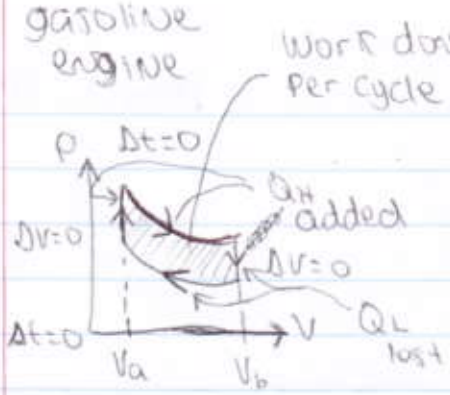
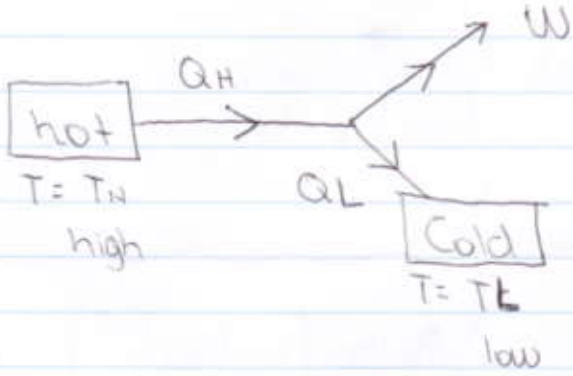
gasoline engine



heat engine: cyclic processes that turn some heat into (useful) mechanical energy.



$Q_H = W + Q_L$

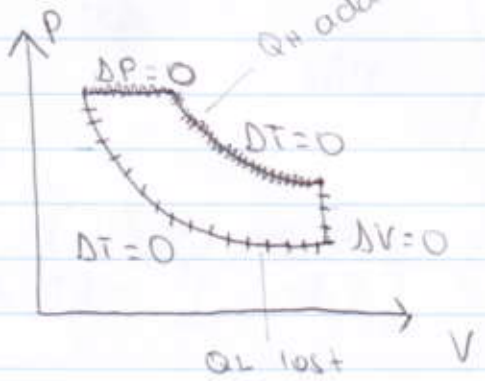
$W = Q_H - Q_L$

efficiency $e = \frac{W}{Q_H} = \frac{Q_H - Q_L}{Q_H}$

$$e = 1 - \frac{Q_L}{Q_H}$$

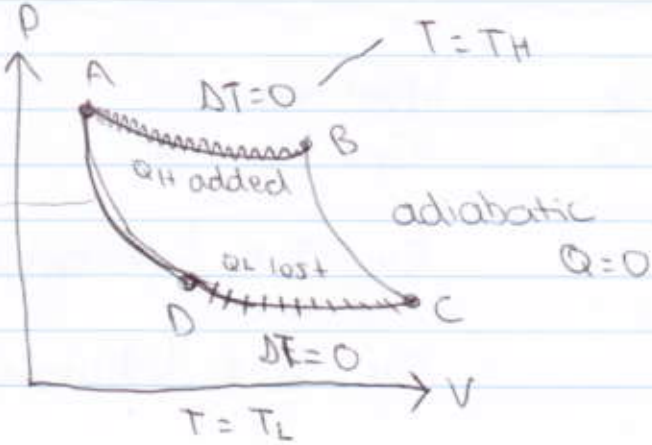
* See pages 531, 535, 536 *

Diesel engine



Diesel engine is more efficient than gasoline engine

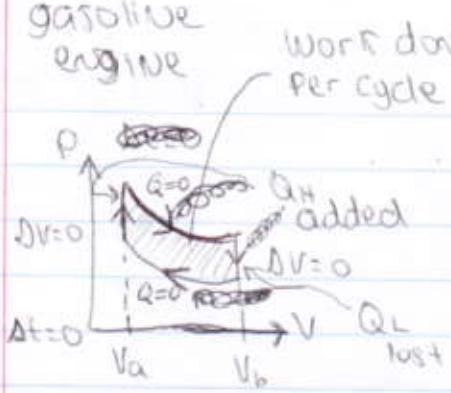
Best e possible:
Carnot engine



Carnot

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

gasoline engine



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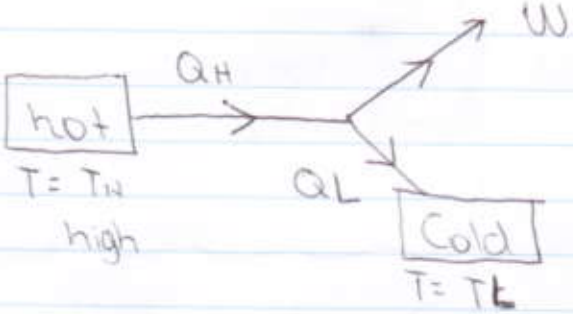

