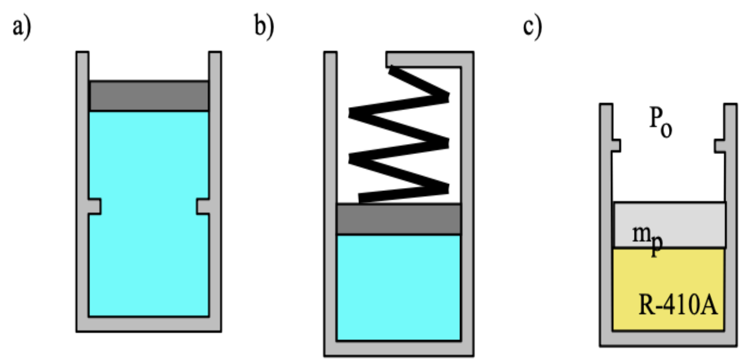
National University of Computer & Emerging Sciences, Lahore
Department of Electrical Engineering
(FALL 2024)

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 1st November 2024

1. Answer following questions: **[10 Marks]**
   a. Two hydraulic piston/cylinder systems are connected via a hydraulic line, resulting in approximately equal pressure in both. Given that the diameters of the pistons are D_1, D_2 and $D_1 = \frac{1}{2}D_2$, determine the relationship between the forces F_1 and F_2 exerted by each piston.
   b. For the indicated physical set-up in a-b and c above write a process equation and the expression for work. Also show the possible process in a P-v diagram.



2. An aircraft carrier launches a 17,500-kg plane using a steam-powered piston and cylinder mechanism. The piston operates at an average pressure of 1250 kPa and contributes 30% of the energy required for the plane to accelerate from 0 to 30 m/s. Determine the piston's displacement volume necessary for this operation. If the steam pressure in the cylinder starts at 1000 kPa and decreases linearly to 100 kPa by the end of the process. The piston contributes 30% of the energy needed for this acceleration. Find the required piston displacement volume under these conditions. **[10 Marks]**

3. A hydraulic system connects two pistons with a line. The master cylinder, with an area of 5 cm², generates a pressure of 1000 kPa and receives a work input of 25 J. The slave cylinder has an area of 3 cm². Determine the force exerted and displacement achieved by each piston, as well as the work output of the slave cylinder piston. **[10 Marks]**

4. A cylinder with a frictionless piston contains 5 kg of superheated R-134a vapor at an initial state of 1000 kPa and 140°C. The system undergoes cooling at constant pressure until the refrigerant reaches a quality of 25%. Determine the work done during this process. **[10 Marks]**

5. A piston-cylinder setup holds 1.5 kg of water at an initial condition of 200 kPa and 150°C. The system undergoes heating, following a process in which pressure changes linearly with volume, reaching a final state of 600 kPa and 350°C. Determine the final volume, the work done, and the heat transfer during this process. Also draw a P-v diagram. **[10 Marks]**

6. A cylinder with a piston restrained by a linear spring contains 2 kg of carbon dioxide at 500 kPa, 400°C. It is cooled to 40°C, at which point the pressure is 300 kPa. Calculate the heat transfer for the process. **[10 Marks]**

7. An adiabatic steam turbine in a power plant processes 5 kg/s of steam entering at 3000 kPa and 500°C. During operation, 20% of the steam is extracted at 1000 kPa and 350°C to supply a feedwater heater, while the remaining steam exits at 200 kPa and 200°C. Calculate the power output of the turbine. **[10 Marks]**

8. In a control volume, two steady flows of air enter while one exits. The first inlet stream has a flow rate of 0.025 kg/s at 350 kPa and 150°C (state 1). The second inlet stream enters at 450 kPa and 15°C (state 2). A single outlet stream exits at 100 kPa and -40°C (state 3). The control volume rejects 1 kW of heat to the surroundings and produces 4 kW of power. Neglecting kinetic energy effects, determine the mass flow rate of the air entering at state 2. **[10 Marks]**

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ME2002 – APPLIED THERMODYNAMICS

Assignment # 2 on CLO # 02, PLO # 7

Name:	**Roll Number:**
Date of Submission: 1st November 2024	**Section:**

Do not write below this line. Do not write below this line.

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 # 02**				
		Exemplary (5)	**Proficient (4)**	**Developing (3)**	**Beginning (2)**	**Novice (1)**
P1 [10]						
P2 [10]						
P3 [10]						
P4 [10]						
P5 [10]						
P6 [10]						
P7 [10]						
P8 [10]						
Total [80]						

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.

