July 17, Week 7

Today: Heat Pumps and Engines, Chapter 11

Final Homework #7 now available. Due Monday at 5:00PM.

First Law of Thermodynamics

First Law of Thermodynamics: $\boxed{W + Q = \Delta E_{th}}$

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There are two ways to change the thermal energy of on object - Work being done to the object (W) and heat (Q)

First Law Signs

In applying the first law of thermodynamics, we have to think about the “system” = the object that is of interest. Everything else is called the environment

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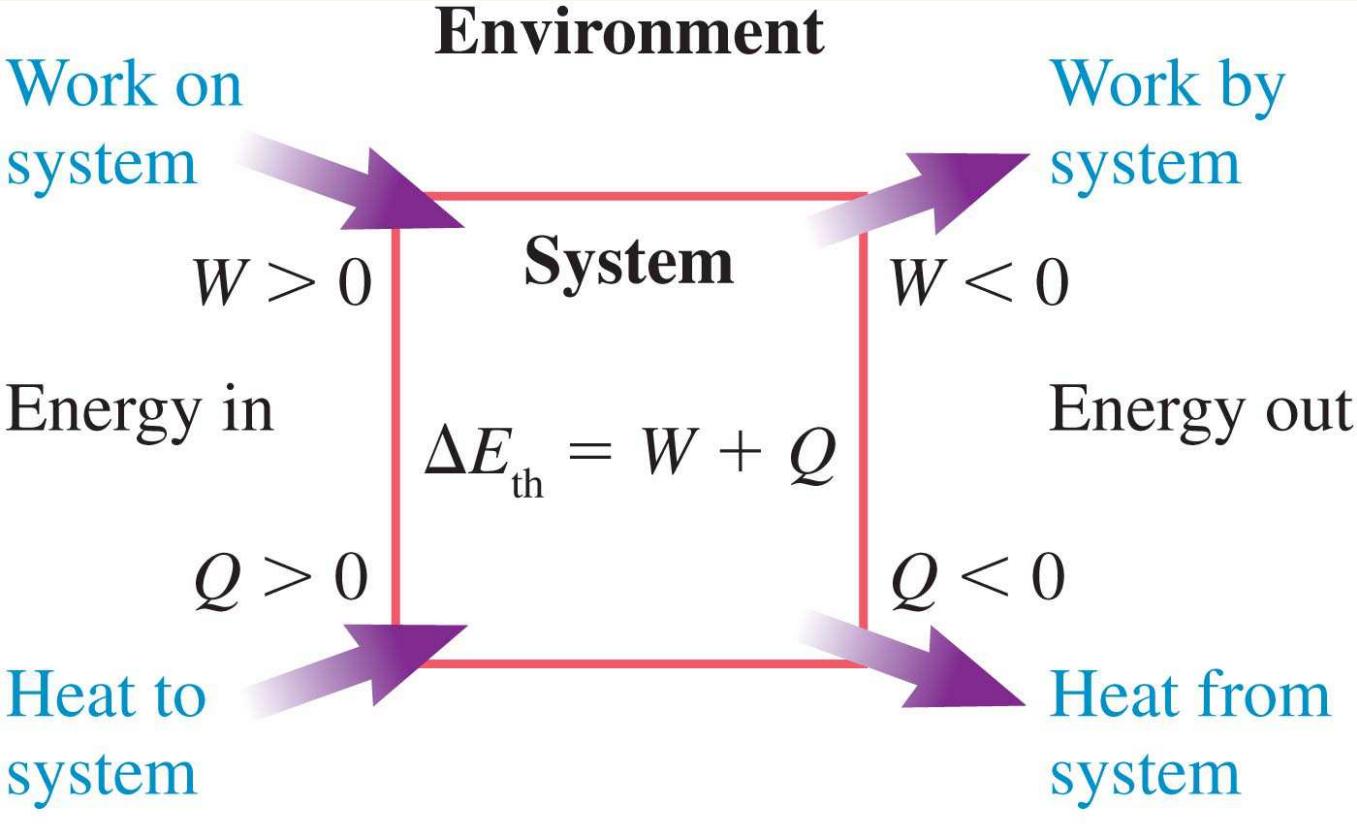

First-Law Followup

Process	W	Q	ΔE_{th}	ΔT

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Steam is used to spin a turbine. (Assume the turbine's temperature remains constant)				

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An expanding gas inflates a balloon Heat depends on how the gas expands	$-$	$?$	$?$	$?$

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Steam is used to spin a turbine. (Assume the turbine's temperature remains constant)	$-$	0	$-$	$-$
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After 30 minutes of baking, a pan is removed from the oven and sits on a counter				

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Steam is used to spin a turbine. (Assume the turbine's temperature remains constant)	$-$	0	$-$	$-$
An expanding gas inflates a balloon Heat depends on how the gas expands	$-$	$?$	$?$	$?$
After 30 minutes of baking, a pan is removed from the oven and sits on a counter	0	$-$	$-$	$-$

Heat Engine

Heat Engine - Device that uses the transfer of heat from a higher temperature to lower temperature to extract work

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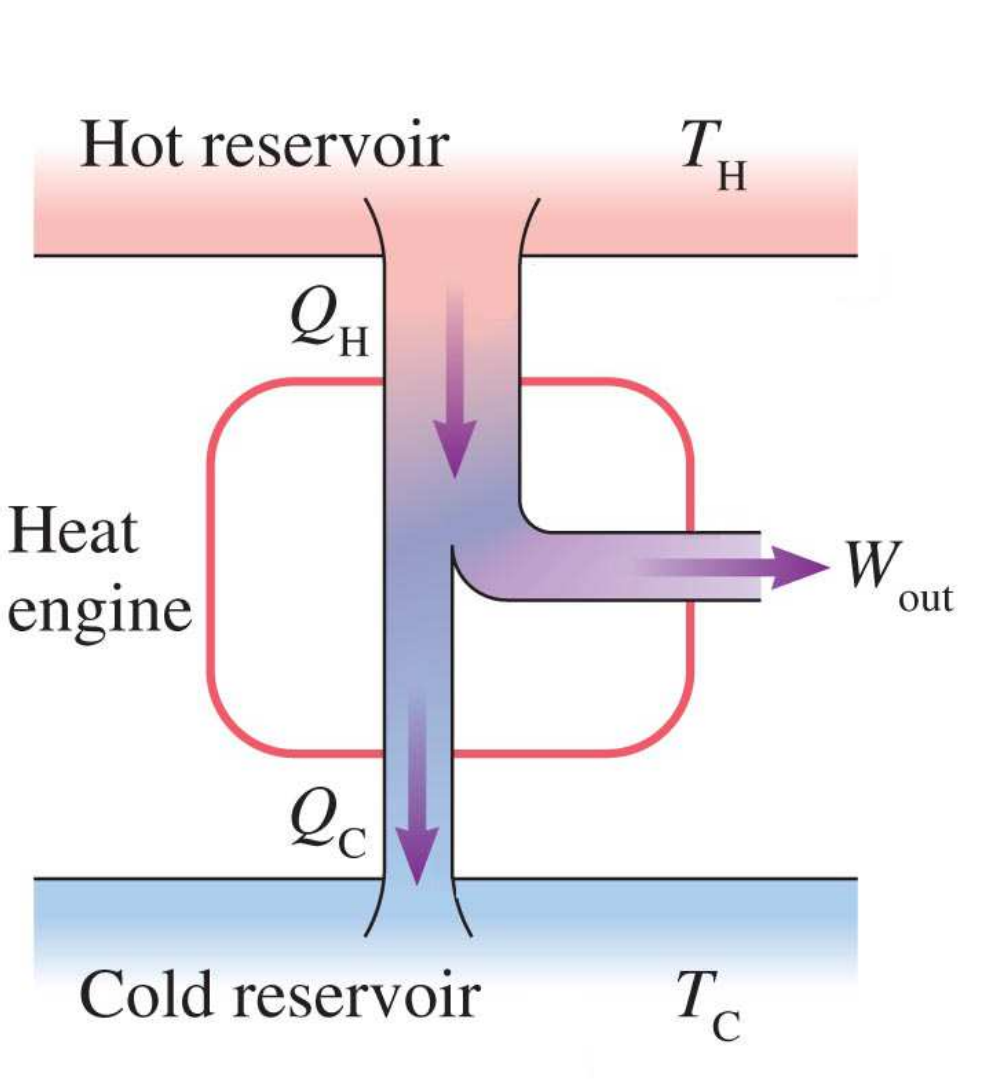

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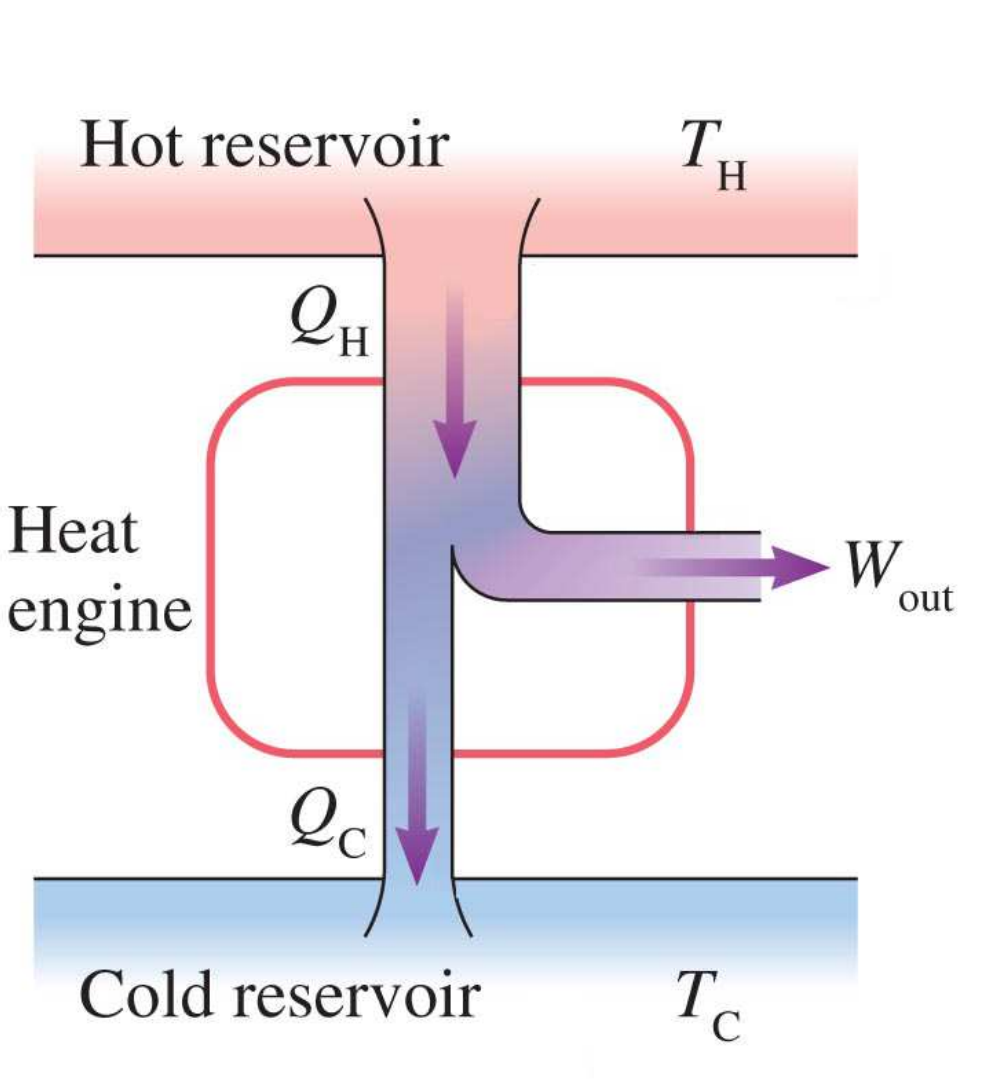

$$W + Q = \Delta E_{th}$$

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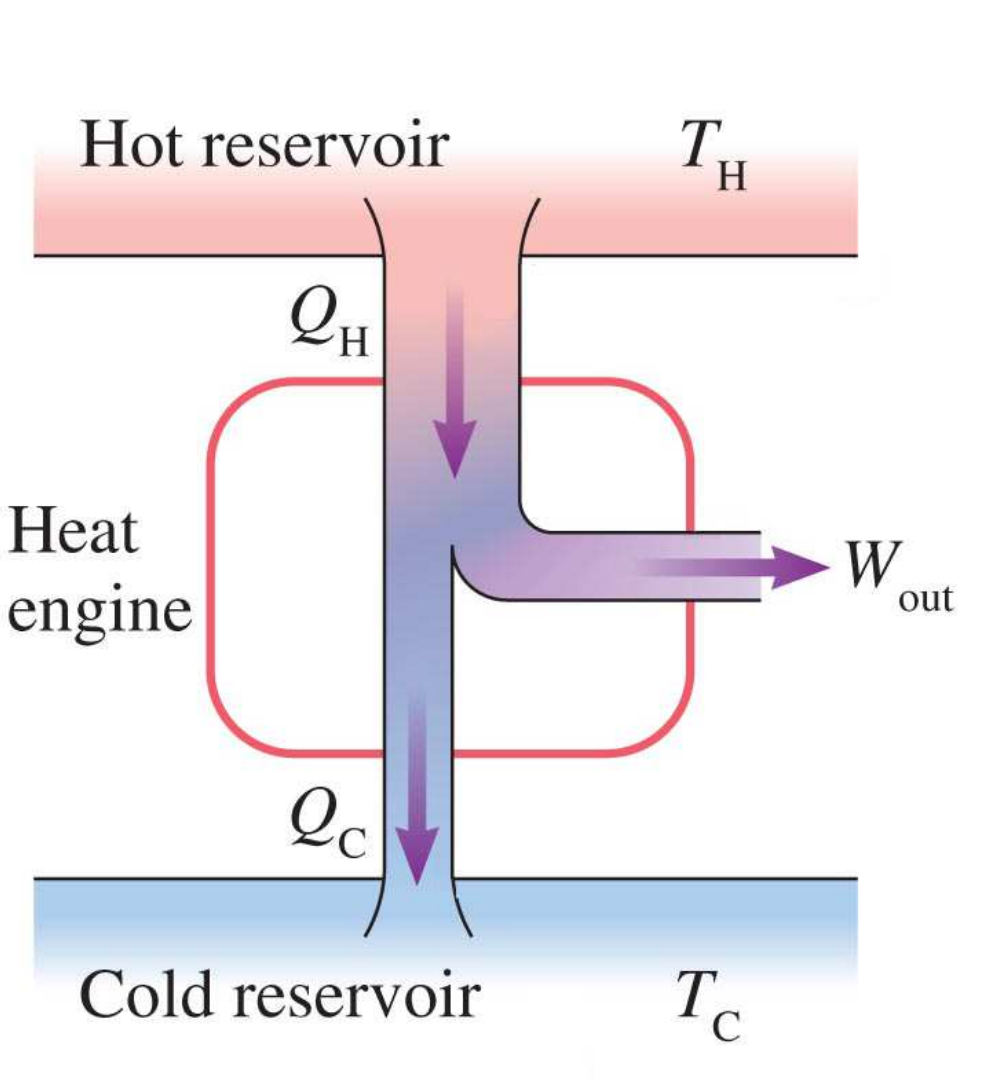

