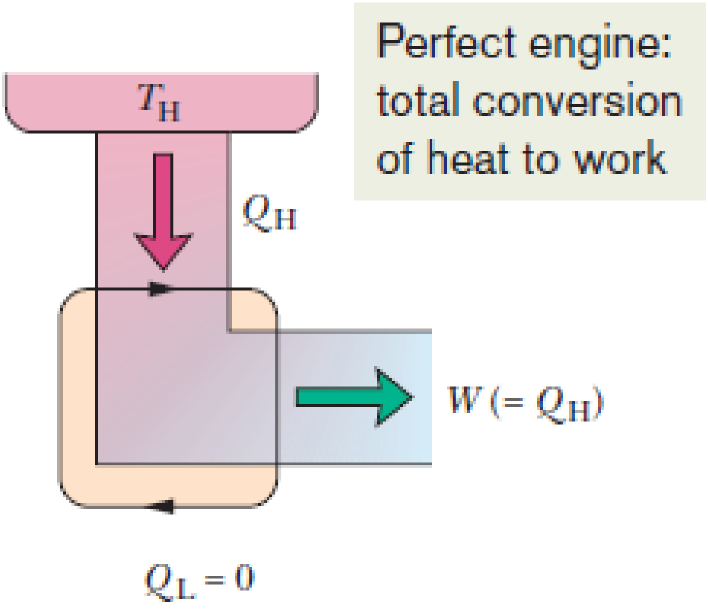
Lecture 12

Chapter 20: **Entropy and the second law of thermodynamics**

20-2 No Perfect Engines:

Inventors continually try to improve engine efficiency by reducing the energy Q_L that is "thrown away" during each cycle. The inventor's dream is to produce the perfect engine, diagrammed in Fig, in which Q_L is reduced to zero and Q_H is converted completely into work.



Also, a perfect engine is only a dream: impossible requirements

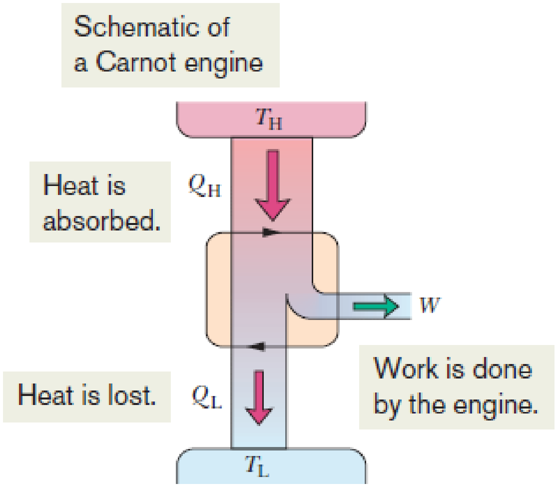
$$\varepsilon = 1 - \frac{T_L}{T_H} = = 1 - \frac{0}{\infty} = 1 = 100\%$$

Instead, experience gives the following alternative version of the second law of thermodynamics, which says in short, there are no perfect engines:

"No series of processes is possible whose sole result is the transfer of energy as heat from a thermal reservoir and the complete conversion of this energy to work".

To summarize:

- The thermal efficiency, $\varepsilon = 1 - \frac{T_L}{T_H}$ applies only to Carnot engines.
- Real engines, in which the processes that form the engine cycle are not reversible, have lower efficiencies.
- If your car were powered by a Carnot engine, it would have an efficiency of about 55% according to $\varepsilon = 1 - \frac{T_L}{T_H}$; its actual efficiency is probably about 25%.
- A nuclear power plant, taken in its entirety, is an engine. It extracts energy as heat from a reactor core, does work by means of a turbine, and discharges energy as heat to a nearby river. If the power plant operated as a Carnot engine, its efficiency would be about 40%; its actual efficiency is about 30%.



