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Homework 1.2

Problem 9-13

An air-standard cycle is executed within a closed piston– cylinder system and consists of three processes as follows:

1-2 $V = \text{constant}$ heat addition from 100 kPa and 27°C to 850 kPa

2-3 Isothermal expansion until $V_3 = 7 \cdot V_2$

3-1 $P = \text{constant}$ heat rejection to the initial state

Assume air has constant properties with

$$C_v = 0.718 \text{ kJ/kg} \cdot \text{K},$$

$$C_p = 1.005 \text{ kJ/kg} \cdot \text{K},$$

$$R = 0.287 \text{ kJ/kg} \cdot \text{K},$$

$$k = 1.4$$

- (a) Sketch the P-v and T-s diagrams for the cycle.
- (b) Determine the ratio of the compression work to the expansion work (the back work ratio).
- (c) Determine the cycle thermal efficiency.

Given:

- $P_1 = 100 \text{ kPa}$
- $P_2 = 850 \text{ kPa}$
- $T_1 = 27^\circ\text{C} = 300.15 \text{ K}$

To Find T_2

Use:

- $T_2 = T_1 \cdot (P_2 / P_1)$
- $T_2 = 300.15 \cdot (850 / 100)$
- $T_2 = 2551.28 \text{ K}$

To Find Volume of Air

Use:

- $V_1 = (R \cdot T_1) / P_1$

- $V_1 = (0.287 * 300.15) / 100$
- $V_1 = 0.86 \text{ m}^3/\text{kg}$

To Find S_2 to S_1

Use:

- $S_2 \text{ to } S_1 = C_p * \ln(T_2 / T_1) - R * \ln(P_2 / P_1)$
- $S_2 \text{ to } S_1 = 1.005 * \ln(2551.28 / 300.15) - 0.287 * \ln(850 / 100)$
- $S_2 \text{ to } S_1 = 1.54 \text{ kJ} / \text{kg} \cdot \text{K}$

To Find Specific Volume at V_3

Use:

- $V_3 = 7 * V_1$
- $V_3 = 7 * 0.86$
- $V_3 = 6.02 \text{ m}^3/\text{kg}$

To Find S_3 to S_2

Use:

- $S_3 \text{ to } S_2 = C_p * \ln(T_3 / T_2) - R * \ln(P_3 / P_2)$
- $S_3 \text{ to } S_2 = 1.005 * \ln(2551.28 / 2551.28) - 0.287 * \ln(100 / 850)$
- $S_3 \text{ to } S_2 = 0.61 \text{ kJ} / \text{kg} \cdot \text{K}$

Part (a)

To Find Work from 2 to 3 ($W_2 - W_3$)

Use:

- $W_2 - W_3 = R * T_2 * \ln(V_3 / V_2)$
- $W_2 - W_3 = 0.287 * 2551.28 * \ln(6.02 / 0.86)$
- $W_2 - W_3 = 1424.83 \text{ kJ/kg}$

To Find Work from 3 to 1 ($W_3 - W_1$)

Use:

- $W_3 - W_1 = R * (T_1 - T_2)$
- $W_3 - W_1 = 0.287 * (300.15 - 2551.28)$
- $W_3 - W_1 = -646.07 \text{ kJ/kg}$

To Find Q_{Loss} from 1 - 2 ($Q_1 - Q_2$)

Use:

- $Q_1 - Q_2 = C_v * (T_2 - T_1)$
- $Q_1 - Q_2 = 0.718 * (2551.28 - 300.15)$
- $Q_1 - Q_2 = 1616.31 \text{ kJ / kg}$

To Find Thermal Efficiency

Use:

- $W_{\text{net}} = (W_2 - W_3) - (W_3 - W_1)$
- $W_{\text{net}} = 1424.83 - 646.07$
- $W_{\text{net}} = 778.76 \text{ kJ / kg}$

- $Q_{\text{net}} = (Q_1 - Q_2) + (W_2 - W_3)$
- $Q_{\text{net}} = 1616.31 + 1424.83$
- $Q_{\text{net}} = 3041.14$

To Find Ratio of Compression (Part (b))

Use:

- $(W_3 - W_1) / (W_2 - W_3)$
- $646.07 / 1424.83$
- $0.453 = 45.3\%$

To Find Thermal Efficiency (Part (c))

Use:

- $N = ((W_2 - W_3) - (W_3 - W_1)) / ((Q_1 - Q_2) + (W_2 - W_3))$
- $N = (1424.83 - 646.07) / (1616.31 + 1424.83)$
- $N = 778.76 / 3041.14$
- $N = 0.256 = 25.6\%$

Problem 9-18

An ideal gas is contained in a piston–cylinder device and undergoes a power cycle as follows:
1-2 isentropic compression from an initial temperature $T_1 = 20^\circ\text{C}$ with a compression ratio $r = 5$

2-3 constant-pressure heat addition

3-1 constant-volume heat rejection

The gas has constant specific heats with

$$C_v = 0.7 \text{ kJ/kg}\cdot\text{K}$$

$$R = 0.3 \text{ kJ/kg}\cdot\text{K}.$$

- (a) Sketch the P-v and T-s diagrams for the cycle.
- (b) Determine the heat and work interactions for each process, in kJ/kg.
- (c) Determine the cycle thermal efficiency.
- (d) Obtain the expression for the cycle thermal efficiency as a function of the compression ratio r and ratio of specific heats k .