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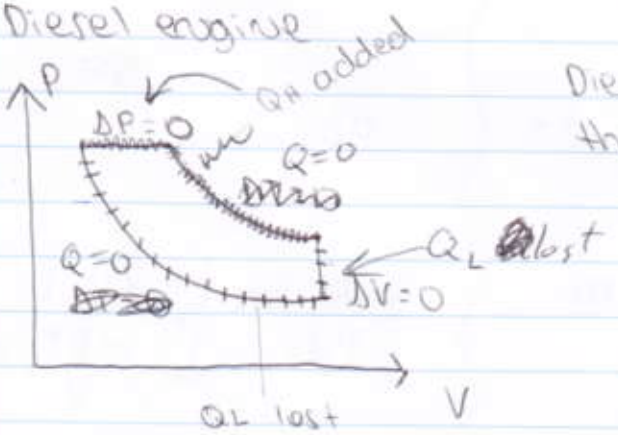
Diesel engine



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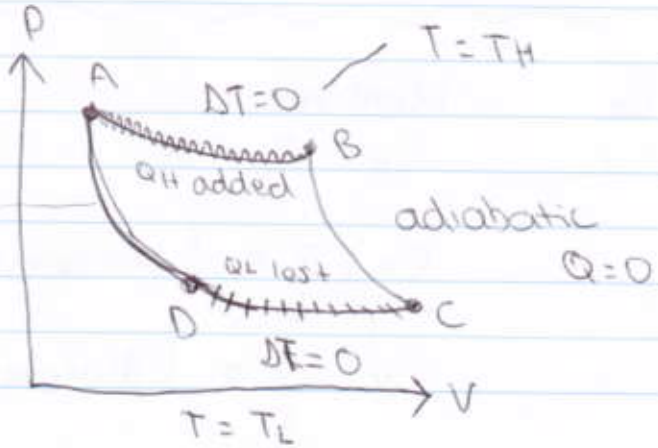
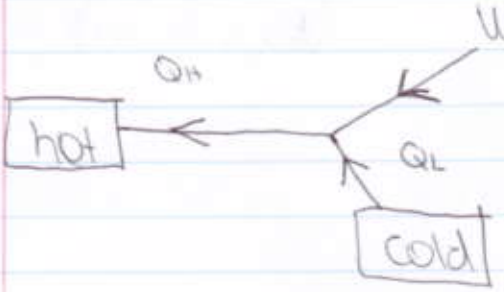


Carnot

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

Refrigerator / air conditioner



$Q_H = Q_L + W$

Coefficient of performance

$COP. = \frac{Q_L}{W} = \frac{Q_L}{Q_H - Q_L}$

$\text{Best possible} = \frac{T_L}{T_H - T_L}$

Why can't we do better?

* 2nd law of ~~thermodynamics~~:

Heat spontaneously flows from hot to cold, Not the other way around.

Equivalently, "disorder" increases.

Quantitative version: S never decreases

S = entropy $\quad \Delta S = \int \frac{dQ}{T}$

T high $\vec{Q}$ T low

before

T Medium

after

In between: heat Q flows from hot to cold

$$Q = \int_{\text{before}}^{\text{after}} dQ \qquad S = \int_{\text{before}}^{\text{after}} dQ/T$$

Break S into two parts

$$\Delta S_{\text{left}} = -\int_{T=T_H}^{T=T_M} dQ/T \qquad \Delta S_{\text{right}} = \int_{T=T_L}^{T=T_M} dQ/T$$

$\Delta S = S_{left} + S_{right}$

From calculus: $\int_a^b F(x)\,dx = F(c)\,\Delta x$ for some c between a and b ($\Delta x = b - a$)

There are T_{MH} and T_{LM} such that

$T_L \leq T_{LM} \leq T_M \leq T_{MH} \leq T_H$ and

$\Delta S_{left} = \frac{-Q}{T_{MH}}$ and $\Delta S_{right} = \frac{Q}{T_{LM}}$

$\Delta S = \frac{Q}{T_{MH}} + \frac{Q}{T_{LM}} = Q\left(\frac{1}{T_{LM}} - \frac{1}{T_{MH}}\right)$

$T_{LM} \leq T_{MH} \Rightarrow \frac{1}{T_{LM}} \geq \frac{1}{T_{MH}} \Rightarrow \Delta S \geq 0$

T constant $\Rightarrow \Delta S = \frac{Q}{T}$