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The system is the engine

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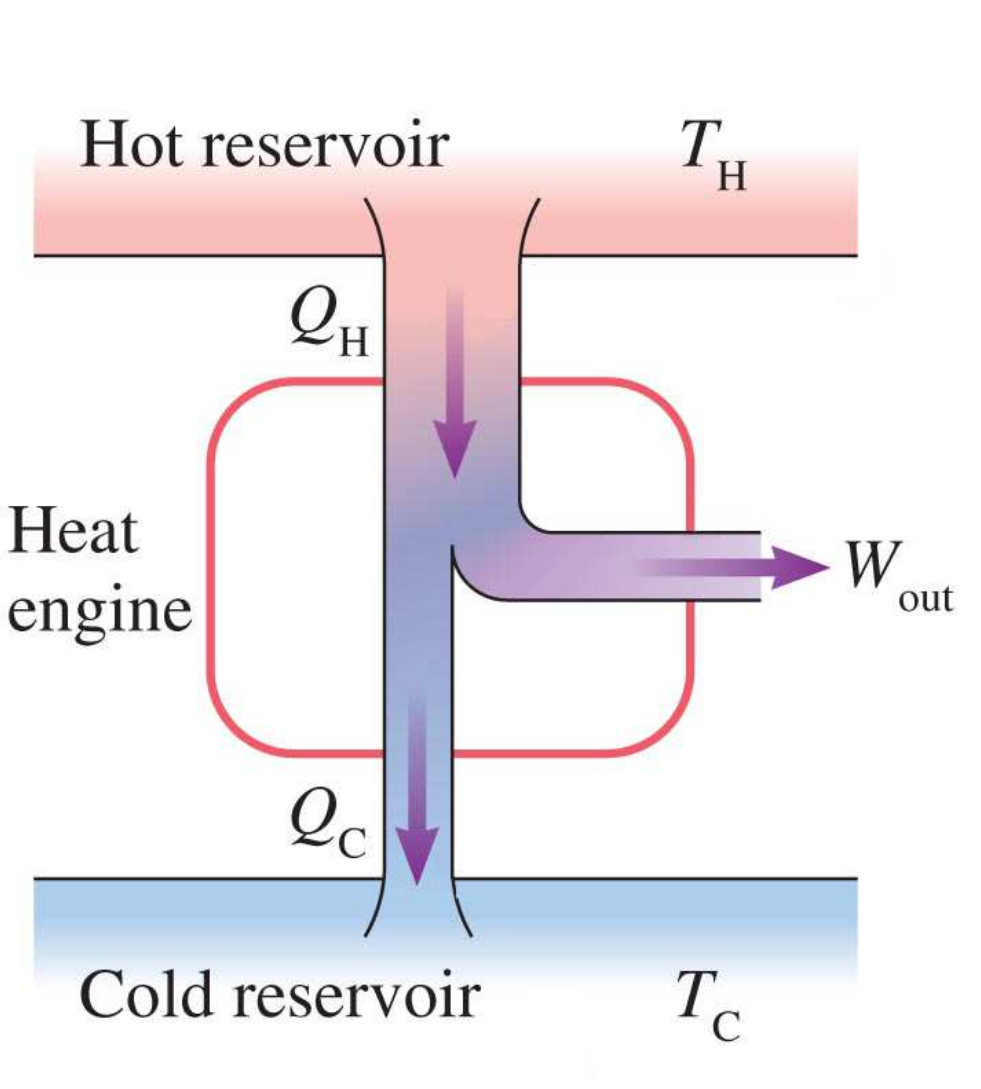

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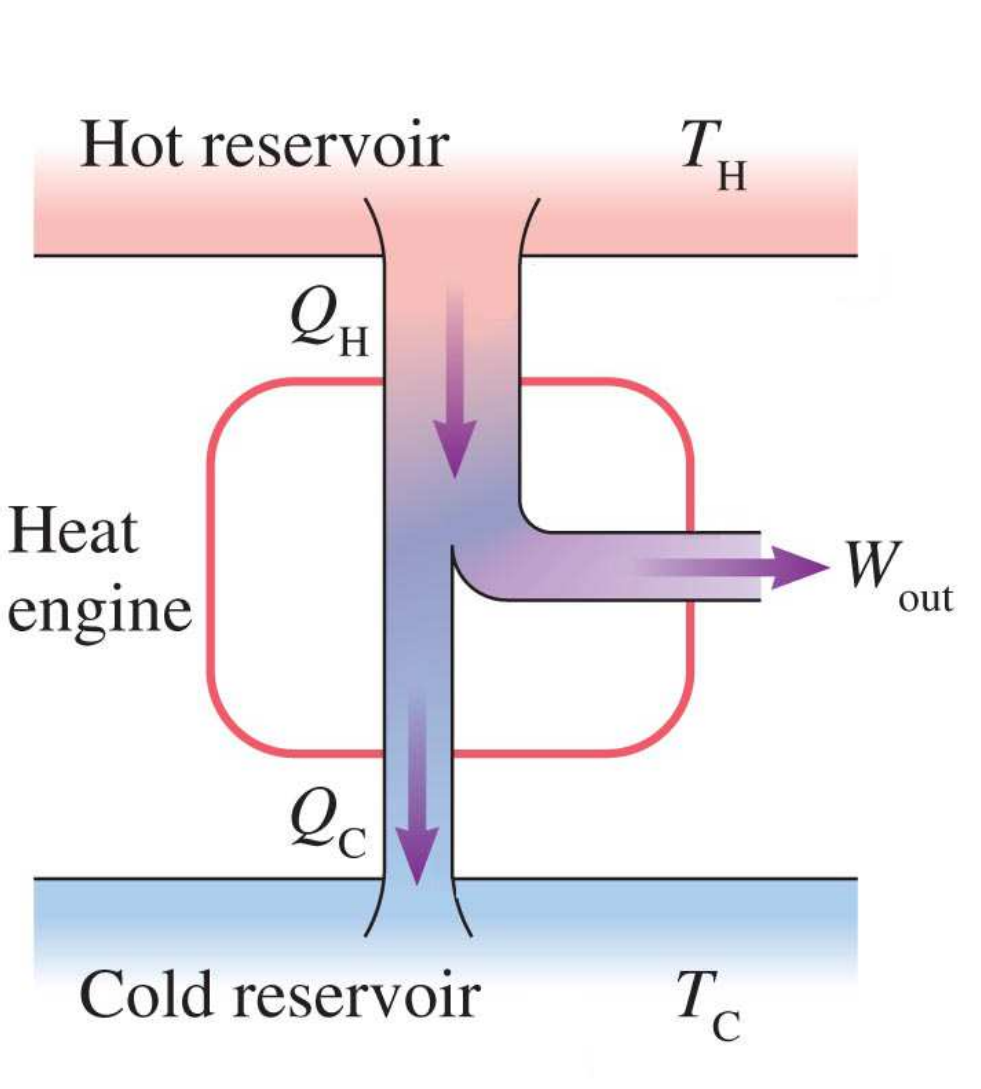

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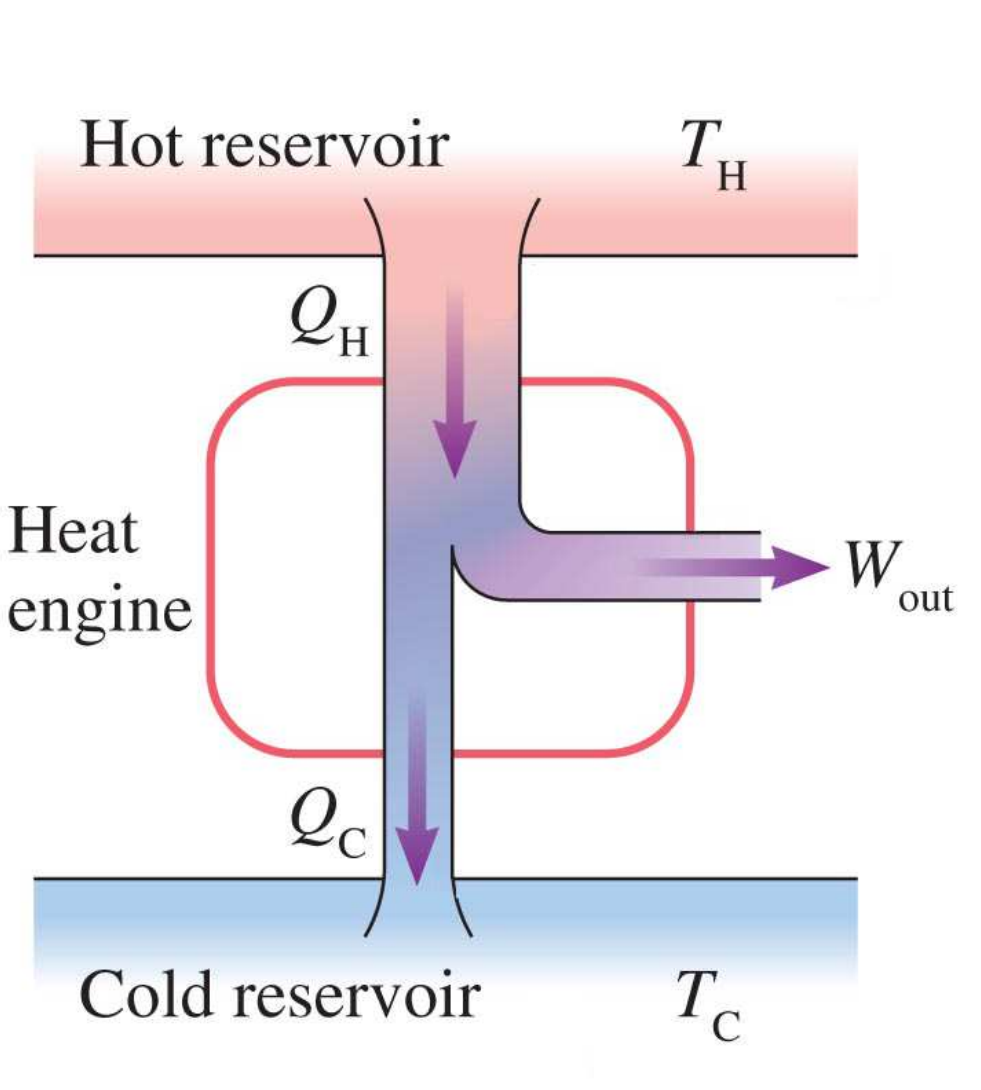


$$W + Q = \Delta E_{th}$$

The system is the engine

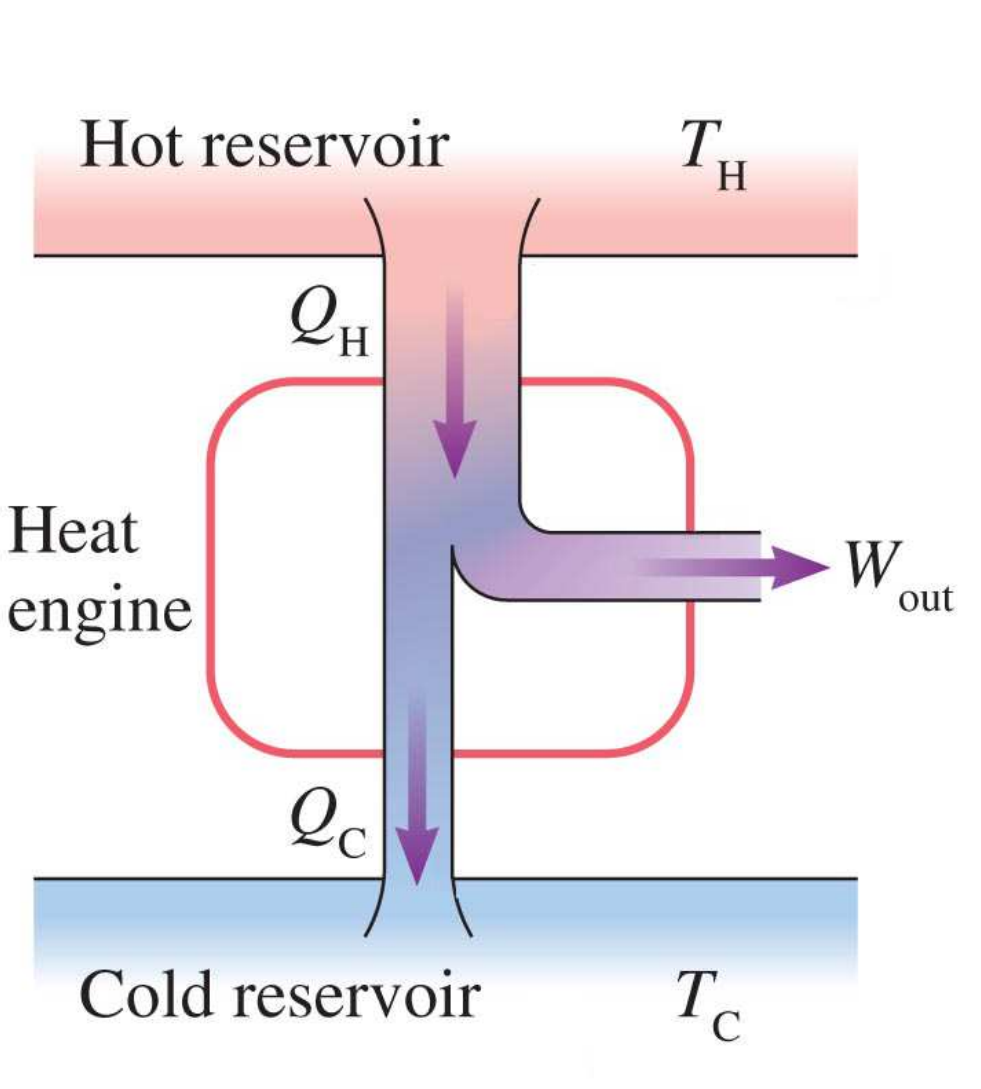
$$W = -W_{out}$$

$$Q = Q_H - Q_C$$

$\Delta E_{th} = 0$ (In a perfect situation, the engine simply uses heat to do work. It doesn't absorb the heat itself.)

