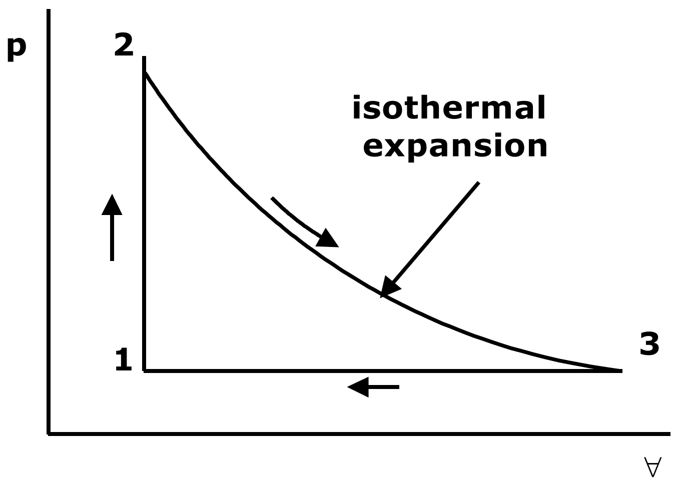
CANKAYA UNIVERSITY
FACULTY OF ENGINEERING
MECHANICAL ENGINEERING DEPARTMENT

ME 211 THERMODYNAMICS I
Fall 2017
CHAPTER 2 EXAMPLES

28) One mole of air is compressed isochorically till its pressure gets doubled. Then, it is allowed to expand reversibly and isothermally to regain its original pressue.



Therefore, it is subjected to isobaric cooling where its volume decreases to restore its initial state. Find the net work done. Assume air is ideal gas.

Solution

$$W = W_{1-2} + W_{2-3} + W_{3-1}$$

$$W = 0 + RT_2 \ln\left(\frac{\forall_3}{\forall_2}\right) + p_1\left(\forall_1 - \forall_3\right)$$

$$W_{2-3} = \text{isothermal work}$$

$$W_{2-3} = p_2\forall_2 \ln\left(\frac{\forall_3}{\forall_2}\right)$$

$$W = RT_2 \ln\left(\frac{p_2}{p_3}\right) + p_1\forall_1\left(1 - \frac{\forall_3}{\forall_1}\right)$$

$p_3 = p_1 \qquad p_2 = 2p_1$

$$W = R\left(T_2\right)\ln\left(2\right) + T_1\left(1 - 2\right)$$

$$W = R\left(T_1\right)\left(2\ln\left(2\right) - RT_1\right)$$

$$W = R\left(T_1\right)\left(2\ln\left(2\right) - 1\right)$$

Path $1-3$:

$$\frac{p_1\forall_1}{T_1} = \frac{p_3\forall_3}{T_3}$$

$$\forall_3 = \left(\frac{T_3}{T_1}\right)\left(\frac{p_1}{p_3}\right)\forall_1$$

$$\forall_3 = \left(\frac{T_2}{T_1}\right)(1)\forall_1$$

And also from figure

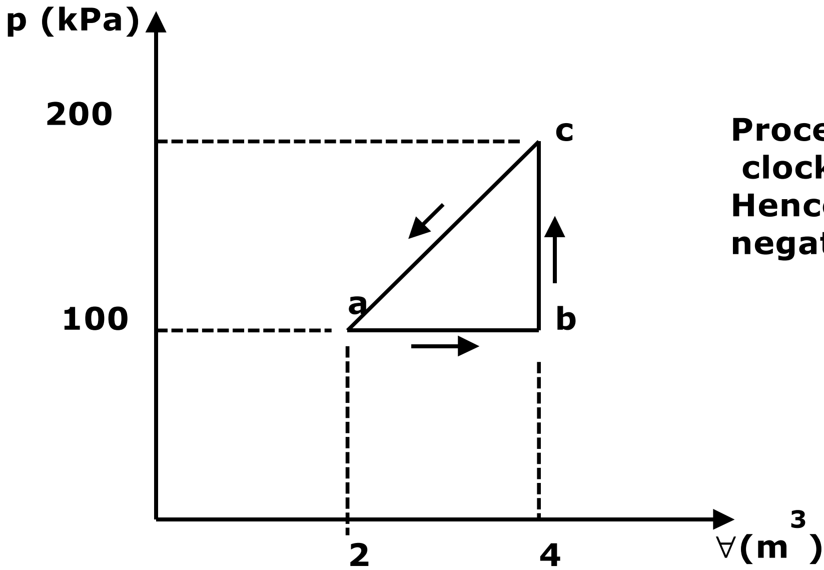
$$\frac{\forall_3}{\forall_1} = \frac{T_2}{T_1} = \frac{\left(p_2\forall_2\right)}{\left(p_1\forall_1\right)} = 2$$

$$p_2 = 2p_1$$

$$V_1 = V_2$$

$$T_2 = T_3$$

29) A gas enclosed in a piston-cylinder assembly undergoes processes ab, bc, and ca as shown.



