ME 201
Thermodynamics

Homework #7 Solutions

1. Refrigerant -134a as saturated vapor at 0.5 MPa is isentropically compressed by a compressor in a refrigeration plant to 1.2 MPa. Determine the enthalpy change for the process and the final fluid phase.

Solution:

Substance Type: Compressible (R-134a)
Problem Type: Process(Isentropic)

State 1	State 2
T_1 = *15.71 °C*	T_2 = *49.3 °C*
P_1 = 0.5 MPa	P_2 = 1.2 MPa
h_1 = *259.30 kJ/kg*	h_2 = *277.4 kJ/kg*
s_1 = *0.9240 kJ/(kg·K)*	s_2 = **0.9240 kJ/(kg·K)**
phase: sat.vap.	phase: *sup.vap.*

Italicized values are from R-134a tables, **bold** values are calculated.

At state 1 we know the pressure and that we have saturated liquid, so that the state is fixed. Going to the saturation pressure table, Table A-12, we find

$$T_1 = 15.71°C, s_1 = 0.9240\ \text{kJ/(kg}\cdot\text{K)}, h_1 = 259.30\ \text{kJ/kg}$$

At state 2 we know the pressure and that we have an isentropic process or

$$s_2 = s_1 = 0.9240\ \text{kJ/(kg}\cdot\text{K)}$$

To determine the fluid phase, we go to the saturation pressure table at 1.2 MPa and find

$$s_f = 0.4244\ \text{kJ/(kg}\cdot\text{K) and } s_g = 0.9130\ \text{kJ/(kg}\cdot\text{K)}$$

Since $s_2 > s_g$, we have a superheated vapor at state 2. Going to the superheat tables, Table A-13, we find after interpolating

$$T_2 = 49.3°C, h_2 = 277.4\ \text{kJ/kg}$$

Our enthalpy change is then

$$\Delta h = h_2 - h_1 = 277.4 - 259.3 = 18.1\ \text{kJ/kg}$$

2. What is the quality and internal energy of 0.1 lb_m of steam contained in a 1.3 ft^3 container at a temperature of 233°F?

Solution:

Substance Type: Compressible (steam)

Problem Type: State

State 1

T_1 = 233°F

v_1 = **13 ft^3/lb_m**

u_1 = ***822.2 kJ/kg***

phase: 2 phase mixture

x = ***0.704***

Italicized values are from steam tables, **bold** values are calculated.

Since we know the temperature and the specific volume can be calculated, the state is fixed. The specific volume is given by

$$v_1 = \frac{V}{m} = \frac{1.3}{0.1} = 13\ ft^3/lb_m$$

Going to the saturation temperature table , Table A-4E, we interpolate to find

$$v_f = 0.0016864\ ft^3/lb_m \text{ and } v_g = 18.46\ ft^3/lb_m$$

Since $v_f < v_1 < v_g$, we must have a two phase mixture with

$$x_1 = \frac{13 - 0.0016864}{18.46 - 0.0016864} = 0.704$$

The internal energy is then given by

$$u = u_f + x \cdot u_{fg} = 201.34 + (0.704)(881.9)$$
$$= 822.2\ Btu/lb_m$$

3. Air enters the combustion chamber of a jet aircraft engine at 800 kPa and 600 K and exits at 2200 K. Since an ideal combustion chamber is isobaric, determine the entropy change and exit specific volume.

Solution:

Substance Type: Ideal Gas (air)

Problem Type: Process(Isobaric)

State 1	State 2
T_1 = 600 K	T_2 = 2200 K
P_1 = 800 kPa	P_2 = **800 kPa**
v_1 = *0.215 m^3/kg*	v_2 = *0.7894 m^3/kg*
ϕ_1= *2.40902 kJ/(kg K)*	ϕ_2 =*3.9191 kJ/(kg K)*

Italicized values are from air tables or ideal gas law, **bold** values are calculated.

At state 1 we know both the temperature and the pressure, so that the state is fixed. Then from the air tables, Table A-17, we find

$$\phi_1 = 2.40902 \text{ kJ / (kg} \cdot \text{K)}$$

and using the ideal gas law

$$v_1 = \frac{RT_1}{P_1} = \frac{(0.287)(600)}{800} = 0.215 \text{ m}^3 \text{ / kg}$$

At state 2 we know the temperature and that the process was isobaric, thus

$$P_2 = P_1 = 800 \text{ kPa}$$

Our state is now fixed and from the air tables, Table A-17, we find

$$\phi_2 = 3.9191 \text{ kJ/(kg} \cdot \text{K)}$$

and using the ideal gas law

$$v_2 = \frac{RT_2}{P_2} = \frac{(0.287)(2200)}{800} = 0.789 \text{ m}^3 \text{ / kg}$$

Then

$$\Delta s = \phi_2 - \phi_1 - R \cdot \ln\left(\frac{P_2}{P_1}\right)$$

$$= 3.9191 - 2.40902 - (0.287)\ln\left[\frac{800}{800}\right]$$

$$= 1.51 \text{ kJ/(kg} \cdot \text{K)}$$