

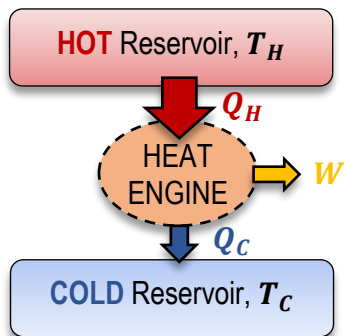
CONCEPT: REFRIGERATORS

- Remember, heat ALWAYS flows from hotter to colder, never the other way around!

Second Law of Thermodynamics – Clausius / “Refrigerator” Statement

- In a cyclic process, it is impossible for heat to flow from COLDER to HOTTER temperature without an input of _____.
- A **Refrigerator** is the opposite of a heat engine – it takes in _____ to pump heat energy from _____ to _____.
 - Your home fridge takes heat from food/liquid (Q_C) and work from electricity (W), and expels heat to the room (Q_H).
 - Efficiency = how “good” a heat engine is. Coefficient of Performance = how “good” a refrigerator is.

Heat Engine



• $\Delta E_{int} = 0 \rightarrow |W| = |Q| = |Q_H| - |Q_C|$

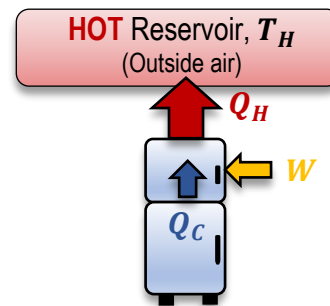
• Efficiency:

$$e = \frac{W}{Q_H} = 1 - \frac{Q_C}{Q_H}$$

What you
got out of it

What you
“paid” to get it

Refrigerator

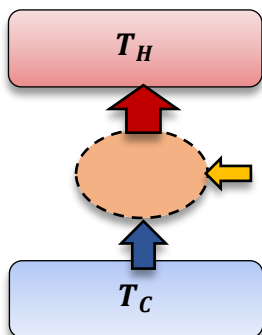


• $\Delta E_{int} = 0 \rightarrow |W| = |Q| = \underline{\hspace{2cm}}$

• Coefficient of
Performance:

$$K = \underline{\hspace{2cm}} = \underline{\hspace{2cm}}$$

EXAMPLE: A refrigerator takes in 600 kJ of heat from the food inside, and releases 720 kJ of energy to the (much warmer) room. Calculate: **a)** the work required to run the refrigerator each cycle; **b)** the coefficient of performance of the refrigerator.



PROBLEM: A refrigerator has a coefficient of performance of 2.4. Each cycle, it takes in 3×10^4 J of heat from the cold reservoir. How much is expelled to the hot reservoir?

- A) 2.5×10^4 J
- B) 4.25×10^4 J
- C) 2.1×10^4 J
- D) 1.25×10^4 J

HEAT ENGINES & REFRIGERATORS

$$\Delta E_{int} = 0$$

$$|W| = |Q_H| - |Q_C|$$

$$e = \frac{W}{Q_H} = 1 - \frac{Q_C}{Q_H}$$

$$K = \frac{Q_C}{W} = \frac{Q_C}{Q_H - Q_C}$$

PROBLEM: A common household mini-refrigerator has $K = 3$ and power input of 85 W. A sample of water of mass 0.5 kg and temperature 20.0°C is placed in the freezer compartment. How long does it take to freeze the water to ice at 0°C?

HEAT ENGINES & REFRIGERATORS

$$\Delta E_{int} = 0$$

$$|W| = |Q_H| - |Q_C|$$

$$e = \frac{W}{Q_H} = 1 - \frac{Q_C}{Q_H}$$

$$K = \frac{Q_C}{W} = \frac{Q_C}{Q_H - Q_C}$$

$$Q = mc\Delta T$$

$$c_{water} = 4186 \text{ J/(kg}\cdot\text{K)}$$

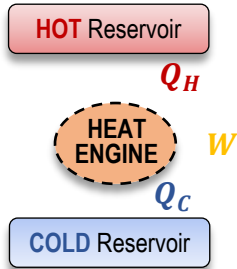
$$L_f = 3.34 \times 10^5 \text{ J/kg}$$

CONCEPT: HEAT PUMPS

- Heat Pumps, like refrigerators, pump heat from **COLDER** to **HOTTER**. However, the reservoirs are _____.

Heat Engine

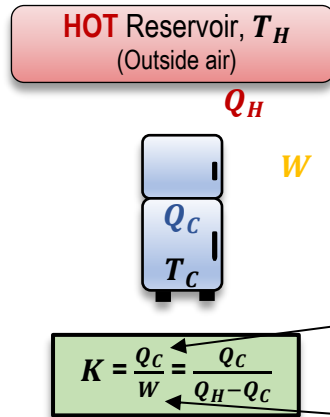
(e.g. generator)



[PRODUCES | REQUIRES] Work

Refrigerator

(e.g. fridge or air conditioner)



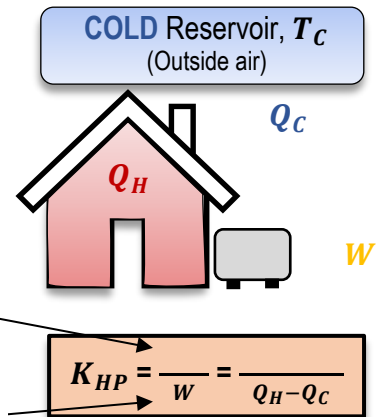
[PRODUCES | REQUIRES] Work

Cold reservoir is [INSIDE | OUTSIDE]

Hot reservoir is [INSIDE | OUTSIDE]

Heat Pump

(e.g. space heater)



[PRODUCES | REQUIRES] Work

Cold reservoir is [INSIDE | OUTSIDE]

Hot reservoir is [INSIDE | OUTSIDE]

EXAMPLE: A heat pump has a coefficient of performance of 3.6 and a power supply of 7×10^3 W. Calculate the heat energy delivered into a home over 4 hours of use.

EQUATIONS

$$|W| = |Q_H| - |Q_C|$$

$$P = \frac{W}{\Delta t}$$