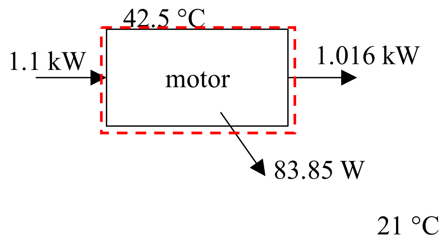
An electric motor operates at steady state, with an electrical power input of 1.1 kW and a shaft power output of 1.016 kW. The surface of the motor casing is 42.5 °C. Far from the motor the temperature is 21 °C. There is 83.85 W of heat transfer from the motor surface to the surroundings.

a. Calculate the rate of entropy production within the motor.
b. Calculate the rate of entropy production within the motor and the surroundings.

SOLUTION



For part (a), apply the Entropy Equation to the system shown above (consisting of just the motor) to determine the rate of entropy production in the motor,

$$\frac{dS_{sys}}{dt} = \int_b \frac{\delta \dot{Q}_{into\ sys}}{T} + \dot{\sigma}_{sys}, \tag{1}$$

where,

$$\frac{dS_{sys}}{dt} = 0 \quad \text{(steady state)}, \tag{2}$$

$$\dot{Q}_{into\ sys} = -83.85\ W \quad \text{(assume heat flux is uniform from the motor surface)} \tag{3}$$

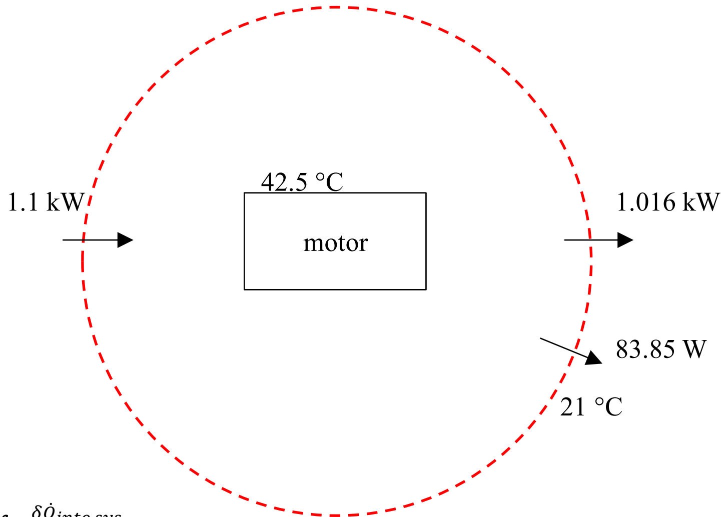
$$T = (42.5 + 273.15)\text{ K} = 315.65\text{ K} \quad \text{(assume the temperature is uniform over the system boundary)} \tag{4}$$

Substitute and calculate,

$$\dot{\sigma}_{sys} = -\int_b \frac{\delta \dot{Q}_{into\ sys}}{T} = -\frac{-83.85\ W}{294.15\ K} \tag{5}$$

$$\boxed{\dot{\sigma}_{sys} = 0.266\ W/K}.$$

For part (b), apply the Entropy Equation to the following system, which contains the motor and most of the surroundings (at the limit where the temperature is equal to the temperature of the surroundings). Note that the same energy that crossed the motor boundary via heat transfer will also cross the larger boundary.



$$\frac{dS_{sys}}{dt} = \int_b \frac{\delta \dot{Q}_{into\ sys}}{T} + \dot{\sigma}_{sys}, \qquad (6)$$

where,

$$\frac{dS_{sys}}{dt} = 0 \quad \text{(steady state)}, \qquad (7)$$

$$\dot{Q}_{into\ sys} = -83.85\ W \quad \text{(the heat flux will be the same as it was in part (a))} \qquad (8)$$

$$T = (21 + 273.15)\text{ K} = 294.15\text{ K} \quad \text{(assume the temperature is uniform over the system boundary)} \qquad (9)$$

Substitute and calculate,

$$\dot{\sigma}_{sys} = -\int_b \frac{\delta \dot{Q}_{into\ sys}}{T} = -\frac{-83.85\ W}{294.15\ K} \qquad (10)$$

$$\boxed{\dot{\sigma}_{sys} = 0.285\ W/K}.$$

The rate of entropy production is larger for part (b) because more material, through which heat transfer is occurring, is included within the system. Recall that heat transfer through a finite temperature gradient is irreversible and, thus, will produce entropy.