App. Thermodynamics

Assgn #02

Owais Rao

221-7638

BEE-5A

Q. No. 1

(a)

$$D_2 = \frac{1}{2} D_2$$

$$\Rightarrow \quad D_2 = 2D_1$$

As Area of cylinder $= \frac{\pi r^2}{4}$

$\Rightarrow$ As $P = \frac{F}{A}$

$$\Rightarrow \quad F_1 = PA_1 = \frac{P\pi D_1^2}{4}$$

$$\Rightarrow \quad F_2 = PA_2 = \frac{P\pi D_2^2}{4}$$

Put $D_2 = 2D_1$

$$F_2 = \frac{P\pi (2D_1)^2}{4} = \frac{P\pi \, 4D_1^2}{4}$$

$$= 4\left(\frac{P\pi D_1^2}{4}\right)$$

$$\Rightarrow \quad F_2 = 4F_1$$

(b)

Q. No.2

$m = 17.5\,kg$ $P = 1250\,kPa$ $V_2 = 30\,m/s$

$P_{start} = 1000\,kPa$ $P_{end} = 100\,kPa$ $V_1 = 0\,m/s$

As $E_2 - E_1 = \frac{m}{2}(V_2^2 - V_1^2)$

$= \frac{(17.5k)}{2}(30^2 - 0^2)$

$= 7875\,kJ$

$W = 30\%(E_2 - E_1) = (0.3)(7875k)$

$= 2362.5\,kJ$

As $W = \int P\,dV$

$W = \frac{1}{2}(P_{start} + P_{end})\Delta V$

$\Delta V = \frac{2W}{P_{start} + P_{end}}$

$= \frac{2(2362.5k)}{(1000 + 100)k}$

$\Delta V = 4.295\,m^3$

Q. No. 3

$A_m = 5\,cm^2$, $P_m = 1000\,kPa$, $W_m = 25\,J$

$A_c = 3\,cm^2$

As $W = \int P\,dV = \int PA\,dx = PA\Delta x$

$\Rightarrow \Delta x = \dfrac{W}{PA}$

$\Rightarrow \Delta x_m = \dfrac{W_m}{P_m A_m} = \dfrac{25}{(1000k)(5\times10^{-4})}$

$= 0.05\,m$

As $\Delta V = A\Delta x = (5\times10^{-4})(0.05)$

$= 2.5\times10^{-5}\,m^3$

$\Rightarrow \Delta V_s = A_s \Delta x_s$

$\Rightarrow \Delta x_s = \dfrac{\Delta V_s}{A_s} = \dfrac{2.5\times10^{-5}}{3\times10^{-4}} = 0.083\,m$

