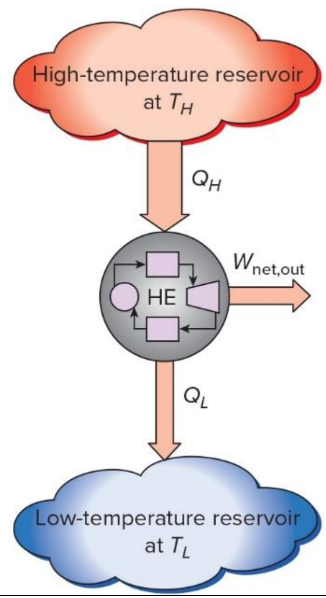
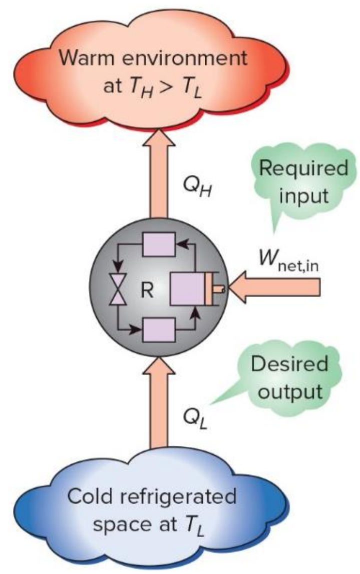
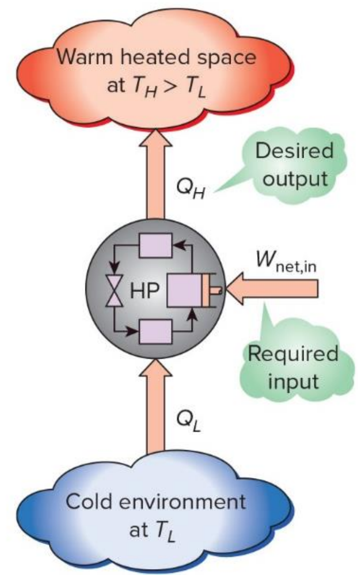
# Second Law of Thermodynamics

<table>
<tr><th>Heat Engine</th><th>Refrigerator</th><th>Heat Pump</th></tr>
<tr><td>
</td><td>
</td><td>
</td></tr>
<tr><td>The thermal efficiency of a heat engine is defined as<br>$\eta_{th} = \frac{W_{net,out}}{Q_H} = 1 - \frac{Q_L}{Q_H}$</td><td>The performance of a refrigerator is expressed in terms of the coefficient of performance, which is defined as<br>$COP_R = \frac{Q_L}{W_{net,in}} = \frac{1}{Q_H/Q_L - 1}$</td><td>The performance of a heat pump is expressed in terms of the coefficient of performance, which is defined as<br>$COP_{HP} = \frac{Q_H}{W_{net,in}} = \frac{1}{1 - Q_L/Q_H}$</td></tr>
<tr><td colspan="3">For a reversible process (Carnot Cycle):<br>$\left(\frac{Q_H}{Q_L}\right)_{rev} = \frac{T_H}{T_L}$</td></tr>
<tr><td>A heat engine that operates on the reversible Carnot cycle is called a Carnot heat engine. The thermal efficiency of a Carnot heat engine, as well as all other reversible heat engines, is given by<br>$\eta_{th,rev} = 1 - \frac{T_L}{T_H}$</td><td>The COP of a reversible refrigerator is<br>$COP_{R,rev} = \frac{1}{T_H/T_L - 1}$</td><td>The COP of a reversible heat pump is given in a similar manner as<br>$COP_{HP,rev} = \frac{1}{1 - T_L/T_H}$</td></tr>
</table>

# Laws of Thermodynamics

- The first law of thermodynamics states that energy can be neither created nor destroyed during a process; it can only change forms. is essentially an expression of the conservation of energy principle and it asserts that energy is a thermodynamic property.
- The second law of thermodynamics states that processes occur in a certain direction, not in any direction. A process does not occur unless it satisfies both the first and second law of thermodynamics. It asserts that energy has quality as well as quantity, and actual processes occur in the direction of decreasing quality of energy.
    - The Kelvin-Planck statement of the second law of thermodynamics states that no heat engine can produce a net amount of work while exchanging heat with a single reservoir only.
    - The Clausius statement of the second law states that no device can transfer heat from a cooler body to a warmer one without leaving an effect on the surroundings.
- The zeroth law of thermodynamics states that if two bodies are in thermal equilibrium with a third body, they are also in thermal equilibrium with each other. By replacing the third body with a thermometer, the zeroth law can be restated as two bodies are in thermal equilibrium if both have the same temperature reading even if they are not in contact.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