ kJ}$