Given:

- $T_1 = 20^\circ\text{C} = 293\text{K}$
- $r = 5$
- $C_v = 0.7 \text{ kJ/kg}\cdot\text{K}$
- $C_p = C_v + R = 1$
- $R = 0.3 \text{ kJ/kg}\cdot\text{K}$
- $Y =$
 - $C_p / C_v = 1 / 0.7 = 1.43$

Part (a)

To Find T_2

Use:

- $T_2 = T_1 * r^{(Y - 1)}$

- $T_2 = 293 * 5^{(1.43 - 1)}$
- $T_2 = 585.36 \text{ K}$

To Find T_3

Use:

- $T_3 = T_2 * r$
- $T_3 = 585.36 * 5$
- $T_3 = 2926.8 \text{ K}$

To Find Heat Interaction from 1 to 2 (Part (b))

Use:

- $Q_{1-2} = C_v * (T_1 - T_2)$
- $Q_{1-2} = 0.7 * (293 - 585.36)$
- $Q_{1-2} = -204.65 \text{ kJ / kg}$

To Find Heat Interaction from 2 to 3 (Part (b))

- $Q_{2-3} = C_p * (T_3 - T_2)$
- $Q_{2-3} = 1 * (2926.8 - 585.36)$
- $Q_{2-3} = 2341.44 \text{ kJ / kg}$

To Find Heat Interaction from 3 to 1 (Part (b))

- $Q_{3-1} = C_v * (T_3 - T_1)$
- $Q_{3-1} = 0.7 * (2926.8 - 293)$
- $Q_{3-1} = 1843.66$

To Find Thermal Efficiency (Part (c))

Use:

- $N = 1 - (Q_{in} / Q_{Out})$
- $N = 1 - (1843.66 / 2341.44)$
- $N = 0.213 = 21.3\%$

Expression for Thermal Efficiency (Part (d))

- $N = 1 - (Q_{3-1} / Q_{2-3})$

Problem 22

Consider a Carnot cycle executed in a closed system with 0.6 kg of air. The temperature limits of the cycle are 300 and 1100 K, and the minimum and maximum pressures that occur during the cycle are 20 and 3000 kPa. Assuming constant specific heats, determine the net work output per cycle.

Given:

- $M = 0.6 \text{ kg}$
- $T_1 = 300 \text{ K}$
- $T_2 = 1100 \text{ K}$
- $P_1 = 20 \text{ kPa}$
- $P_3 = 3000 \text{ kPa}$
- Used Table A2 to find:
 - $R = 0.287 \text{ kJ/kg}\cdot\text{K}$
 - $K = 1.4$

To Find P_2

Use:

- $P_2 = P_1 * (T_2 / T_1)^{(K / (K-1))}$
- $P_2 = 20 * (1100 / 300)^{(1.4 / (1.4 - 1))}$
- $P_2 = 1887.9 \text{ kPa}$

To Find Heat Input ($S_1 - S_2$ and Q)

Use:

- $S_1 - S_2 = -R * \ln(P_2 / P_3)$
- $S_1 - S_2 = -0.287 * \ln(1887.9 / 3000)$
- $S_1 - S_2 = 0.13 \text{ kJ / kg}\cdot\text{K}$

Use:

- $Q = m * T_2 * (S_1 - S_2)$
- $Q = 0.6 * 1100 * 0.13$
- $Q = 85.8 \text{ kJ}$

To Find Thermal Efficiency

Use:

- $N = 1 - (T_1 / T_2)$

- $N = 1 - (300 / 1100)$
- $N = 0.727 = 72.7\%$

To Find Work Output

Use:

- $W_{\text{Out}} = N * Q$
- $W_{\text{Out}} = 0.727 * 85.8$
- $W_{\text{Out}} = 62.38 \text{ kJ}$

Problem 31

What is the difference between fuel-injected gasoline engines and diesel engines?

- Fuel-Injection Gasoline engines utilize a spark plug within the combustion chamber to ignite the octane fuel and begin the reaction process. Diesel engines utilize the heat of the compressed air within the combustion chamber to ignite the diesel fuel and begin the reaction process
 - In other words, during the compression cycle of an engine, a piston in a diesel engine compresses fresh air that was brought into the engine from the intake cycle. This air is then highly compressed, and when diesel fuel is sprayed into the combustion chamber it ignites
 - For Fuel-Injection Gasoline engines, a separate electrical component called a Spark Plug is needed to ignite the fuel. Air is still compressed within the combustion chamber, but when the fuel is injected into the chamber the spark plug creates an electrical arc to ignite the fuel