19.20. Model: For a refrigerator $Q_H = Q_C + W_{in}$, and the coefficient of performance and the Carnot coefficient of performance are

$$K = \frac{Q_C}{W_{in}} \qquad K_{Carnot} = \frac{T_C}{T_H - T_C}$$

Visualize: Please refer to Figure Ex19.20.
Solve: **(a)** For refrigerator (a) $Q_H = Q_C + W_{in}$ $(60\text{ J} = 40\text{ J} + 20\text{ J})$, so the first law of thermodynamics is obeyed. For refrigerator (b) $50\text{ J} = 40\text{ J} + 10\text{ J}$, so the first law of thermodynamics is obeyed. For the refrigerator (c) $40\text{ J} \neq 30\text{ J} + 20\text{ J}$, so the first law of thermodynamics is violated.
(b) For the three refrigerators, the maximum coefficient of performance is

$$K_{Carnot} = \frac{T_C}{T_H - T_C} = \frac{300\text{ K}}{400\text{ K} - 300\text{ K}} = 3$$

For refrigerator (a),

$$K = \frac{Q_C}{W_{in}} = \frac{40\text{ J}}{20\text{ J}} = 2 < K_{Carnot}$$

so the second law of thermodynamics is obeyed. For refrigerator (b),

$$K = \frac{Q_C}{W_{in}} = \frac{40\text{ J}}{10\text{ J}} = 4 > K_{Carnot}$$

so the second law of thermodynamics is violated. For refrigerator (c),

$$K = \frac{30\text{ J}}{20\text{ J}} = 1.5 < K_{Carnot}$$

so the second law is obeyed.