Heat Engine II

Heat Engine - Device that uses the transfer of heat from a higher temperature to lower temperature to extract work



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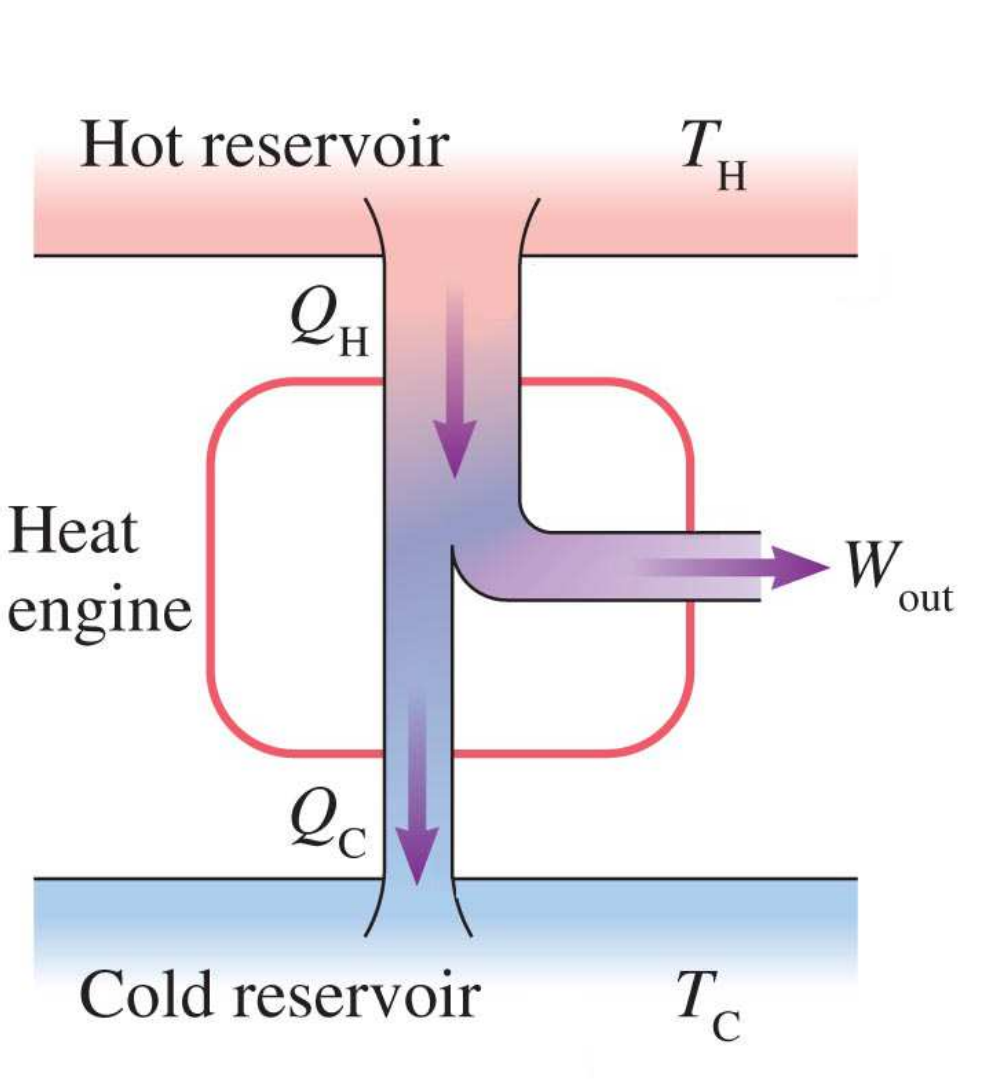

$$W + Q = \Delta E_{th}$$

$$-W_{out} + Q_H - Q_C = 0$$

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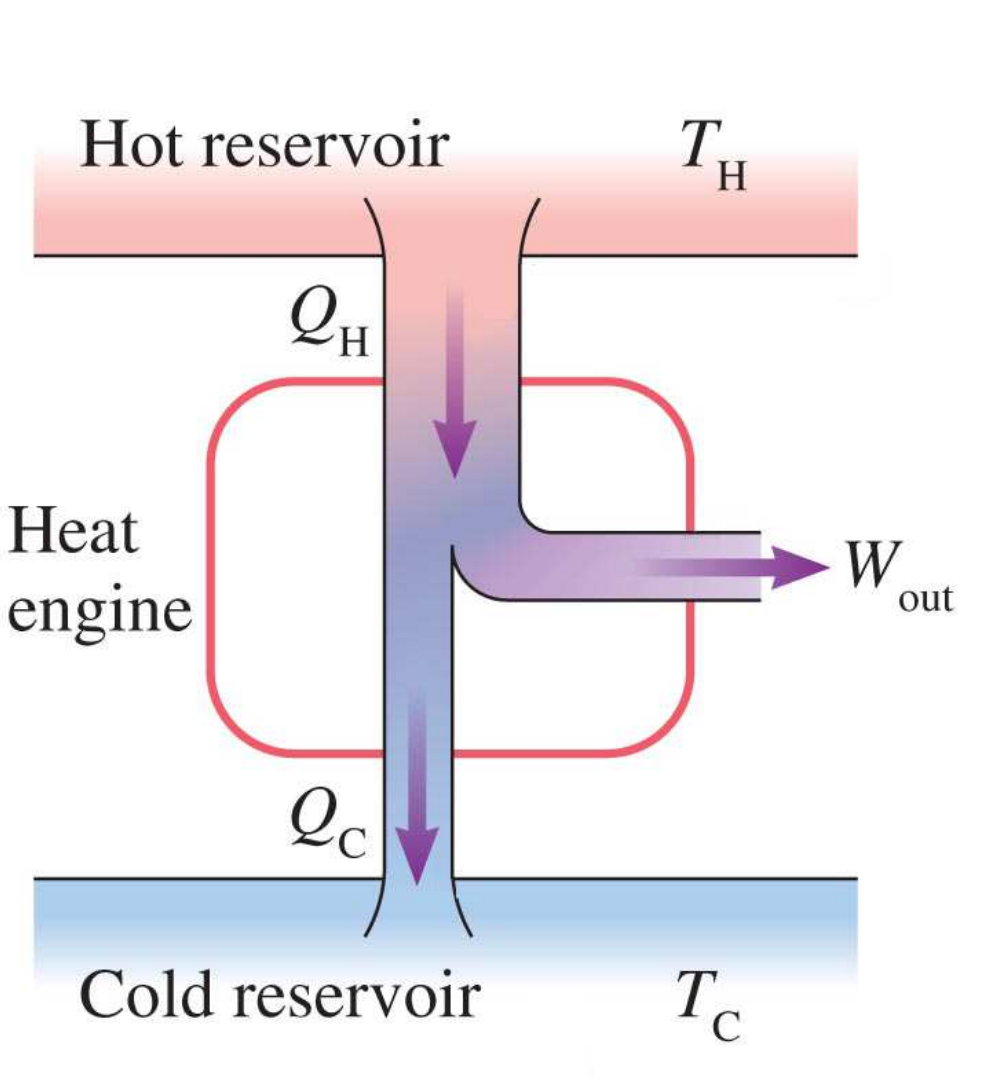

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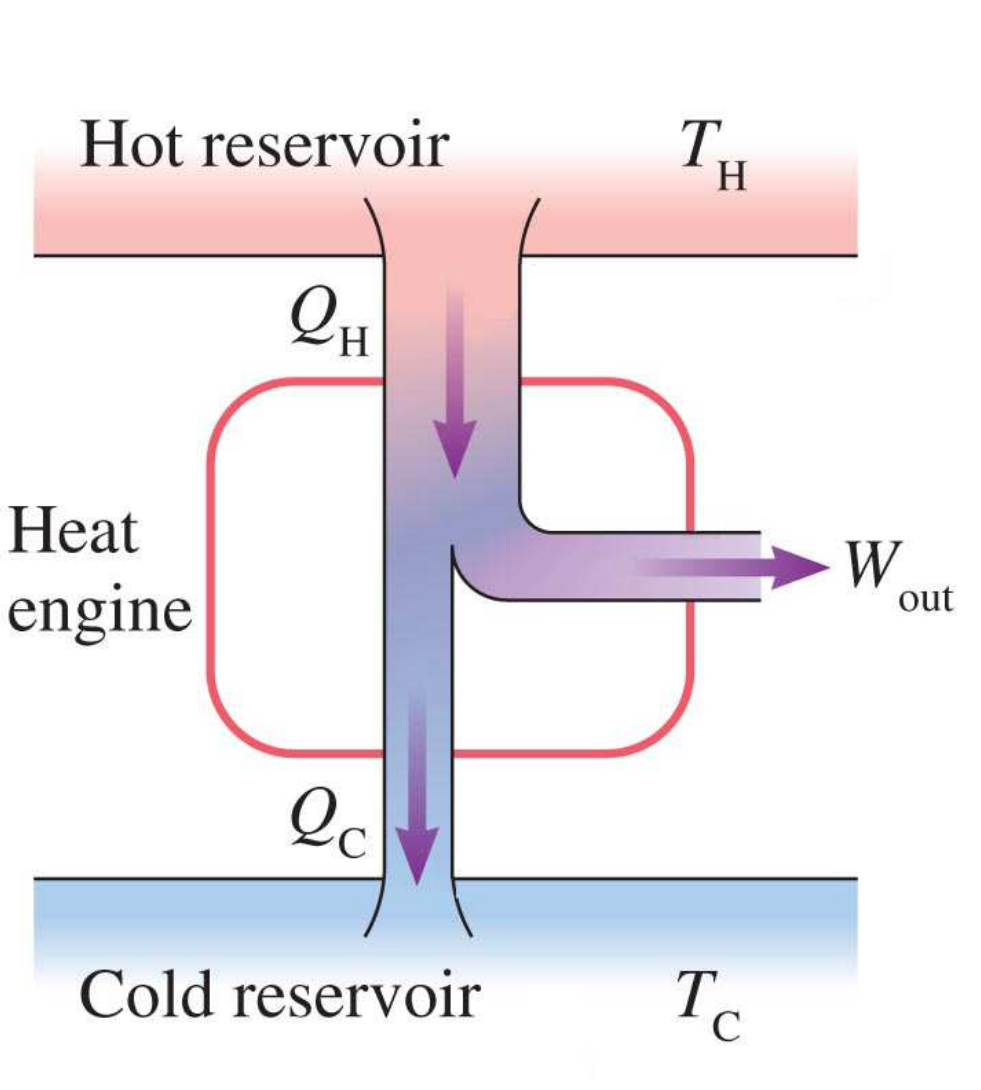

$$W + Q = \Delta E_{th}$$

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$$W_{out} = Q_H - Q_C$$

Better Form: $\boxed{Q_H = W_{out} + Q_C}$

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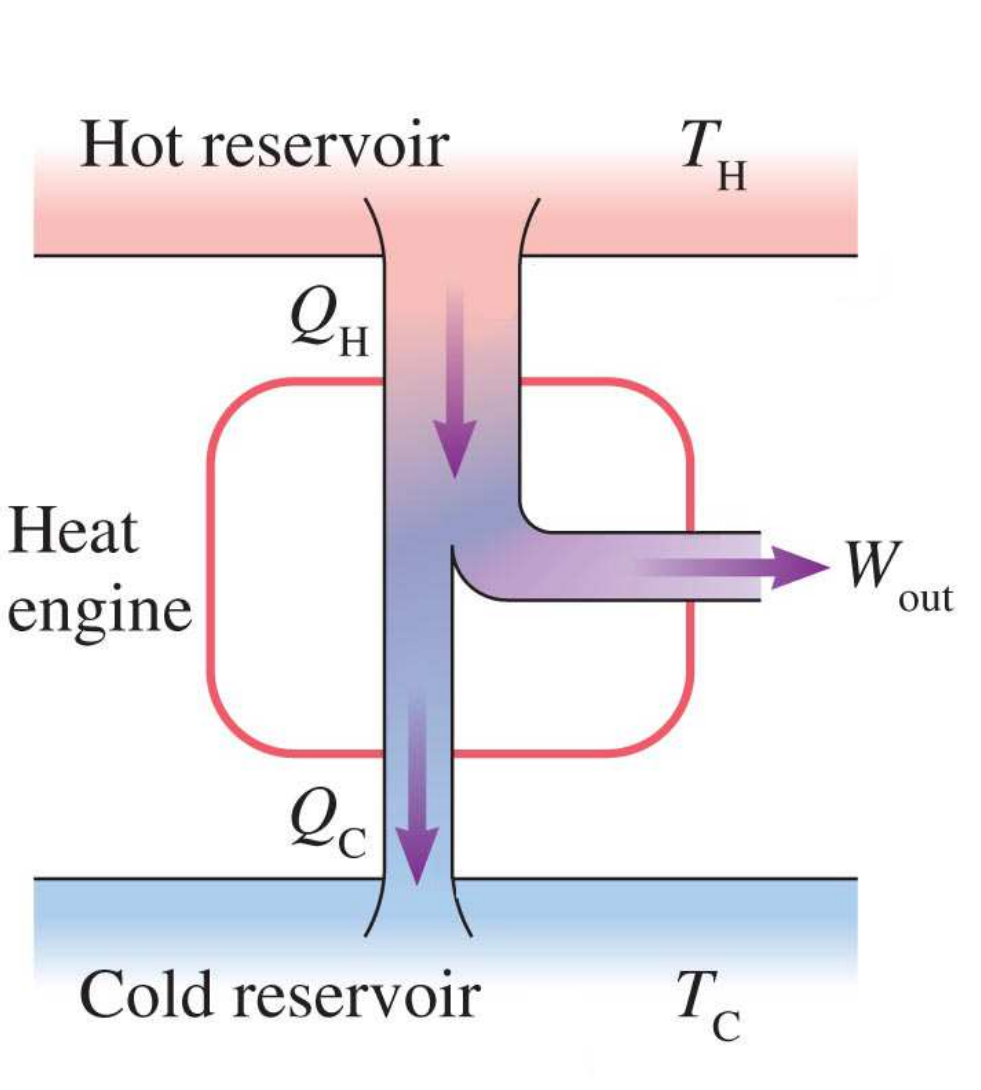

$$W + Q = \Delta E_{th}$$

$$-W_{out} + Q_H - Q_C = 0$$

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Efficiency: $\boxed{e = \frac{W_{out}}{Q_H}}$

