Fundamentals of Engineering Thermodynamics

Example 1: Consider a steady-state system consisting of a combination of a heat source and a refrigerator. The system is maintained at a constant temperature of 300 K. The heat source transfers 1000 W of heat to the system. The refrigerator removes 500 W of heat from the system. Determine the entropy generation of the system.

Answer:

The entropy generation of the system can be calculated using the formula:

\[ \Delta S_{gen} = \frac{Q}{T} \]

where \( Q \) is the heat transferred to or from the system, and \( T \) is the temperature of the system.

For this system, \( Q = 1000 \text{ W} \) and \( T = 300 \text{ K} \). Substituting these values into the formula, we get:

\[ \Delta S_{gen} = \frac{1000}{300} = 3.33 \text{ W/K} \]

Therefore, the entropy generation of the system is 3.33 W/K.

Example 2: A heat exchanger is used to transfer heat from a hot fluid at 80°C to a cold fluid at 20°C. The heat of the hot fluid is 200000 J. If the heat transfer coefficient is 100 W/m²K and the heat exchanger has an area of 10 m², calculate the temperature rise of the cold fluid.

Answer:

The temperature rise of the cold fluid can be calculated using the formula:

\[ \Delta T = \frac{Q}{U \cdot A} \]

where \( Q \) is the heat transferred, \( U \) is the heat transfer coefficient, and \( A \) is the heat exchanger area.

Substituting the given values into the formula, we get:

\[ \Delta T = \frac{200000}{100 \times 10} = 20 \text{ °C} \]

Therefore, the temperature rise of the cold fluid is 20°C.

Example 3: A Carnot engine operates between two thermal reservoirs at temperatures of 200°C and 50°C. If the engine has a thermal efficiency of 30%, determine the work output of the engine per cycle.

Answer:

The work output of the Carnot engine per cycle can be calculated using the formula:

\[ W = T_H \cdot Q_H - T_L \cdot Q_L \]

where \( W \) is the work output, \( T_H \) and \( T_L \) are the temperatures of the two reservoirs, \( Q_H \) is the heat absorbed from the high temperature reservoir, and \( Q_L \) is the heat rejected to the low temperature reservoir.

First, we need to calculate the heat absorbed and rejected by the engine. These can be calculated using the formula:

\[ Q_H = W / (1 - \eta) \]

\[ Q_L = W \cdot \eta \]

Substituting the given values into these formulas, we get:

\[ Q_H = \frac{W}{0.7} \]

\[ Q_L = 0.3W \]

Now, we can substitute these values into the work output formula:

\[ W = T_H \cdot Q_H - T_L \cdot Q_L \]

\[ W = 200 \cdot \frac{W}{0.7} - 50 \cdot 0.3W \]

Simplifying this equation, we get:

\[ 1.4W = 150W - 15W \]

\[ 1.4W = 135W \]

\[ W = \frac{135W}{1.4} \]

\[ W = 96.42857W \]

Therefore, the work output of the Carnot engine per cycle is approximately 96.43 W.
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