

P1.1 This example shows how the First Law can be applied to individual processes and how these can make up a cycle.

A cycle of events is shown in Fig A.10. It is made up of four processes, and the heat and work associated with those processes is as given.

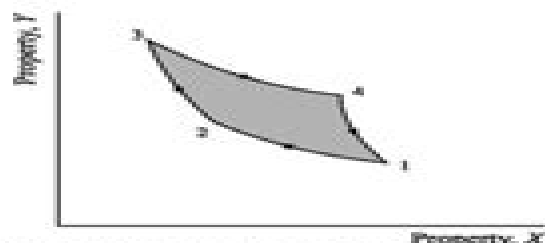


Fig A.10: Cycle of events made up of four processes.

Process 12: $\delta Q = +10\text{J}$ $\delta W = -18\text{J}$

Process 23: $\delta Q = +100\text{J}$ $\delta W = 0\text{J}$

Process 34: $\delta Q = -20\text{J}$ $\delta W = +70\text{J}$

Process 41: $\delta Q = -10\text{J}$ $\delta W = +28\text{J}$

Calculate the values of $U_3 - U_1$, the net work, the net heat transfer and the heat supplied for the cycle.

Solution

This problem can be solved by applying the First Law to each of the processes in turn, when the change in internal energy is $dU = \delta Q - \delta W$.

Process 1→2: $dU_{12} = U_2 - U_1 = \delta Q_{12} - \delta W_{12} = 10 + 18 = 28\text{J}$

Process 2→3: $dU_{23} = U_3 - U_2 = \delta Q_{23} - \delta W_{23} = 100 - 0 = 100\text{J}$

Process 3→4: $dU_{34} = U_4 - U_3 = \delta Q_{34} - \delta W_{34} = -20 - 70 = -90\text{J}$

Process 4→1: $dU_{41} = U_1 - U_4 = \delta Q_{41} - \delta W_{41} = -10 - 28 = -38\text{J}$

The change in internal energy relative to the internal energy at point 1, U_1 , is given by

$$\begin{aligned} dU_n &= U_n - U_1 = U_n - U_{n-1} + U_{n-1} - U_{n-2} + \dots + U_2 - U_1 \\ &= dU_{n-1,n} + dU_{n-2,n-1} + \dots + dU_{12} \end{aligned}$$

Hence:

$$dU_{12} = U_2 - U_1 = 28\text{J}$$

$$dU_{13} = dU_{12} + dU_{23} = 28 + 100 = 128\text{J}$$

$$dU_{14} = dU_{12} + dU_{23} + dU_{34} = 28 + 100 + (-90) = 38\text{J}$$

$$dU_{11} = dU_{12} + dU_{23} + dU_{34} + dU_{41} = 28 + 100 + (-90) + (-38) = 0\text{J}$$

The result $dU_{11} = 0$ confirms that the four processes constitute a cycle, because the net change of state is zero.

The net work done in the cycle is

$$\begin{aligned} \sum_{\text{cycle}} W &= \delta W_{12} + \delta W_{23} + \delta W_{34} + \delta W_{41} \\ &= -18 + 0 + 70 + 28 = +80\text{J} \end{aligned}$$

The positive sign indicates that the system does work on the surroundings.

The net heat supplied in the cycle is

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Solutions Manual for Advanced Thermodynamics Engineering Ishwar K. Puri, 2002-07

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