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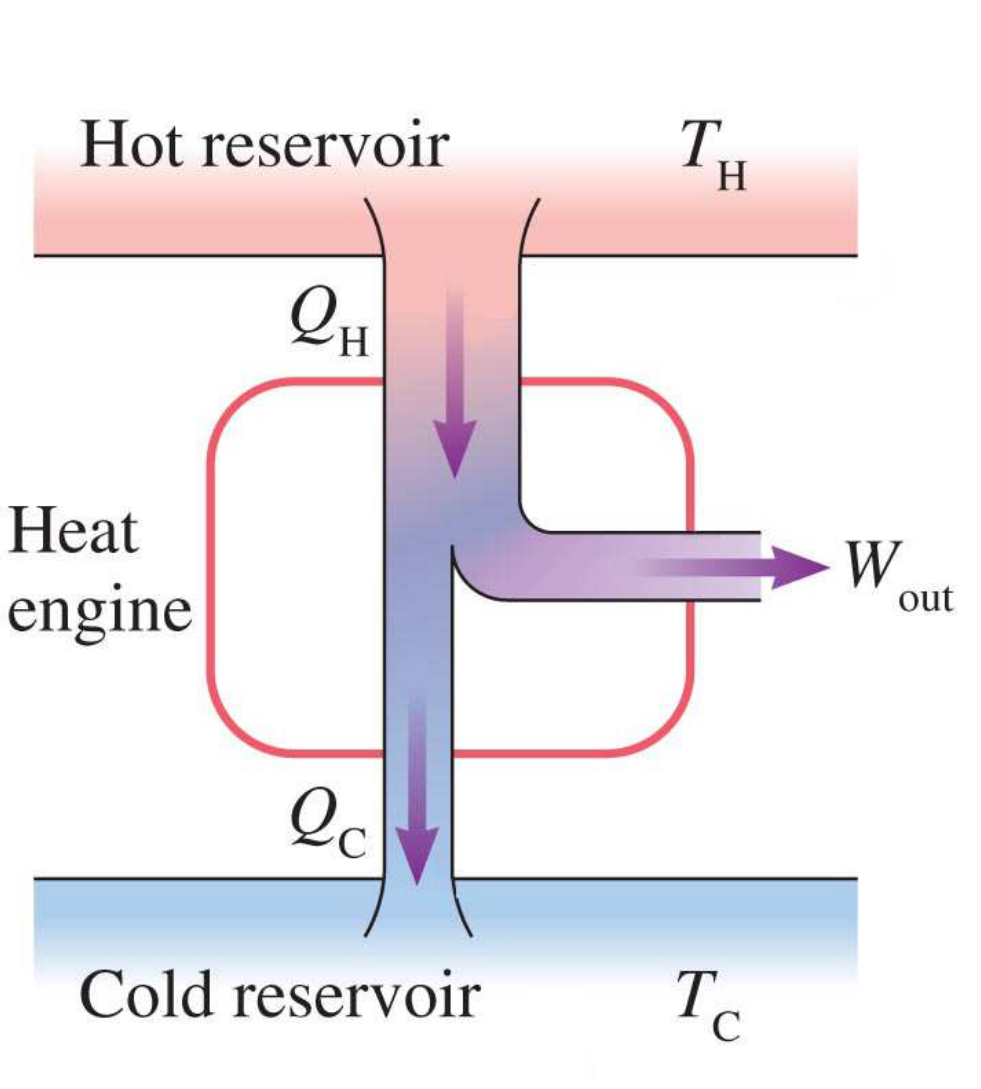


$$W + Q = \Delta E_{th}$$

$$-W_{out} + Q_H - Q_C = 0$$

$$W_{out} = Q_H - Q_C$$

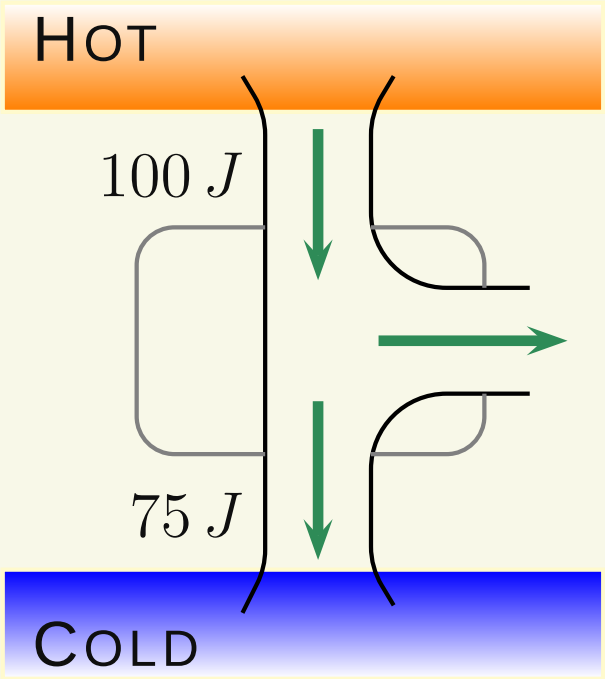
Better Form: $\boxed{Q_H = W_{out} + Q_C}$

Efficiency: $\boxed{e = \frac{W_{out}}{Q_H}}$

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

Heat Engine Exercise

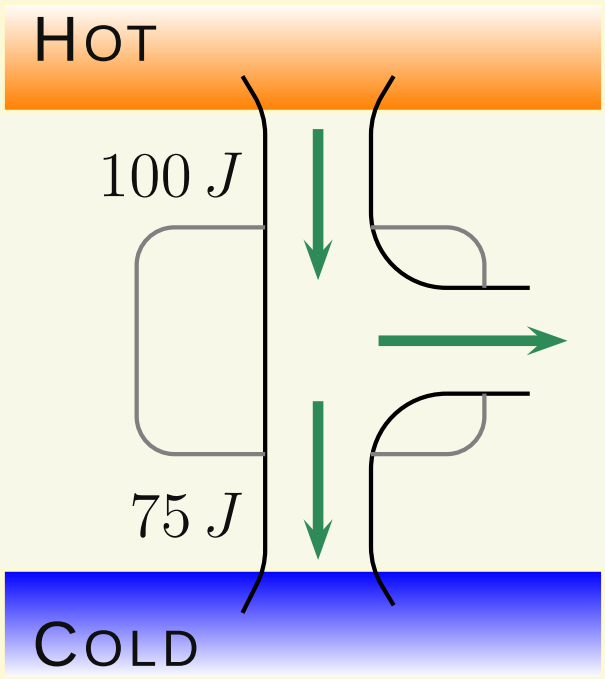
What is the efficiency (W_{out}/Q_H) of the following heat engine?



Heat Engine Exercise

What is the efficiency (W_{out}/Q_H) of the following heat engine?

(a) 0%



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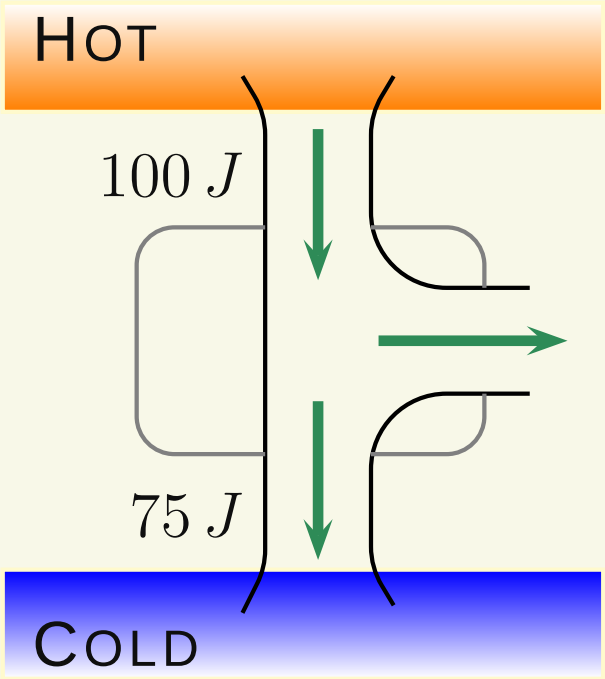

(a) 0%

(b) 25%

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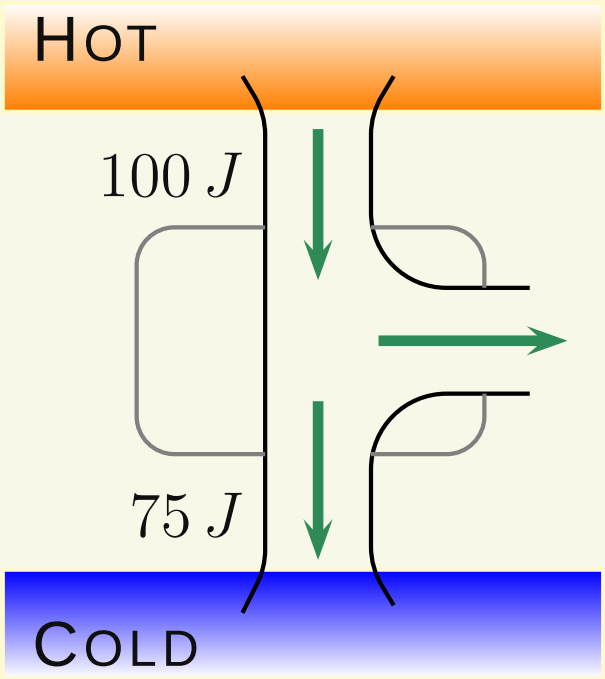

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(c) 50%

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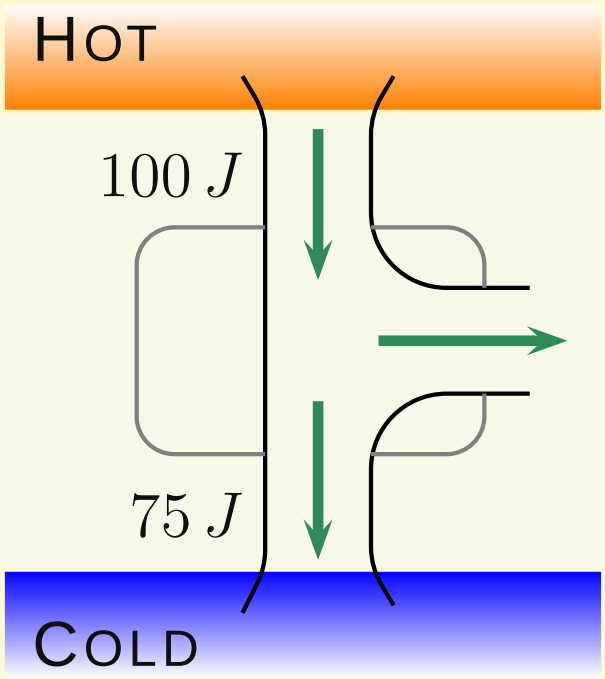

(a) 0%

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(c) 50%

(d) 75%

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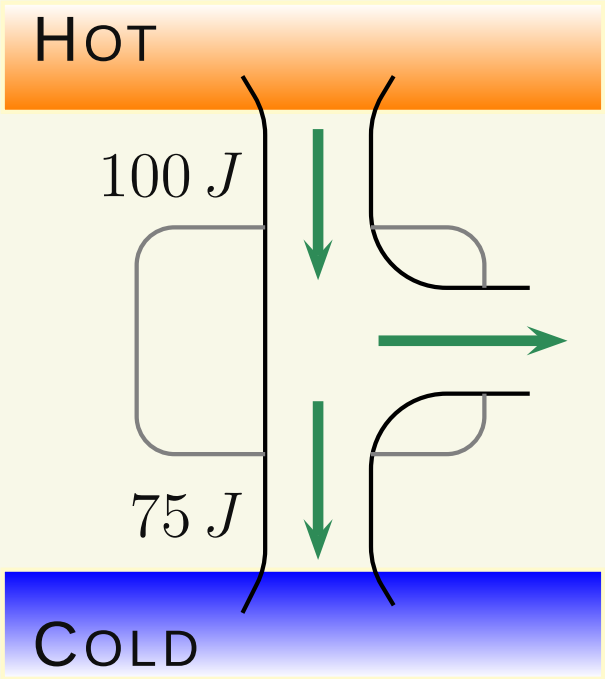

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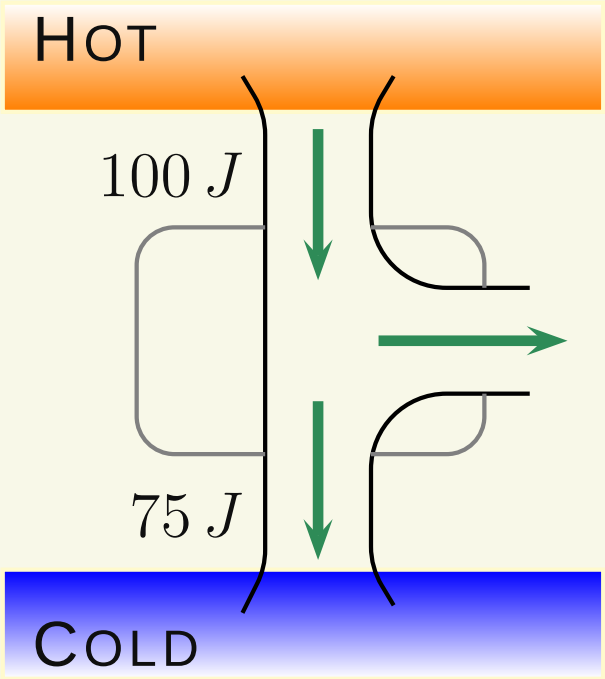

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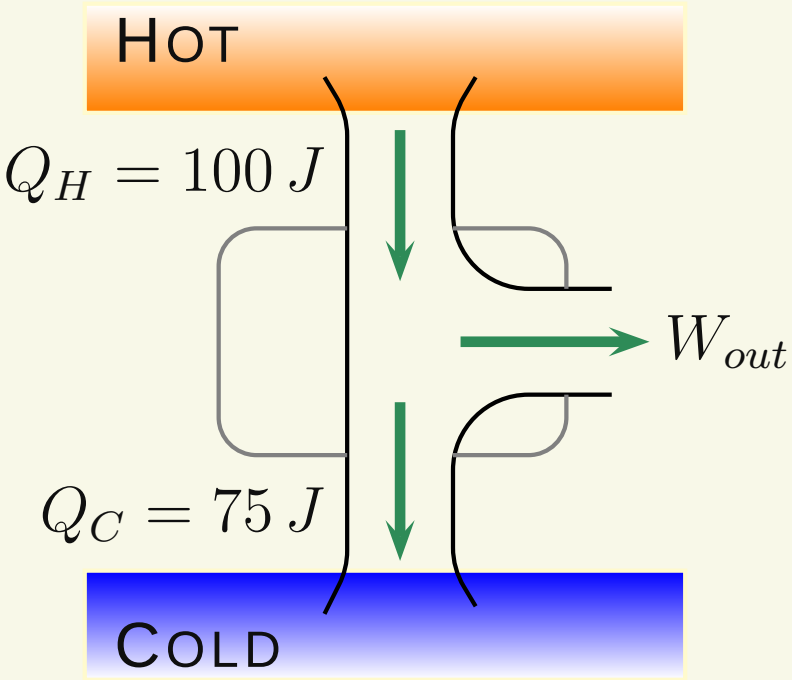

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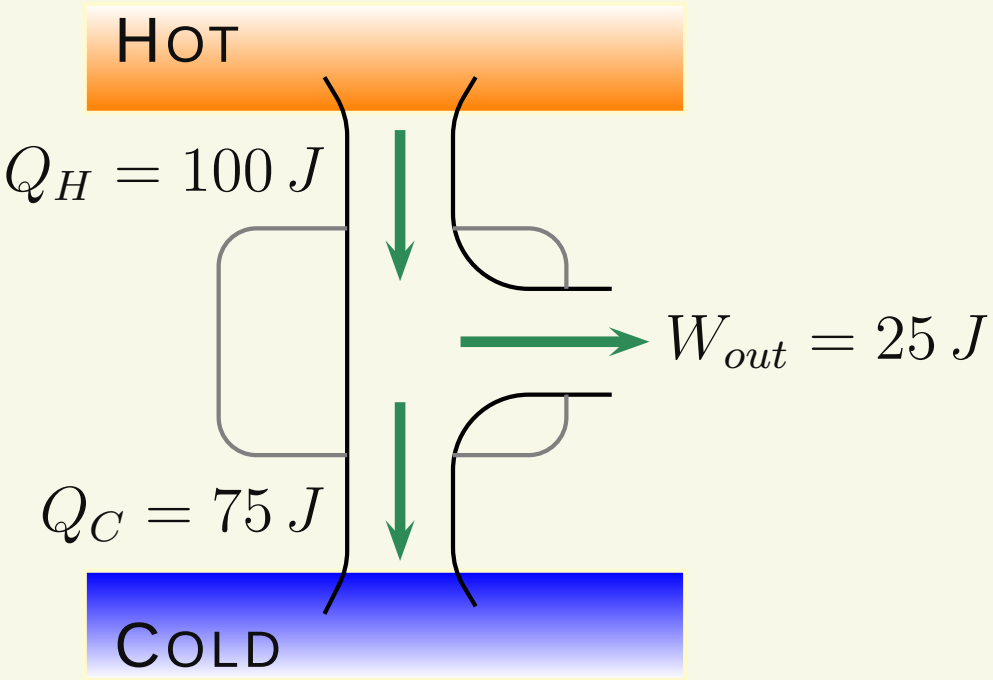

