Reference book Assignment

Submission not required (for practice purpose)

Instruction: Solve it after watching videos up to lecture -3 & problem-solving lecture

1. Air is expanded in an insulated cylinder equipped with a frictionless piston. The initial temperature of the air is 1400 K. The original volume is 1/10 of the final volume. Calculate (a) the change in temperature, (b) the work removed from the gas, and (c) the pressure ratio (p_2/p_1).

   [Ans. (a) -842.65 K; (b) 6.04×10^5Nm/kg; (c) 0.0398]
2. A 15 m^3 tank contains air at $p_1 = 5.0 \times 10^5$ N/m^2 and $T_1 = 500$ K. The air is discharged into the atmosphere through a nozzle until the mass of the air contained in the tank is reduced to one-half of its original value. Assuming that the process is adiabatic and frictionless, calculate the pressure and the temperature of the air remaining in the tank. Consider a calorically perfect gas.

   [Ans. 1.8946×10^5 N/m^2, 378.92 K]
3. The unit weight of air is compressed adiabatically from an initial state with $p_1 = 10^5$ N/m^2 and $T_1 = 303$ K to a final state of $p_2 = 2p_1$ and T_2. If the air enters and leaves the compressor with same velocities, calculate the shaft work necessary. Assume air as an ideal gas.

   [Ans. $W_S = -66.66\text{kN} - \text{m/kg}$]
4. A fluid in a cylinder at a pressure of 6 atm and volume 0.3 m^3 is expanded at constant pressure to a volume of 2 m^3. Determine the work done by this expansion.

   [Ans. 1.0335MJ]
5. A gas at pressure 150kPa and density 1.5 kg/m^3 is compressed to 690kPa isentropically. Determine the final density. Assume the isentropic index to be 1.3.

   [Ans. 4.85 kg/m^3]
6. Air undergoes a change of state isentropically. The initial pressure and temperature are 101kPa and 298 K, respectively. The final pressure is seven times the initial pressure. Determine the final temperature. Assume air to be an ideal gas with ratio of specific heats $\gamma = 1.4$.

   [Ans. 519.9 K]
7. Air at 30°C is compressed isentropically to occupy a volume which is 1/30 of its initial volume. Assuming air as an ideal gas determine the final temperature.

   [Ans. 908.55°C]
8. An ideal gas is cooled under constant pressure from 200°C to 50°C. Assuming constant specific heats with $c_p = 1000$ J/kg $-$ K, and $\gamma = 1.4$, determine, (a) the molecular weight of the gas and (b) the ratio of final to initial volume of the gas.

   [Ans. (a) 29.1; (b) 0.683]
9. If the velocity of sound in an ideal gas with a molecular weight of 29 is measured to be 400 m/s at 100°C, determine the c_p and c_v of the gas at 100°C.

   [Ans. $c_p = 860.1$ J/kg $-$ K, $c_0 = 573.4$ J/kg $-$ K]
10. Air flows isentropically through a nozzle. If the velocity and the temperature at the exit are 390 m/s and 28°C, respectively, determine the Mach number and stagnation temperature at the exit. What will be the Mach number just upstream of a station where the temperature is 92.5°C ?

    [Ans. 1.12, 103.29°C, 0.387]
11. Hydrogen gas in a cylinder at 7 atm and 300 K is expanded isentropically through a nozzle to a final pressure of 1 atm. Assuming hydrogen to be a perfect gas with $\gamma = 1.4$, determine the velocity and Mach number corresponding to the final pressure. Also, find the mass flow rate through the nozzle for an exit area of 10 cm^2.

[Ans. $1923\ \mathrm{m/s}, 1.93, 0.275\ \mathrm{kg/s}$]

12. Air in a cylinder changes state from $101\mathrm{kPa}$ and $310\ \mathrm{K}$ to a pressure of $1100\mathrm{kPa}$ according to the process

$$pv^{1.32} = \text{ constant}$$

Determine the entropy change associated with this process. Assume air to be an ideal gas with $c_p = 1004\ \mathrm{J/kg-K}$ and $\gamma = 1.4$.

[Ans. $-103.8\ \mathrm{J/kg-K}$]

13. Oxygen gas is heated from $25°\mathrm{C}$ to $125°\mathrm{C}$. Determine the increase in its internal energy and enthalpy. Take $\gamma = 1.4$.

[Ans. $64950\ \mathrm{J/kg-K}, 90930\ \mathrm{J/kg-K}$]

14. Air enters a compressor at $100\mathrm{kPa}$ and $1.175\ \mathrm{kg/m^3}$ and exits at $500\mathrm{kPa}$ and $5.875\ \mathrm{kg/m^3}$. Determine the enthalpy difference between the outlet and inlet states.

[Ans. 0]

15. A quantity of air at $0.7\mathrm{MPa}$ and $150°\mathrm{C}$ occupies a volume of $0.014\ \mathrm{m^3}$. If the gas is expanded isothermally to a volume of $0.084\ \mathrm{m^3}$, calculate the change in entropy.

[Ans. $513.4\ \mathrm{J/kg-K}$]

16. $0.3\ \mathrm{kg}$ of air at $350\mathrm{kPa}$ and $35°\mathrm{C}$ receives heat energy at constant volume until its pressure becomes $700\mathrm{kPa}$. It then receives heat energy at constant pressure until its volume becomes $0.2289\ \mathrm{m^3}$. Calculate the entropy change associated with each process.

[Ans. $149.2\ \mathrm{J/K}, 333\ \mathrm{J/K}$]

17. Air flows through a frictionless diffuser. At a station in the diffuser the temperature, pressure and velocity are $0°\mathrm{C}, 140\mathrm{kPa}$ and $900\ \mathrm{m/s}$, respectively and at a downstream station the velocity decreases to $300\ \mathrm{m/s}$. Assuming the flow to be adiabatic, calculate the increase in pressure and temperature of the flow between these stations.

[Ans. $358.39\ \mathrm{K}, 2.491\mathrm{MPa}$]

18. Nitrogen gas is compressed reversibly and isothermally from $100\mathrm{kPa}$ and $25°\mathrm{C}$ to a final pressure of $300\mathrm{kPa}$. Calculate the entropy change associated with this compression process.

[Ans. $-0.3263\ \mathrm{kJ/kg-K}$]

19. Air undergoes a change of state isentropically from $300\ \mathrm{K}$ and $110\mathrm{kPa}$ to a final pressure of $550\mathrm{kPa}$. Assuming ideal gas behavior determine the change in enthalpy.

[Ans. $176.29\ \mathrm{kJ/kg}$]

20. Air at low pressure inside a rigid tank is heated from $50°\mathrm{C}$ to $125°\mathrm{C}$. What is the change in entropy associated with this heating process?

[Ans. 149.75 J/kg K]

21. Compute the temperature rise at the nose of an aircraft flying with Mach number 2 at an altitude of where temperature is 223 K.

[Ans. 178.4]

22. A gas at an initial volume of $0.06\ \mathrm{m^3}$ and $15°\mathrm{C}$ is expanded to a volume of $0.12\ \mathrm{m^3}$ while the pressure remains constant. Determine the final temperature of the gas.

[Ans. $303.15°\mathrm{C}$]