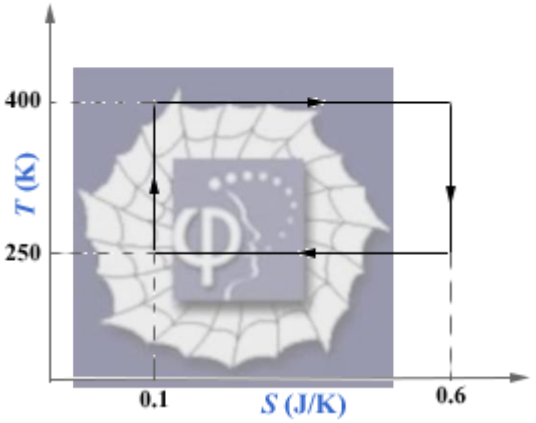
256.

Problem 26.31 (RhK)

We have to show that a Carnot cycle, plotted on an absolute temperature versus entropy (*TS*) *diagram, graphs as a rectangle. For the Carnot cycle shown in the figure,* (b) *we have to calculate the heat that enters; and* (c) *the work done on the system.*



Solution:

We will show that a Carnot cycle when plotted on a *T*-*S* plane has a rectangular graph.

The Carnot cycle consists of two adiabatic processes and two isothermal processes. In an adiabatic process, as the system is thermally insulated, there is no exchange of heat and as the process is reversible there is no change in entropy.

In isothermal processes during the expansion phase an amount of heat Q_H is absorbed by the working substance during its contact with the high temperature heat reservoir, which is at temperature T_H. Therefore, the entropy of the system increases by an amount equal to Q_H/T_H. And during the compression phase an amount of heat $|Q_L|$ is released to the cold heat reservoir, which is at temperature T_L. Therefore, the entropy of the working substance gets decreased by an amount $|Q_L|/T_L$. As the Carnot cycle is a reversible thermodynamic process, the change in entropy of the system over one cycle is zero. Therefore,

$$\frac{Q_H}{T_H} = \frac{|Q_L|}{T_L}.$$

From the discussion above we note that the graph of the Carnot cycle on a *T*-*S* plane is a rectangle.

(b)

For the Carnot engine shown in the figure the amount of heat that enters the system at temperature $T_H = 400$ K is $Q_H = (0.6 - 0.1) \times 400$ J $= 200$ J.

The amount of heat that leaves the system at $T_L = 250$ K is $|Q_L| = (0.6 - 0.1) \times 250$ J $= 125$ J.

Therefore, the work done by the system

$W = Q_H - |Q_L| = (200 - 125)$ J $= 75$ J.

And the work done on the system will be -75 J.