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Heat Pump

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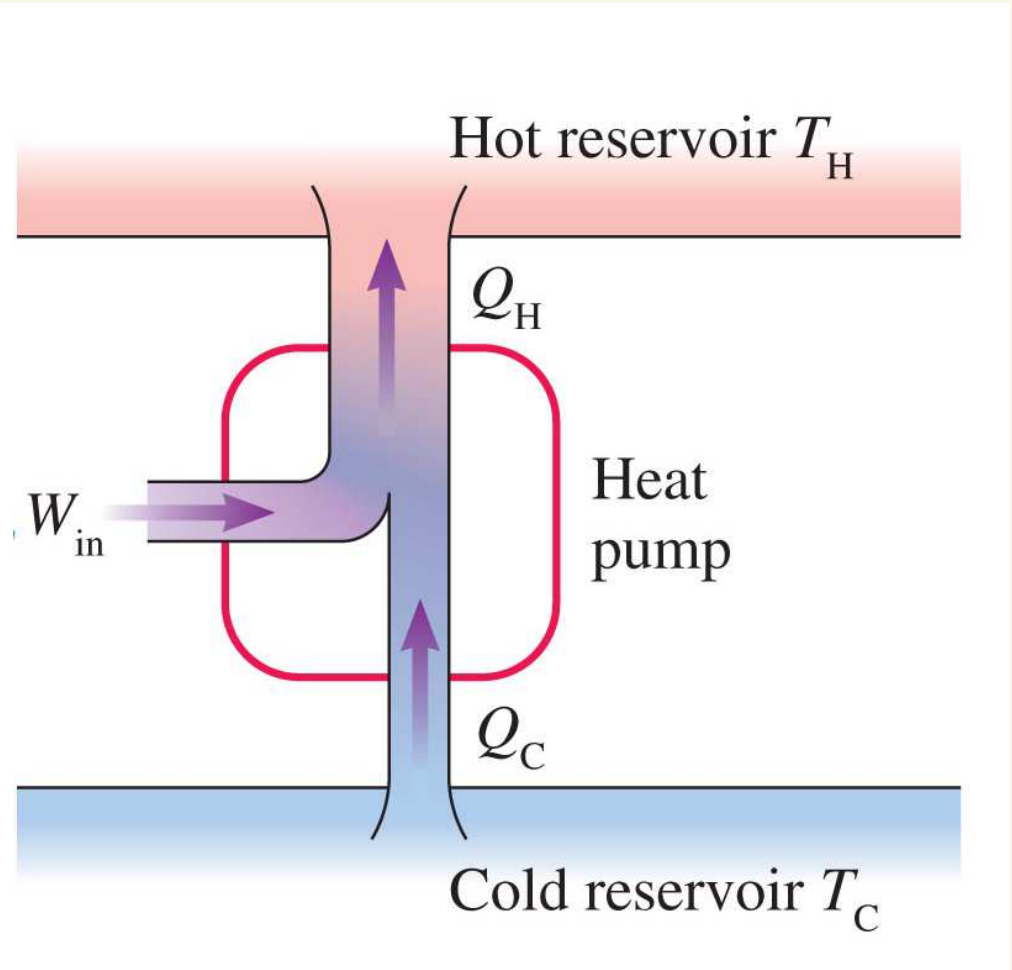

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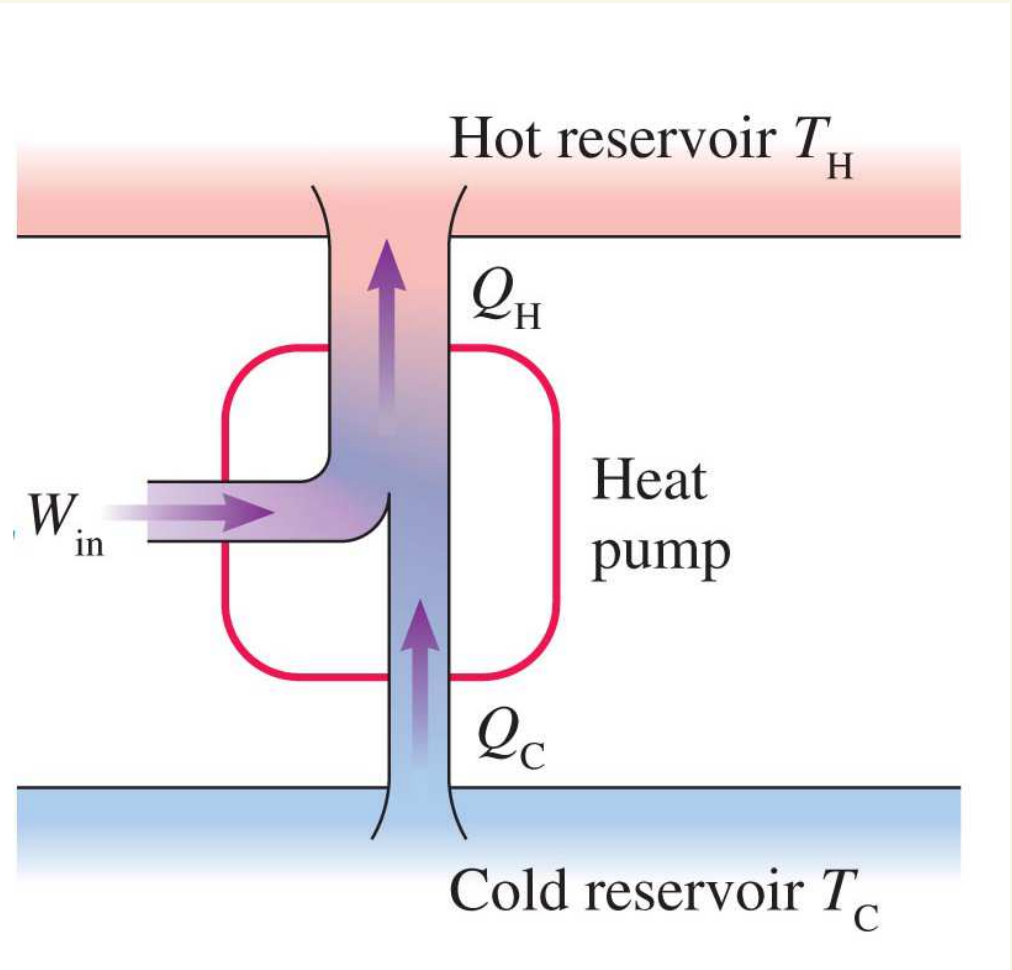

$$W + Q = \Delta E_{th} = 0$$

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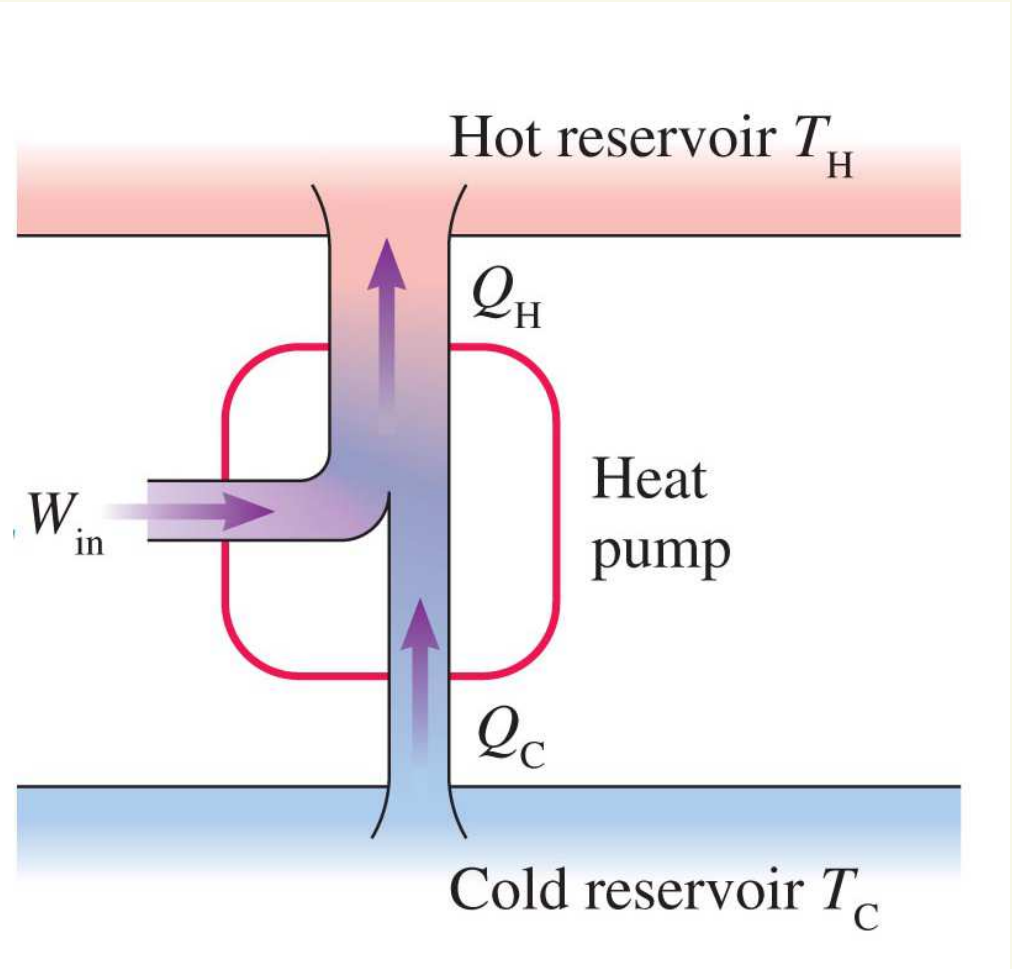

$$W + Q = \Delta E_{th} = 0$$

$$W = W_{in}$$

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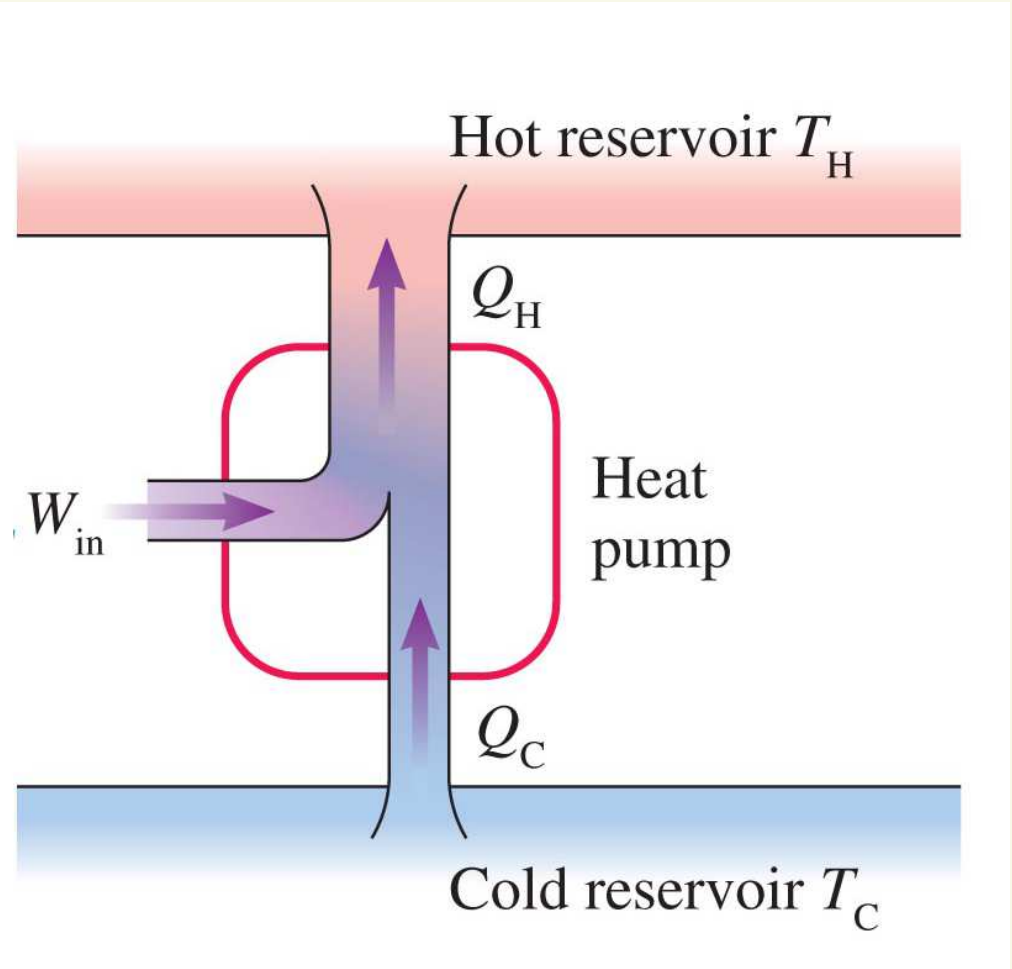

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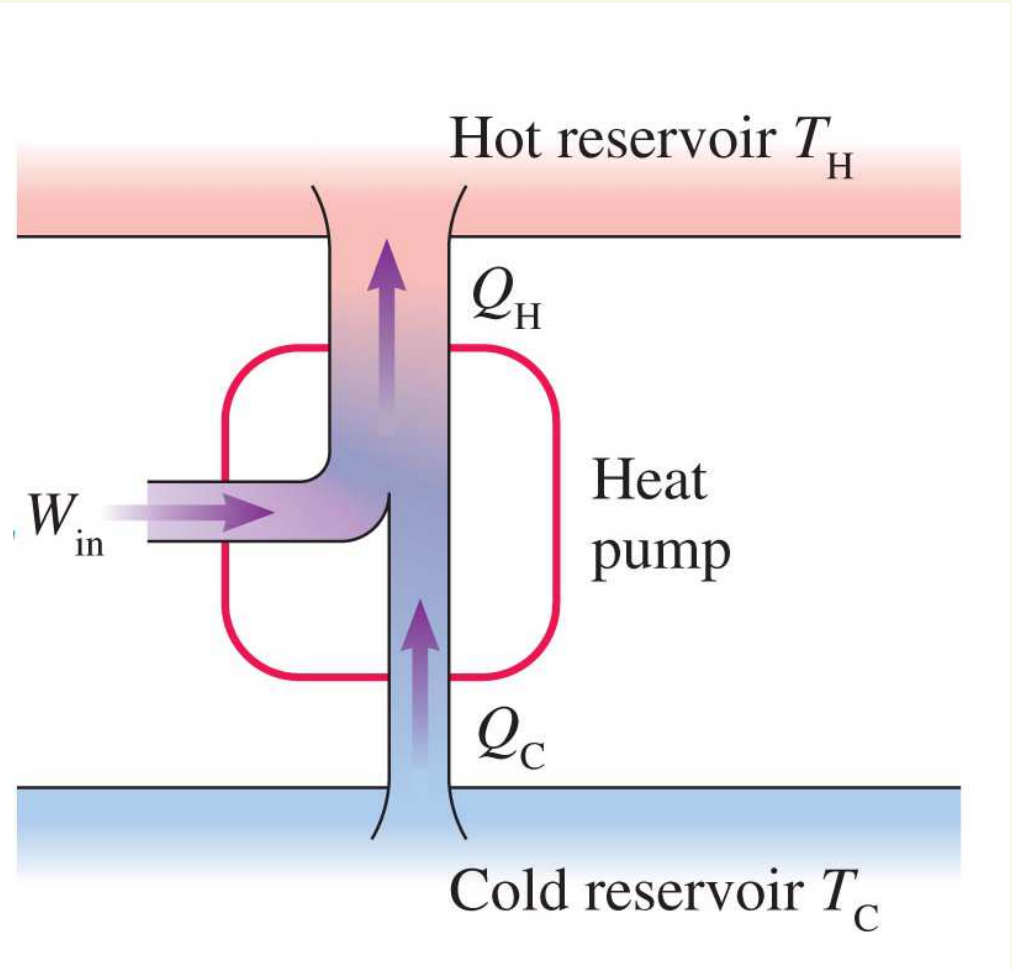

