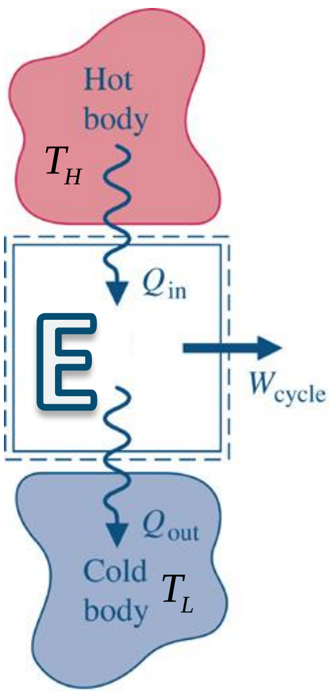
Carnot Heat Engine



$$\eta_{th} = \frac{W_{cycle}}{Q_{in}} = \frac{Q_{in} - |Q_{out}|}{Q_{in}} = 1 - \frac{|Q_{out}|}{Q_{in}}$$

$$\eta_{th,Carnot} = \frac{W_{cycle}}{Q_{in}} = \frac{Q_{in} - |Q_{out}|}{Q_{in}} = 1 - \left(\frac{|Q_{out}|}{Q_{in}}\right)_{rev}$$

Kelvin and Rankine suggested that,

$$\left(\frac{|Q_{out}|}{Q_{in}}\right)_{rev} = \frac{T_L}{T_H}$$

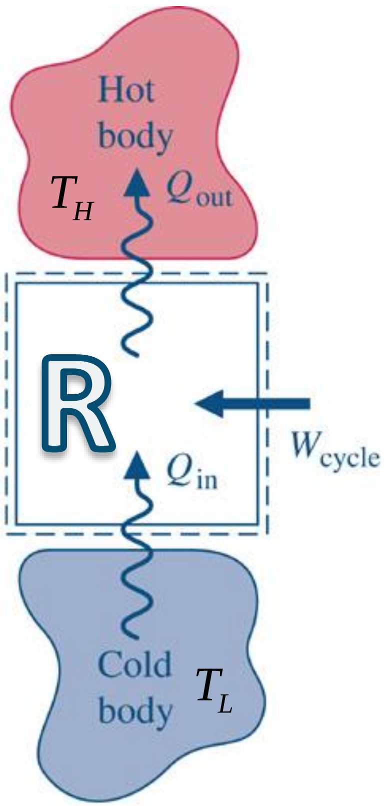
Temperatures must be on the absolute scale!

Therefore, the thermal efficiency of a Carnot Heat Engine is,

$$\eta_{th,Carnot} = 1 - \frac{T_L}{T_H}$$

This is the **maximum** efficiency of a heat engine!

Carnot Refrigerator & Heat Pump



For the Refrigeration cycle …

$$\eta_{th} = \text{COP}_{\text{R}} = \frac{Q_{in}}{|W_{cycle}|} = \frac{Q_{in}}{|Q_{out}| - Q_{in}} = \frac{1}{|Q_{out}|/Q_{in} - 1}$$

$$\text{COP}_{\text{R},Carnot} = \frac{1}{\left(|Q_{out}|/Q_{in}\right)_{rev} - 1} = \frac{1}{T_H/T_L - 1}$$

$$\boxed{\text{COP}_{\text{R},Carnot} = \frac{T_L}{T_H - T_L}}$$

For the Heat Pump cycle …

$$\eta_{th} = \text{COP}_{\text{H}} = \frac{|Q_{out}|}{|W_{cycle}|} = \frac{|Q_{out}|}{|Q_{out}| - Q_{in}} = \frac{1}{1 - Q_{in}/|Q_{out}|}$$

$$\text{COP}_{\text{H},Carnot} = \frac{1}{1 - \left(Q_{in}/|Q_{out}|\right)_{rev}} = \frac{1}{1 - T_L/T_H}$$

$$\boxed{\text{COP}_{\text{H},Carnot} = \frac{T_H}{T_H - T_L}}$$