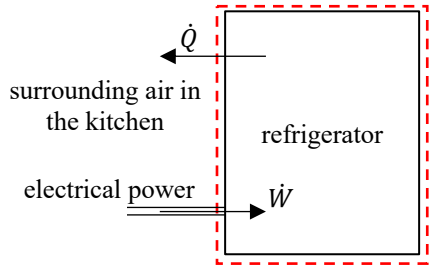
An ordinary household refrigerator operating in steady state receives electrical work while discharging net energy by heat transfer to its surroundings (e.g., the kitchen).

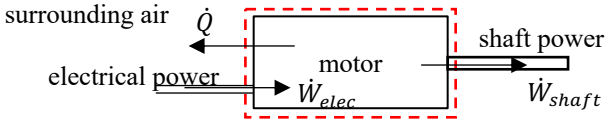
a. Is this a violation of the Kelvin-Planck statement of the Second Law of Thermodynamics? Explain your answer.
b. Consider the same question, but now consider an electric motor operating in steady state.

SOLUTION:
Consider the system to be the refrigerator (shown in the following schematic), which operates over a cycle in normal operation.



There is one thermal reservoir: the surrounding air. The Kelvin-Planck statement of the Second Law states: "It is impossible for any system to operate in a thermodynamic cycle and deliver a net amount of energy by work to its surroundings while receiving energy by heat transfer from a single thermal reservoir." or, mathematically, $W_{by\ sys,cycle} \leq 0$ (single thermal reservoir). In the case of a refrigerator, although there is heat transfer with a single thermal reservoir, there is work being done on the system over the cycle, not by the system, i.e., $\dot{W}_{by\ sys,cycle} \leq 0$ (zero only if the heat transfer is zero). Thus, there is no violation of the Kelvin-Planck statement of the 2nd Law.

Now consider the system to be an electric motor, which also operates cyclically in normal operation.



Furthermore, from the 1st Law, $\dot{W}_{shaft} \leq \dot{W}_{elec}$ (zero only if there's no heat transfer). As in the previous case, net work is done on the motor rather than by the motor, i.e., $\dot{W}_{net,by\ sys,cycle} \leq 0$. Thus, there is no violation of the Kelvin-Planck statement of the 2nd Law.