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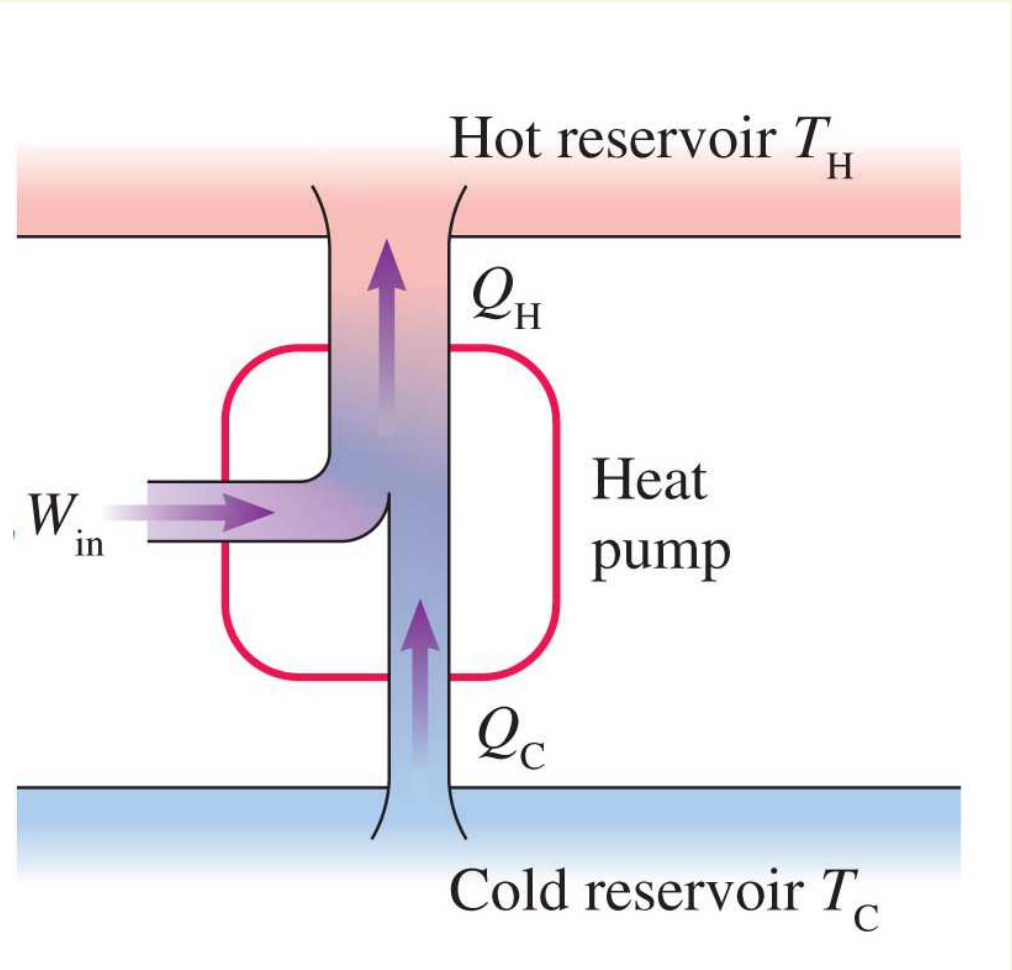

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$$W_{in} + Q_C - Q_H = 0 \Rightarrow$$

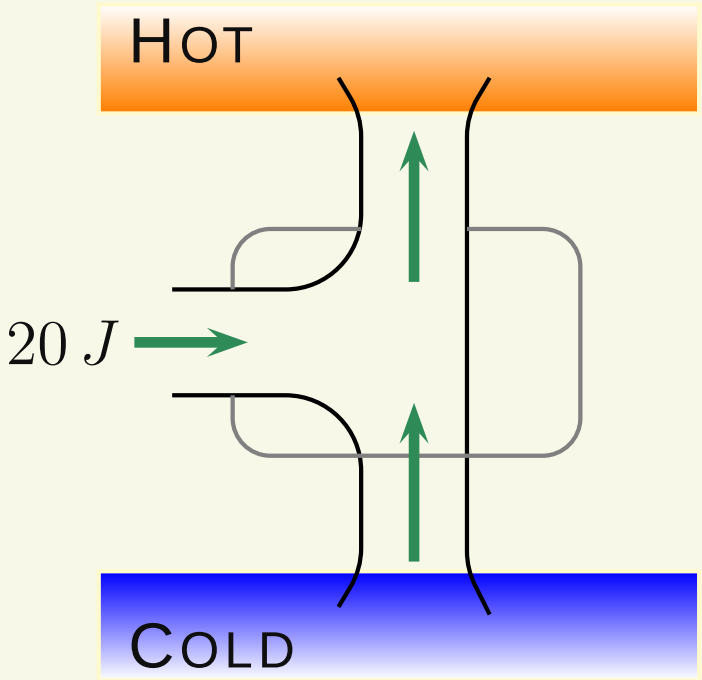
$$\boxed{W_{in} + Q_C = Q_H}$$

Coefficient of Performance:

$$\boxed{COP = \frac{Q_C}{W_{in}} = \frac{Q_C}{Q_H - Q_C}}$$

Heat Pump Exercise

If the COP (Q_C/W_{in}) of the following heat pump is 2, how much heat was removed from the cold reservoir and how much heat was released to the hot reservoir?



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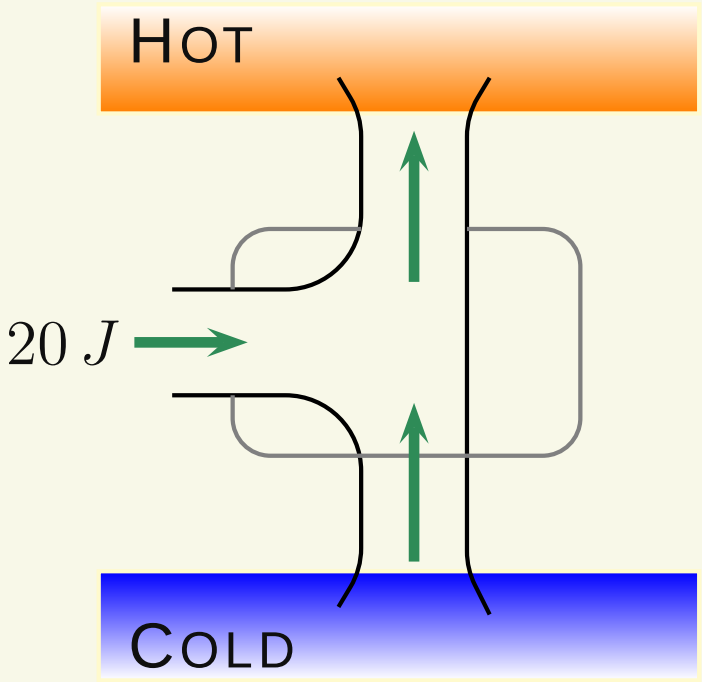

(a) $Q_C = 10\,J, \quad Q_H = 30\,J$

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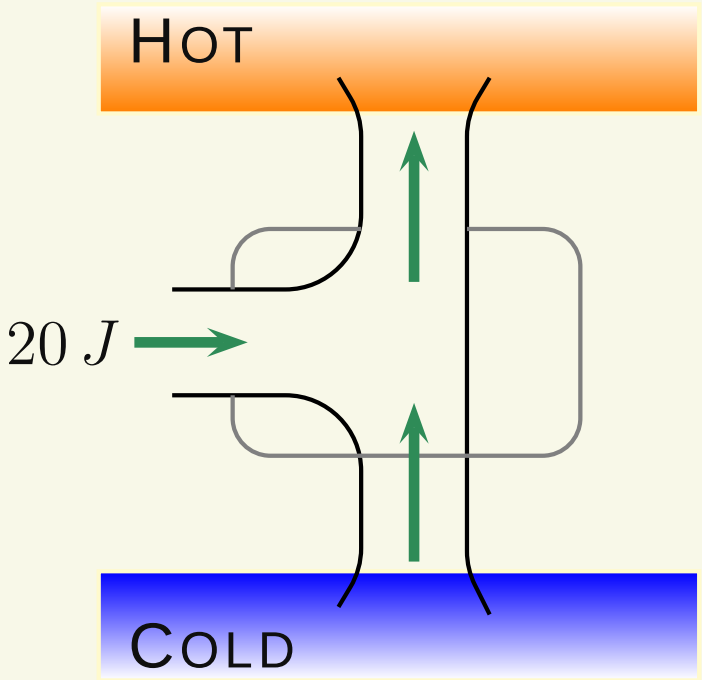

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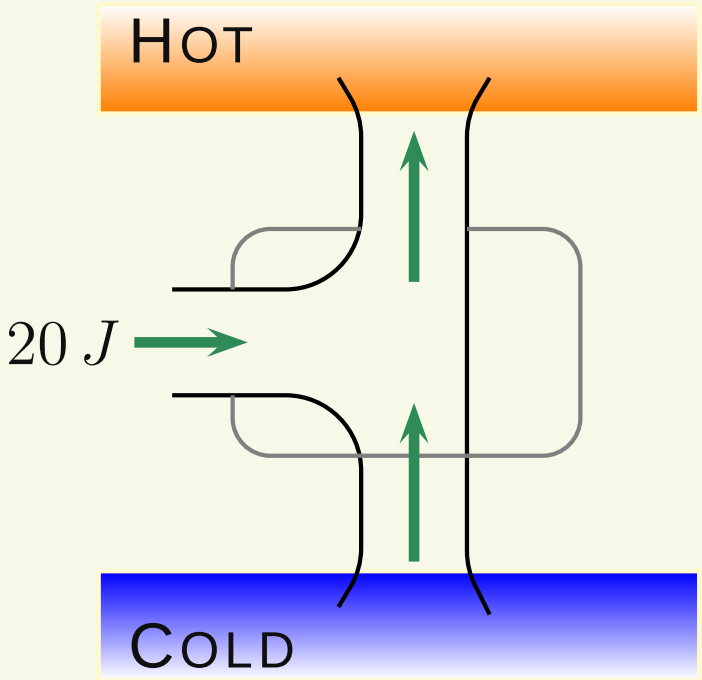

(a) $Q_C = 10\,J, \quad Q_H = 30\,J$

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(c) $Q_C = 20\,J, \quad Q_H = 20\,J$

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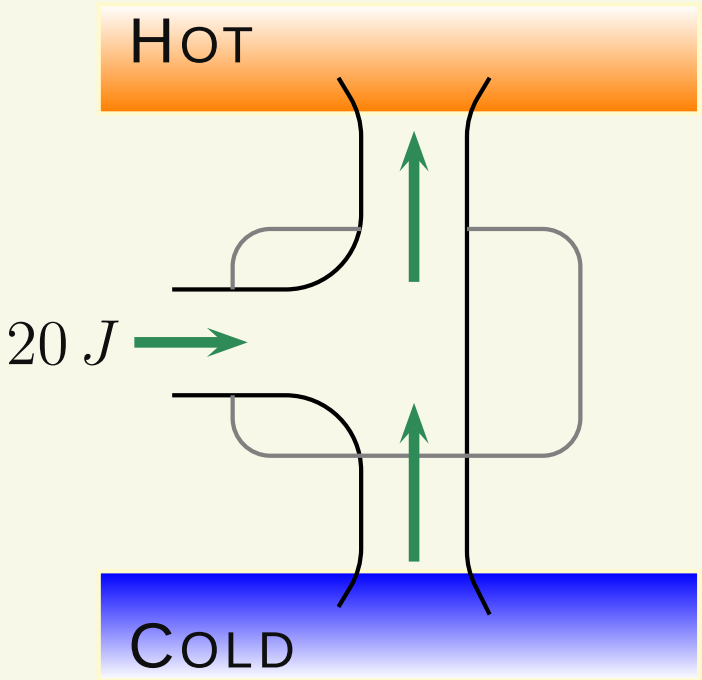

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(c) $Q_C = 20\,J, \quad Q_H = 20\,J$

(d) $Q_C = 40\,J, \quad Q_H = 60\,J$

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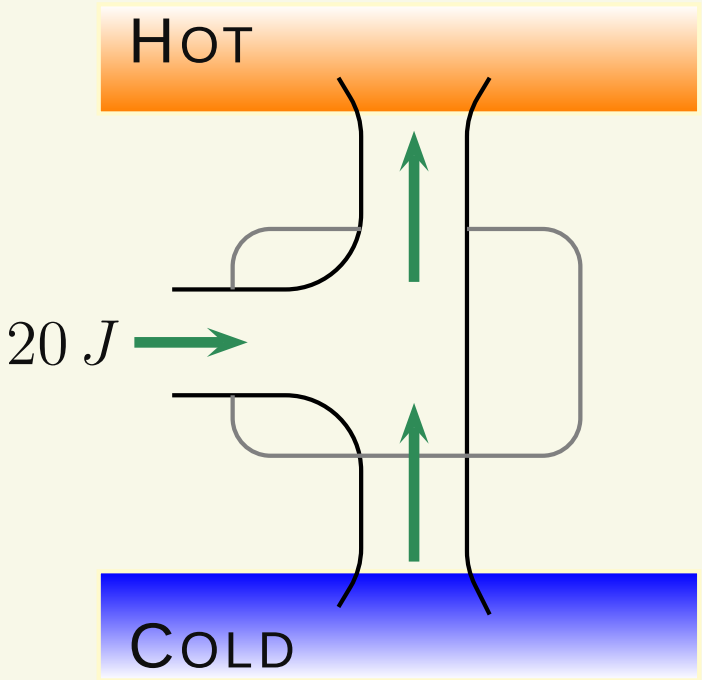

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(d) $Q_C = 40\,J, \quad Q_H = 60\,J$