$\Rightarrow$ As $P = \dfrac{F}{A}$

$F_m = P_m A_m = (1000k)(5\times10^{-4}) = 500N$

$F_s = P_m A_s = (1000k)(3\times10^{-4}) = 300N$

As $W_s = F_s \Delta x_s = (300)(0.083)$

$= 24.9\,J$

Q. No.4

R-134a

$m = 5\,kg$

$P = 1000\,kPa$

$T = 140^\circ C$

From Table B5.2,

At $T = 140^\circ C$ & $P = 1000\,kPa$

$v_1 = 0.03150\ m^3/kg$

From Table B5.1,

$P = 1000\,kPa \approx 1017\,kPa$

$\Rightarrow\ v_2 = v_f + x v_{fg} = 0.000871 + (0.25)(0.01915)$

$= 0.00566\ m^3/kg$

As $W = \int P\,dV$

$\Rightarrow\ W_{12} = P(V_2 - V_1) = mP(v_2 - v_1)$

$= (5)(1000k)(0.00566 - 0.03150)$

$= -129.2\ kJ$

Q. No. 5

$m = 1.5 kg$

Initial: $P = 200$ kPa, $T = 150°C$

Final: $P = 600$ kPa, $T = 350°C$

From B1.3

$u_1 = 2576.84$ kJ/kg , $v_1 = 0.95964$ m³/kg

$u_2 = 2881.12$ kJ/kg , $v_2 = 0.47424$ m³/kg

As $v = \frac{V}{m} \Rightarrow V = vm$

$V_1 = mv_1 = (1.5)(0.95964) = 1.43946$ m³

$V_2 = mv_2 = (1.5)(0.47424) = 0.71136$ m³

As $W_{12} = \int P dV$

$= \frac{1}{2}(P_1 + P_2)(V_2 - V_1)$

$= \frac{1}{2}(200k + 600k)(0.71136 - 1.43946)$

$= -291.24$ kJ

As $Q_{12} - W_{12} = m(u_2 - u_1)$

$\Rightarrow Q_{12} = m(u_2 - u_1) + W_{12}$

$= (1.5)(2881.12 - 2576.84) + (-291.24)$

$= 165.18$ kJ

Q. No 0.6

$m = 2\,kg$

$P_1 = 500\,kPa$, $T_1 = 400°C = 673\,K$

$P_2 = 300\,kPa$, $T_2 = 40°C = 313\,K$

Due to linear spring, mass remains constant.

Hence, $m_2 - m_1 = 0$

As $Q_{12} - W_{12} = m(u_2 - u_1)$ — ①

As $W_{12} = \int P\,dV = \frac{1}{2}(P_1 + P_2)(V_2 - V_1)$ — ②

Using ideal gas equation,

$$PV = mRT$$

$$\Rightarrow V_1 = \frac{mR_1T_1}{P_1} = \frac{(2)(0.18892)(673)}{500k}$$

$$= 0.5086\ m^3$$

$$\Rightarrow V_2 = \frac{mRT_2}{P_2} = \frac{(2)(0.18892)(313)}{300\ k}$$

$$= 0.3942\ m^3$$

Putting values in eq ②

$$W_{12} = \frac{1}{2}(500k + 300k)(0.3942 - 0.5086)$$

$$= -45.760\ kJ$$

From eq ①

$$Q_{12} - W_{12} = mC\ (T_2 - T_1)$$

$$\Rightarrow Q_{12} = mC\ (T_2 - T_1) + W_{12}$$

From Table A.5,

$C_{p0} = \cancel{0.842}$ kJ/kg K
0.842

$$Q_{12} = (2)(0.842(313 - 673) + (-45.76k)$$

$$= -652\ kJ$$

Q. No. 7

$P_1 = 3000\ kPa$, $T_1 = 500°C$, $m_1 = 5\ kg$

$20\% \Rightarrow P_2 = 1000\ kPa$, $T_2 = 350°C$, $m_2 = 20\% \cdot m_1 = 1\ kg$

$80\% \Rightarrow P_3 = 200\ kPa$, $T_3 = 200°C$, $m_3 = 80\% \cdot m_1 = 4\ kg$

From Table B1.3,

$h_1 = 3456.48\ kJ/kg$

$h_2 = 3157.65\ kJ/kg$

$h_3 = 2870.46\ kJ/kg$

As $W_T = m_1 h_1 - m_2 h_2 - m_3 h_3$

$= (5)(3456.48) - (1)(3157.65) - (4)(2870.46)$

$= 2642.91\ kW$

Q. No. 8

~~Enter~~ Inlet:-

Stream-1 : $\dot{m}_1 = 0.025\ kg/s$

$P_1 = 350\ kPa$

$T_1 = 150°C = 423\ K$

Stream 2 : $P_2 = 450\ kPa$

$T_2 = 15°C = 288\ K$

Outlet:-

Stream 3: $P_3 = 100\ kPa$

$T_3 = -40°C = 233\ K$

As $\dot{m}_1 h_1 + \dot{m}_2 h_2 = \dot{m}_3 h_3 + \dot{W}_{cv} + \dot{Q}_{loss}$ — 1

and $\dot{m}_1 + \dot{m}_2 = \dot{m}_3$

$\Rightarrow \dot{m}_3 = 0.025 + \dot{m}_2$

From eq 1

$\dot{m}_1 C_{P_0} T_1 + \dot{m}_2 C_{P_0} T_2 = (0.025 + \dot{m}_2) C_{P_0} T_3 + \dot{W}_{cv} + \dot{Q}_{loss}$

From Table A.5

$C_{P_0} = 1.004 \ \frac{kJ}{kg K}$

$\Rightarrow (0.025)(1.004)(423) + \dot{m}_2 (1.004)(288) = (0.025 + \dot{m}_2)(1.004)(233) + 4k + 1k$

$\Rightarrow 10.6173 + 289.152 \dot{m}_2 = 233.932(0.025 + \dot{m}_2) + 5k$

$10.6173 - 5.8483 - 5k = 233.932 \dot{m}_2 - 289.152 \dot{m}_2$

$\frac{-0.231}{-55.22} = \dot{m}_2$

$\dot{m}_2 = 0.00418 \ kg/s$