Process is taking place in clockwise direction Hence, Work has negative sign

Process ab:

$$W_{ab} = 100\,\text{kPa} \times (4-2)\text{m}^3 = 200\,\text{kJ}$$

Process bc:

$$W_{bc} = 0 \qquad \forall = \text{const}$$

Process ca: Pressure reduction accompanied by a cooling causing a volume reduction.

$$W_{ca} = -\left[\frac{1}{2}(200-100)\,\text{kPa} \times (4-2)\,\text{m}^3 + (4-2)\text{m}^3 \times 100\text{kPa}\right] = -300\,\text{kPa}$$

or

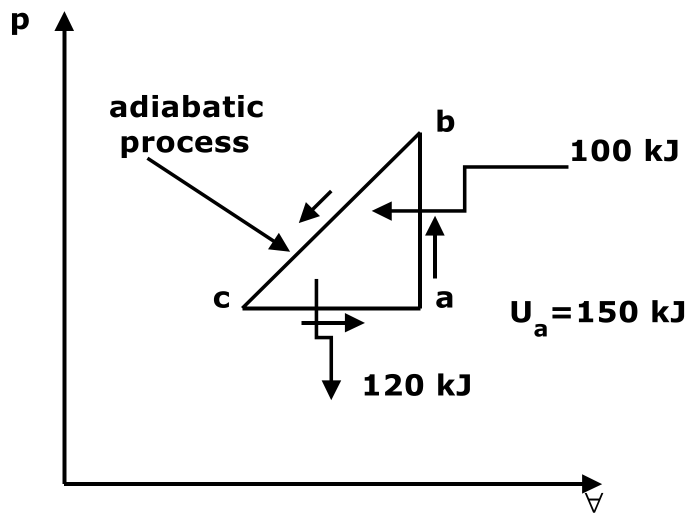
$$W_{ca} = -\left[\frac{1}{2}(200+100)\,\text{kPa} \times (4-2)\,\text{m}^3\right] = -300\,\text{kPa}$$

Net work is

$$W_{ab} + W_{bc} + W_{ca} = 200\,\text{kJ} + 0 + (-300\,\text{kJ}) = -100\,\text{kJ}$$

Negative sign indicates that work is done on the system (gas)

30) A gas in a closed system is taken through a cyclic process. First it is heated isochorically from state a state b whereupon its pressure increases from p_a to p_b .



Then it is compressed adiabatically from b to c (process bc) to its pressure p_a .Finally it is allowed to expand isobarically from state c to state a.
Process ab: heat absorption of 100 kJ
Process bc: Work done on gass= 70 kJ
Process ca: Heat rejection of 120 kJ

Determine

1. U_b
2. U_c
3. W_{ca}

Solution

Process ab: constant volume $W_{ab}=0$
First Law $\Delta U = Q - W$

$Q_{ab} = \Delta U_{ab} + 0$

Entire heat supplied goes to increase the internal energy of the system. Therefore,

$$U_b - U_a = 100\,kJ$$
$$U_b - 150\,kJ = 100\,kJ$$
$$U_b = 250\,kJ$$

Process bc

Adiabatic process. Q=0
From the first law of thermodynamics for a closed system
$$Q_{bc} = \Delta U_{bc} + W_{bc}$$

The process accompanies a volume reduction, therefore, W_{bc} is $(-)$
$$0 = U_c - U_b + (-70\,kJ)$$
$$U_c = 250\,kJ + 70\,kJ = 320\,kJ$$

Process ca

Isobaric volume expansion

Work is done by system (gas). First Law

$$Q_{ca} = \Delta U_{ca} + W_{ca}$$
$$(-120\,kJ) = (U_c - U_a) + W_{ca}$$
$$W_{ca} = -120\,kJ + (150 - 320)\,kJ = 50\,kJ$$

$$U_a = U_b = 150\,kJ$$