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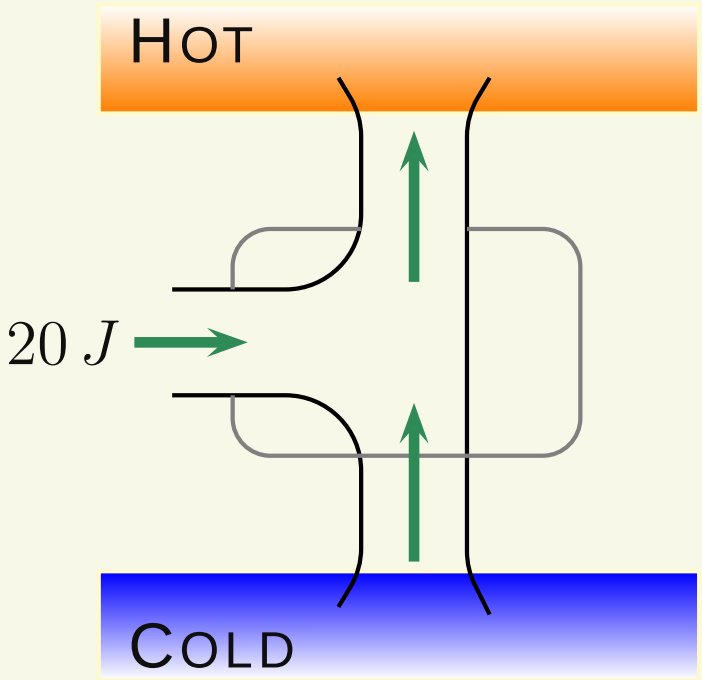

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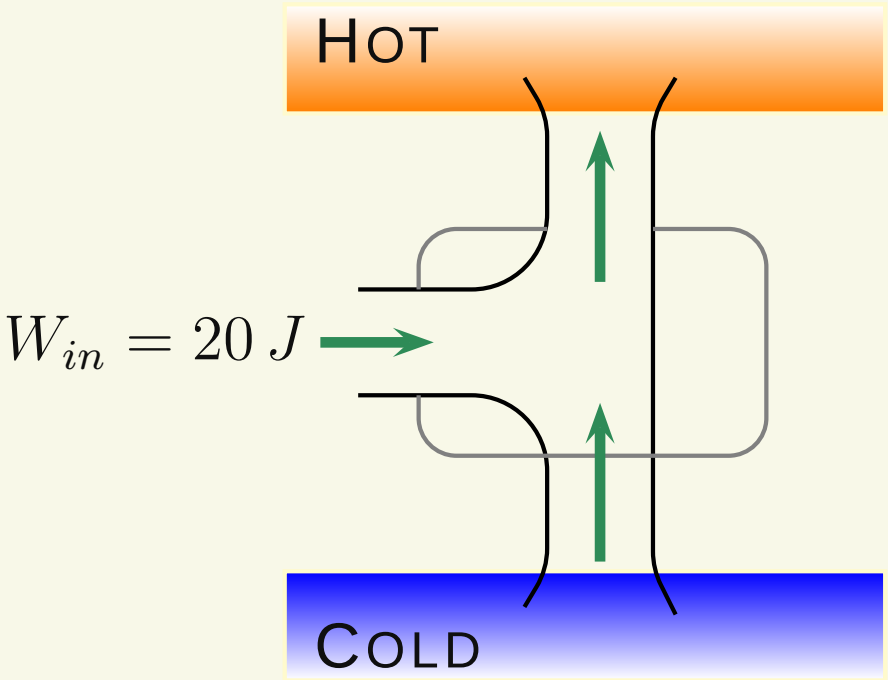

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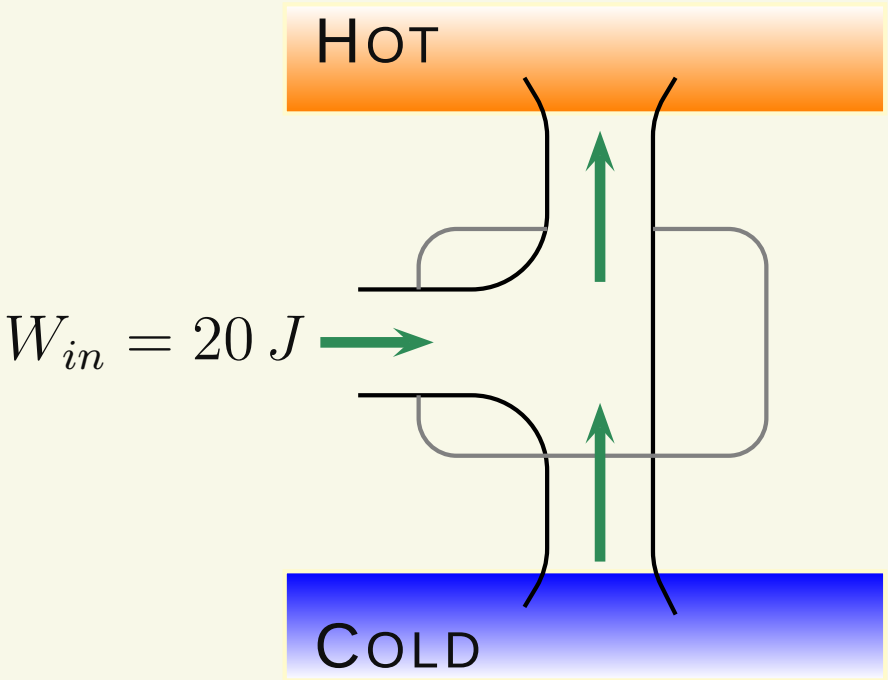

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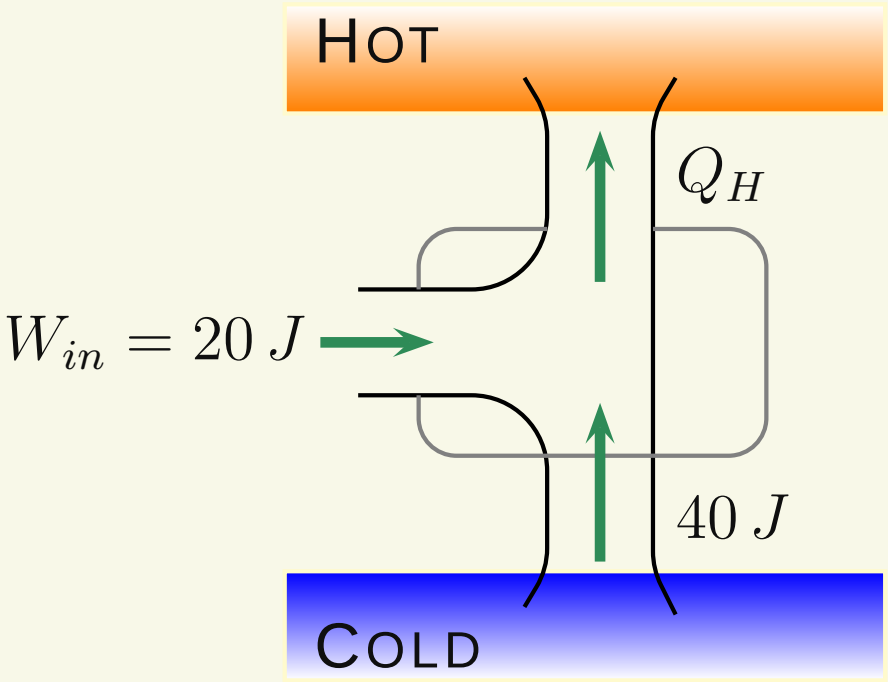

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Entropy - Measures the amount of disorder in a system.

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Disordered systems are more likely to occur, so entropy is also a measure of the probability that a state of a system will occur.

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On the macroscopic scale, any process that obeys the second law will be irreversible. (Irreversible processes increase entropy.)

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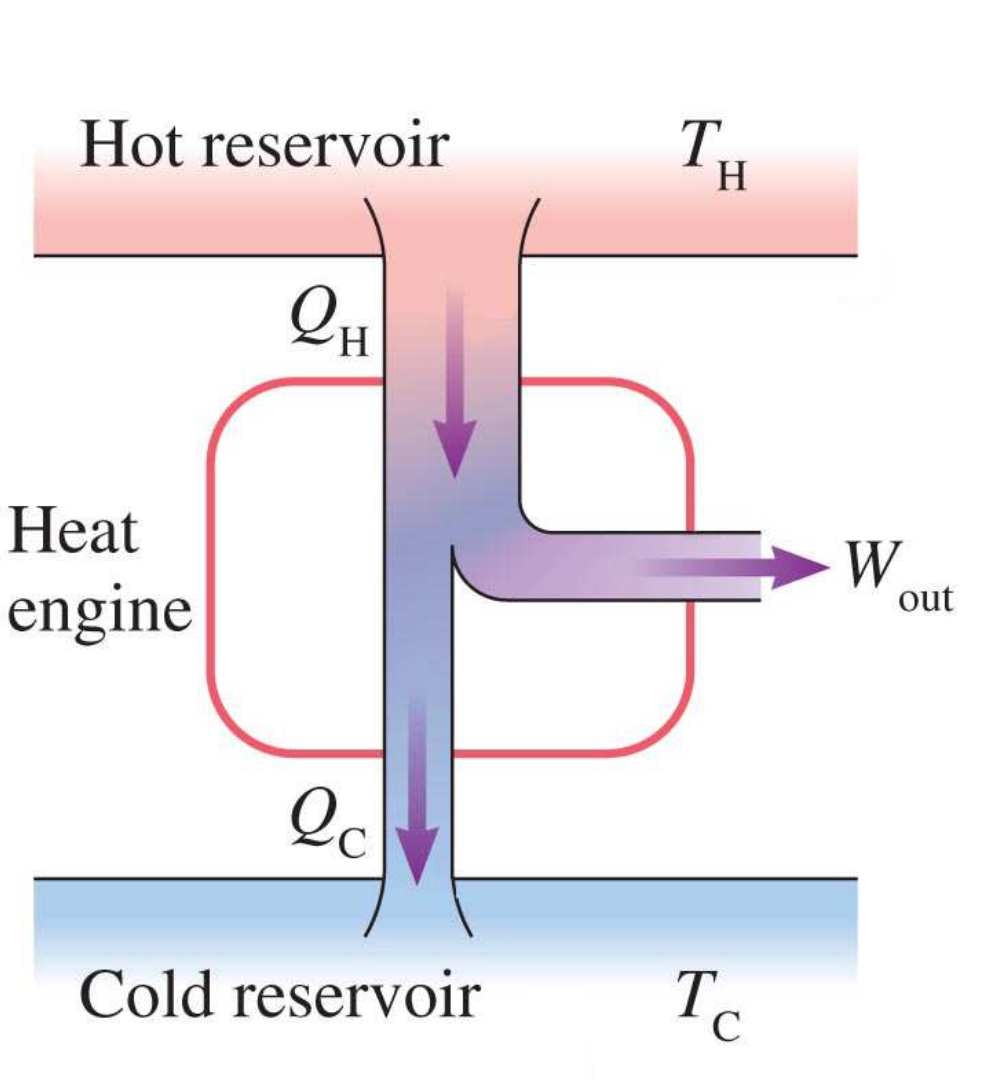
This is the “reverse” of an everyday event. The wind can scatter the leaves from a neat pile, but it cannot gather them.

Heat Engine II

Heat Engine - Device that uses the transfer of heat from a higher temperature to lower temperature to extract work



$$W + Q = \Delta E_{th}$$

$$-W_{out} + Q_H - Q_C = 0$$

$$W_{out} = Q_H - Q_C$$

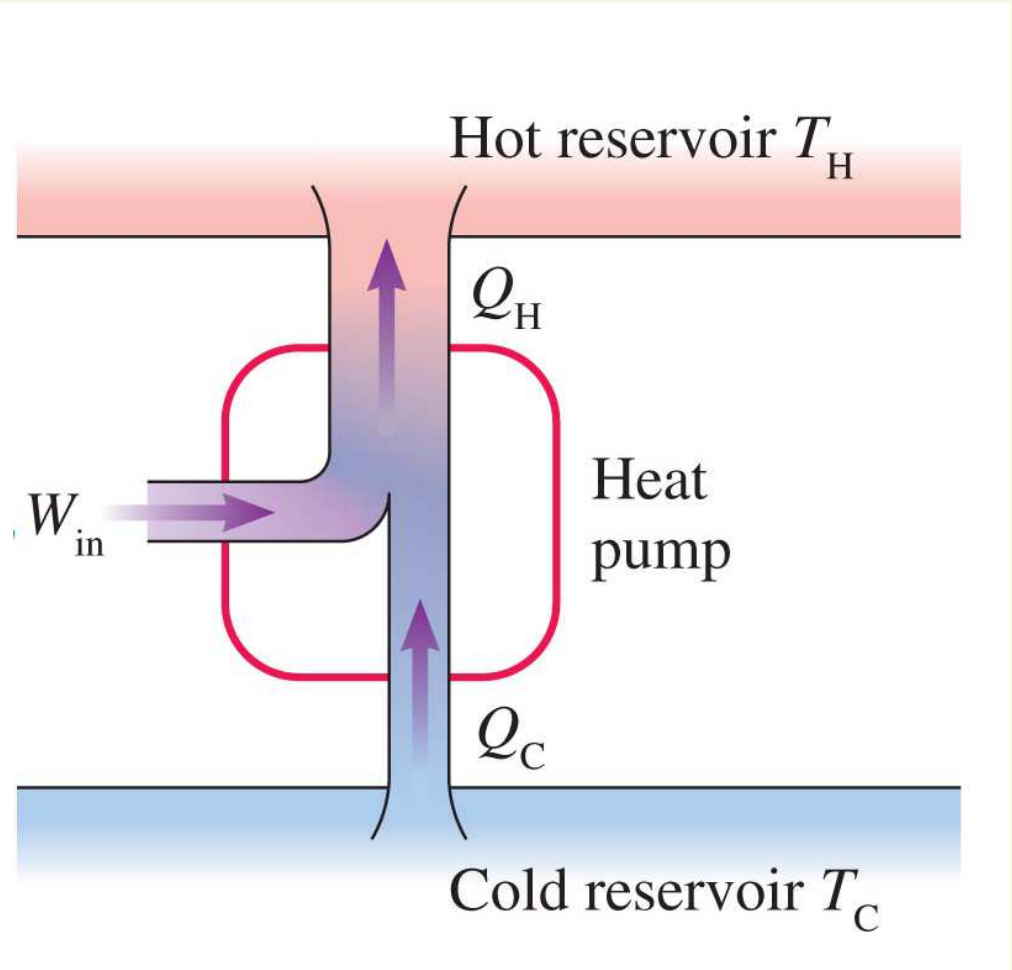
Better Form: $\boxed{Q_H = W_{out} + Q_C}$