25. A Carnot engine has an efficiency of 22.0%. It operates between constant-temperature reservoirs differing in temperature by 75.0 C^0. What is the temperature of the (a) lower-temperature and (b) higher-temperature reservoir?

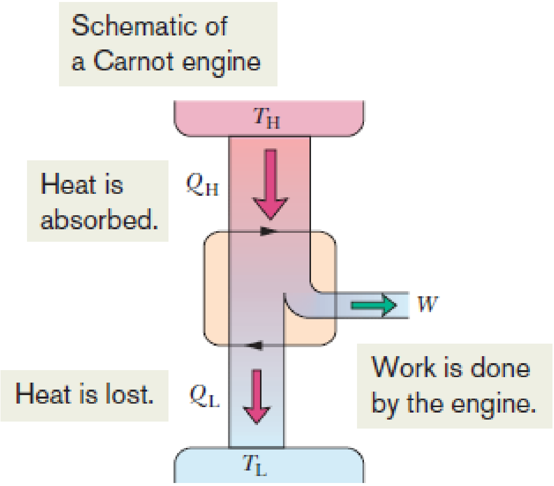
Given,

Efficiency, $\varepsilon_c = 22.0\% = 0.22$

Difference in temperature, $T_H - T_L = 75C^0 = 75\ K$

$$(T_H + 273) - (T_L + 273) = 75K$$

$$(a)\ T_L = ?$$



We know,

$$\varepsilon_c = 1 - \frac{T_L}{T_H}$$

$$\Rightarrow 22\% = 1 - \frac{T_L}{75 + T_L} \qquad [as \quad T_H = 75 + T_L]$$

$$\Rightarrow 0.22 = \frac{75 + T_L - T_L}{75 + T_L}$$

$$\Rightarrow 0.22 = \frac{75}{75 + T_L}$$

$$\Rightarrow 0.22(75 + T_L) = 75$$

$$\therefore T_L = 266 \text{ K}$$

(b) $T_H = ?$

We have,

$$T_H - T_L = 75 \ K$$

$$T_H - 266 = 75$$

$$\therefore T_H = 341 \text{ K}$$

27. A Carnot engine operates between 235 ^{0}C and 115 ^{0}C, absorbing 6.30x10^4 J per cycle at the higher temperature. (a) What is the efficiency of the engine? (b) How much work per cycle is this engine capable of performing?

Given,

$$T_H = 235^0C = 508\ K$$

$$T_L = 115^0C = 388\ K$$

$$Q_H = 6.3 \times 10^4\ J$$

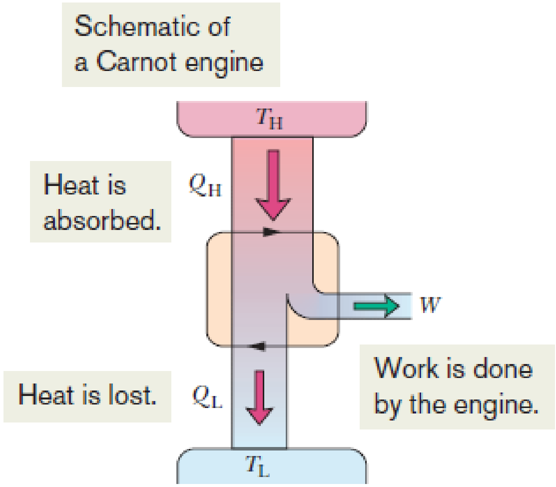
$$(a)\ \varepsilon_c = ?$$

We know,

$$\varepsilon_c = \left(1 - \frac{T_L}{T_H}\right)$$

$$= \left(1 - \frac{388}{508}\right)$$

$$= 0.2362 = 23.62\%$$



$\boldsymbol{The\ work\ done\ per\ cycle,}$

$$W = \varepsilon_c\,|Q_H| \qquad\qquad [\varepsilon_c = \frac{W}{|Q_H|}]$$

$$= 0.2362 \times (6.3 \times 10^4)$$

$$W = 1.48 \times 10^4\ J$$