**Heat engine**

- High-temp source, $T_H$
- Low-temp sink, $T_L$
- Thermal efficiency:
  $$\eta_{th} = \frac{W_{net, out}}{Q_{in}}$$

1st law:

- $\Delta E = 0 = Q_{net, in} - W_{net, out}$
- $W_{net, out} = Q_{in} - Q_{out}$
- $\eta_{th} = 1 - \frac{Q_{out}}{Q_{in}} < 1$

**Refrigeration cycle**

- Hot thermal reservoir, $T_H$
- Cold thermal reservoir, $T_L$
- Coefficient of performance:
  $$\text{COP}_R = \frac{Q_L}{W_{net, in}}$$
  $$\text{COP}_{HP} = \frac{Q_H}{W_{net, in}}$$

1st law:

- $\Delta E = 0 = Q_{in} - Q_{out} - W_{in}$
- $W_{net, in} = Q_{H} - Q_{L}$