Efficiency: $\boxed{e = \frac{W_{out}}{Q_H}}$

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

Heat Pump

Heat Pump - Device that does work in order to move heat from cold to hot



$$W + Q = \Delta E_{th} = 0$$

$$W = W_{in}$$

$$Q = Q_C - Q_H$$

$$W_{in} + Q_C - Q_H = 0 \Rightarrow$$

$$\boxed{W_{in} + Q_C = Q_H}$$

Coefficient of Performance:

$$\boxed{COP = \frac{Q_C}{W_{in}} = \frac{Q_C}{Q_H - Q_C}}$$

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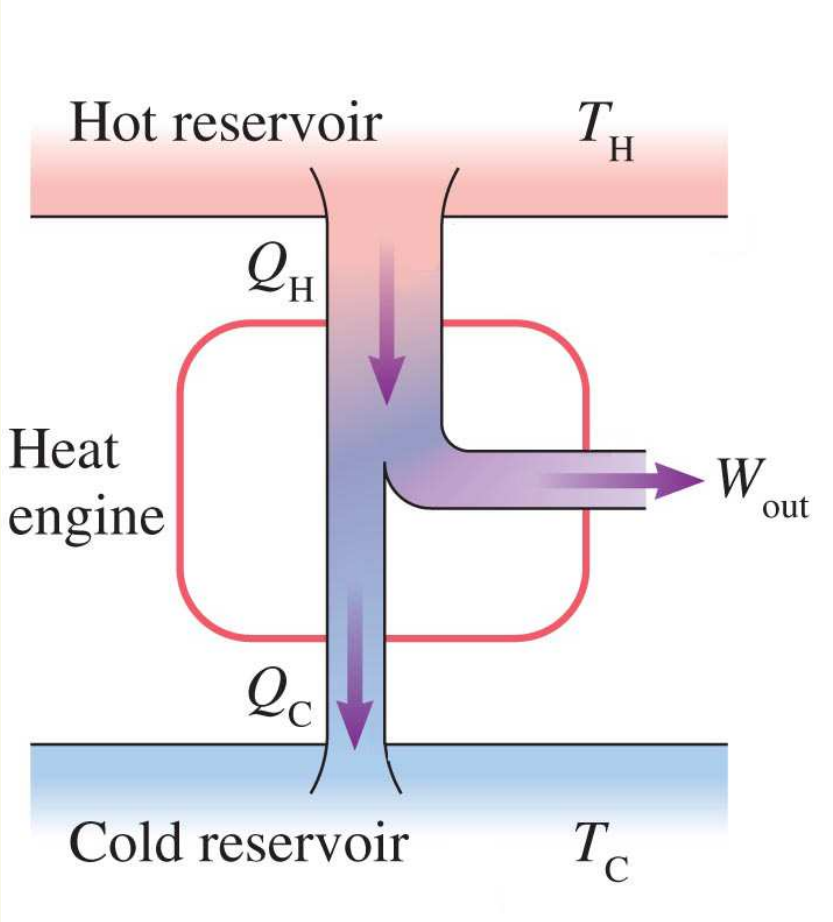

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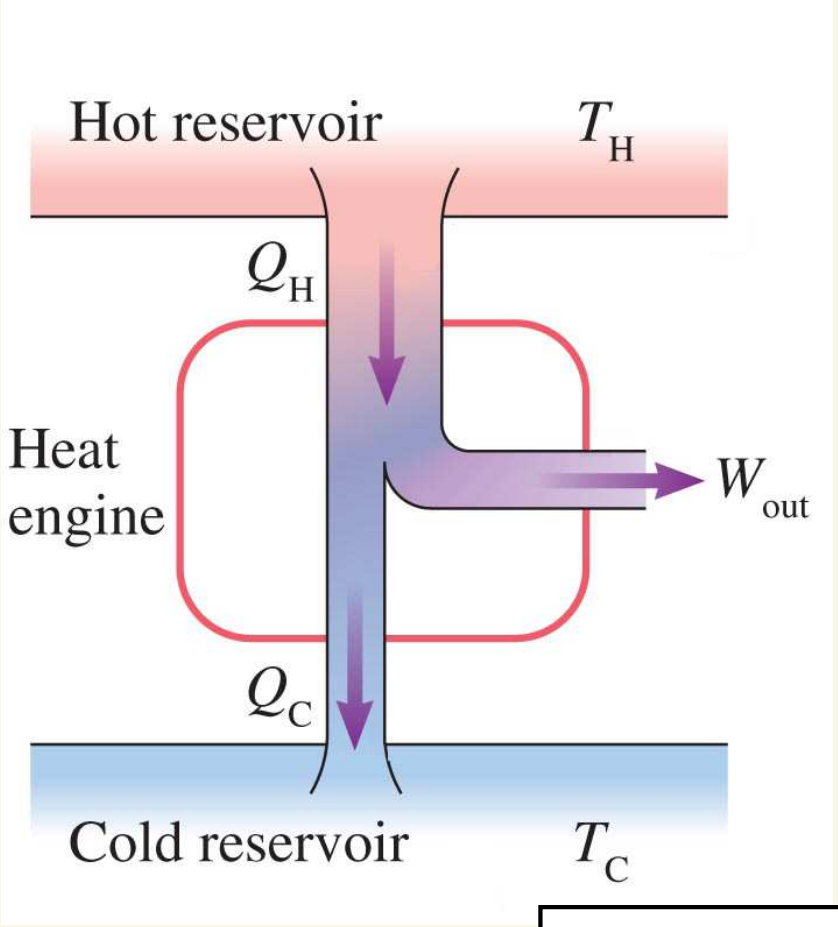

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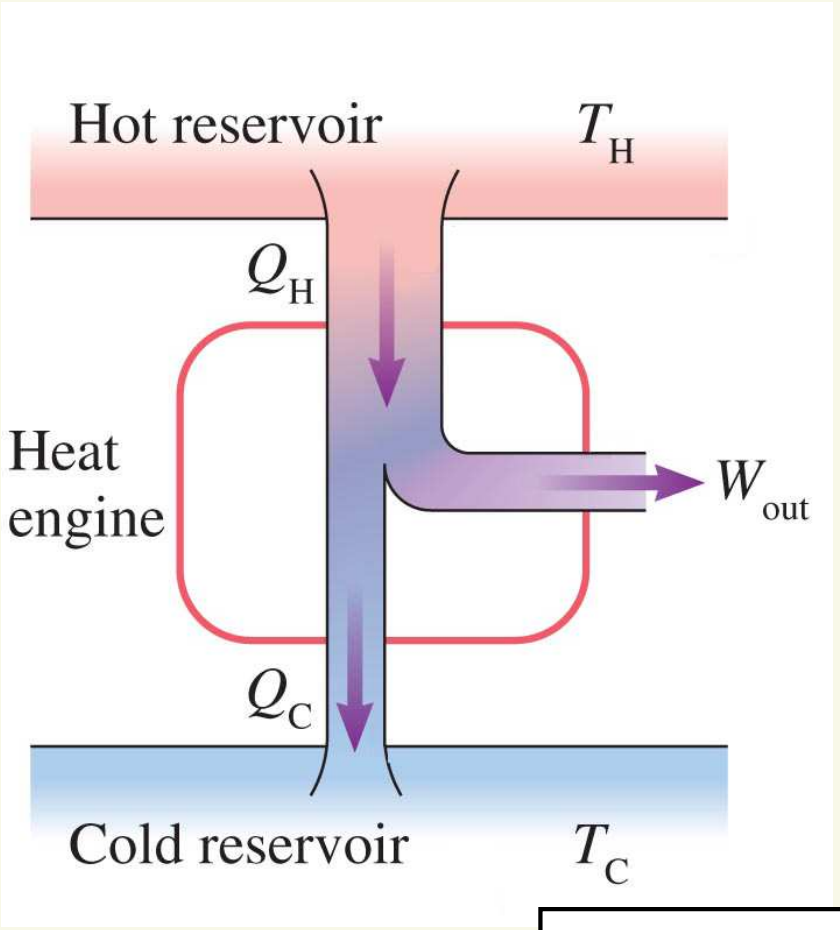

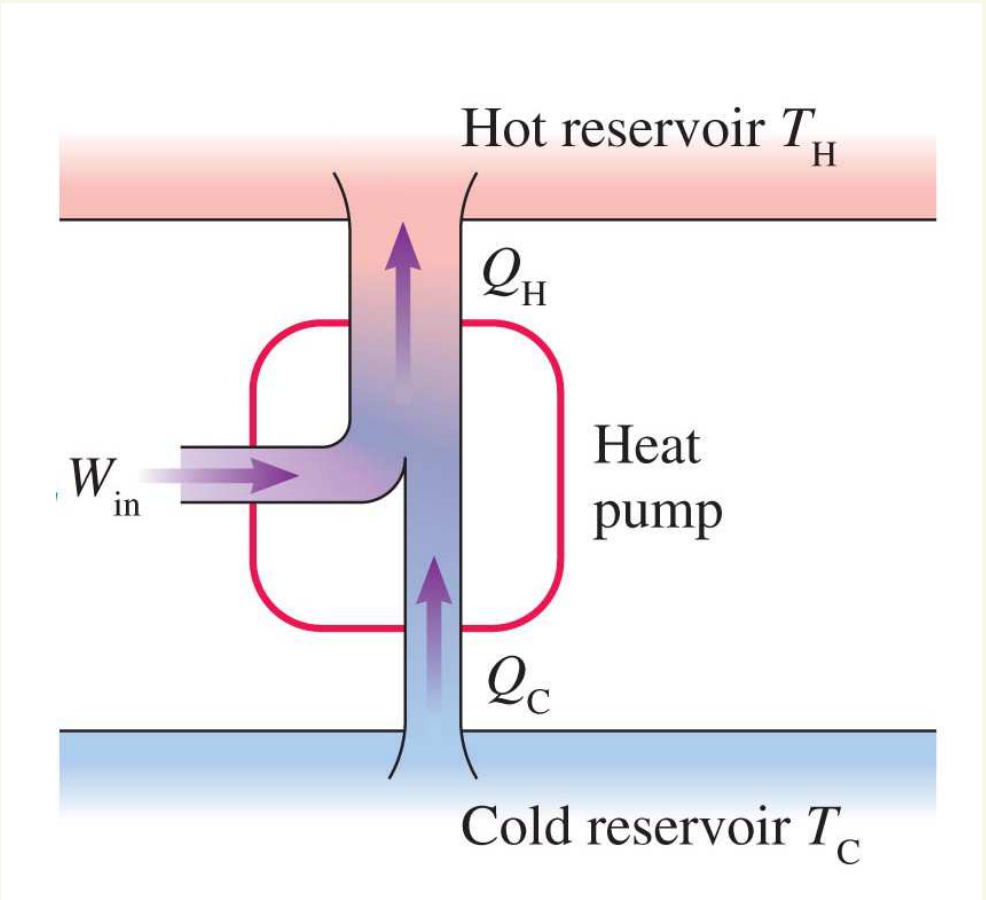

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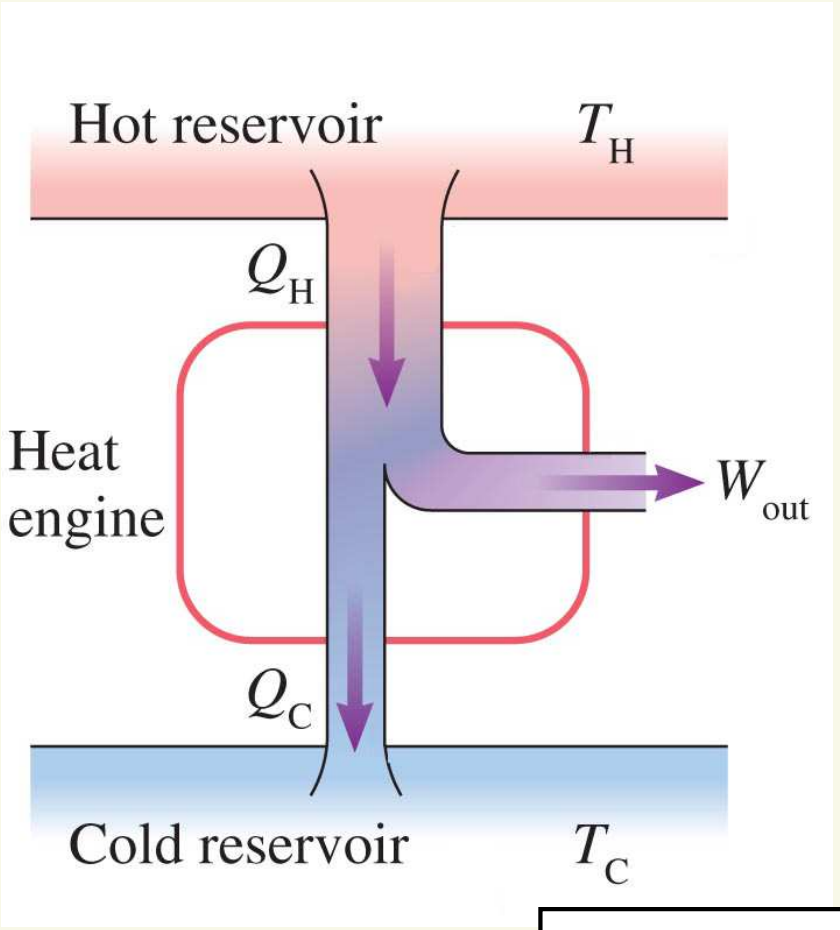

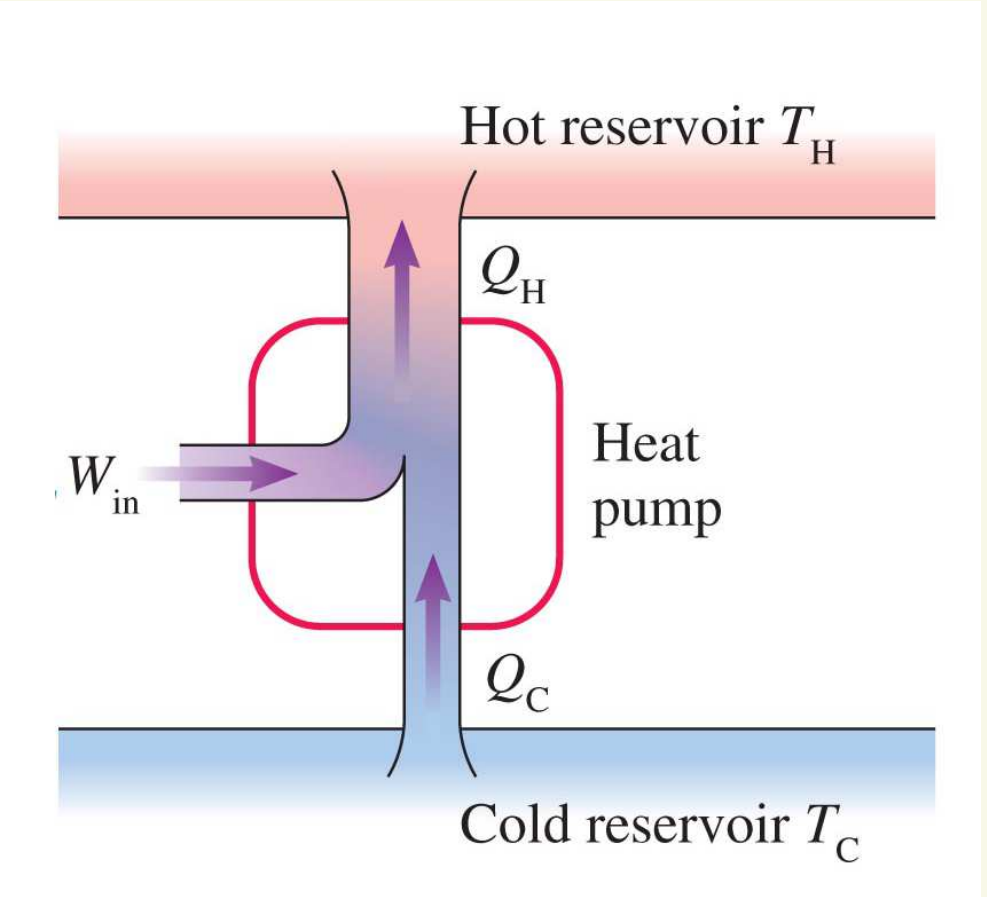

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