TOPIC IV - The Second Law

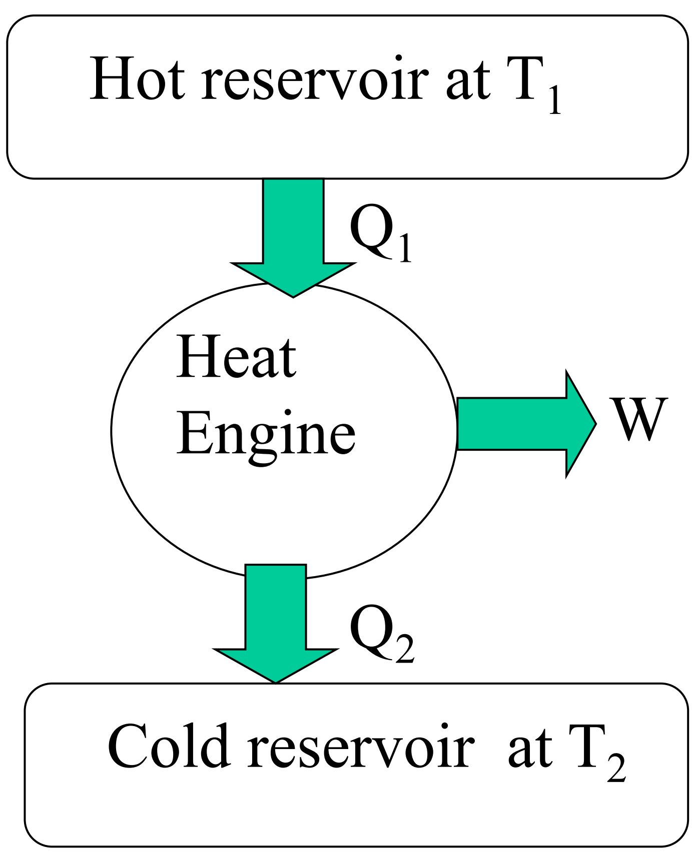
Reversible Heat Engines (Lecture 1/4)

<u>2 Heat Engines (abstract idea)</u>

Hot reservoir (= source)

Cold reservoir (= sink)

Energy flows Q_1, Q_2, W



TOPIC IV - The Second Law

Reversible Heat Engines (Lecture 1/4)

Energy balance and efficiency,

$$W = -Q_1 - Q_2 \qquad (1)$$

$$\eta = \frac{|W|}{Q_1} = \frac{|Q_1 + Q_2|}{Q_1} = \frac{|Q_1| - |Q_2|}{|Q_1|} \qquad (2)$$

(If $|Q_2| > 0$ then $\eta < 100\%$)

Cyclic processes

- by turbomachines or piston-cylinders
- charted on p-v (or T-s) diagrams
- sequence 1-2-3-4-1-2-3-4 etc

3. Kelvin-Planck Statement

"It is impossible for any device that operates on a cycle to receive heat from a single reservoir and produce an amount of work."

This is axiomatic.

(a) Heat engine must exchange heat with ≥ 2 reservoirs

(b) System exchanging heat with 1 reservoir only

* ***does*** *zero work … or*

* ***accepts*** *positive work from surroundings*

(a) Work is more valuable than heat.

4) Clausius Statement of the Second Law

Corollary 1: "It is impossible to construct a device that operates in a cycle and transfers heat from a cooler to a hotter body without work being done on the system by the surroundings" (Clausius statement of the second law.)

Proof (by argument)

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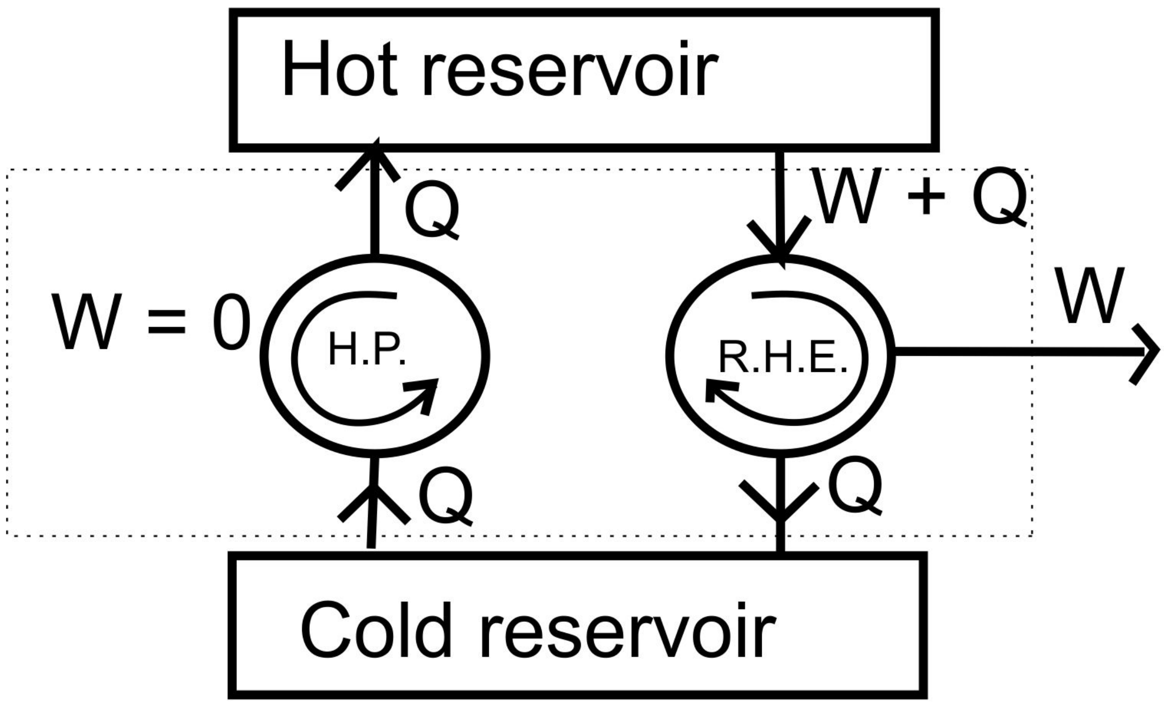

Heat pump moves Q from cold to hot with no external work.

Reversible heat engine rejects identical Q.

Net flow of heat across boundary from hot reservoir only, producing W. Contravenes Kelvin Planck.

Reversible Heat Engines (Lecture 1/4)

Q can be moved from cold to hot if work W is added – a heat pump. Coefficient of performance is heating effect per unit work.

$$COP_{HP} = \frac{|Q_1|}{|W|} = \frac{|Q_1|}{|Q_1| - |Q_2|} \qquad (3)$$

Reversible Heat Engines (Lecture 1/4)

Conclusions

Cyclic heat engines must exchange heat with two or more reservoirs.

The concept of efficiency – the useful work per unit heat added.

A heat pump demands the addition of work.