Heat Engines

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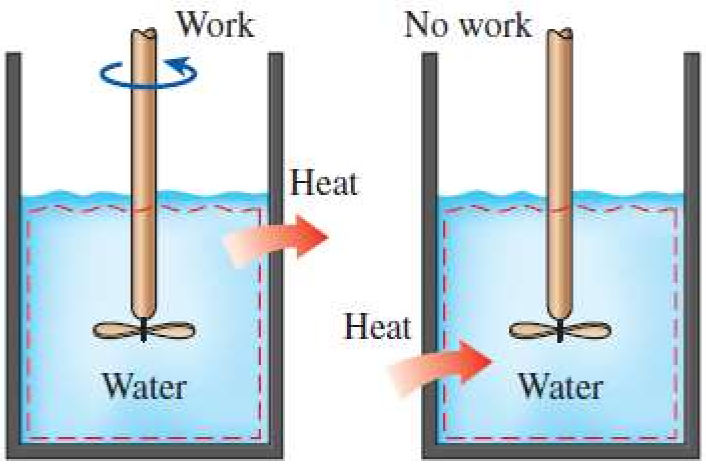
Previous lecture: Motivation & Scope of 2nd law

- Beyond 1st TD Law: Despite energy being obeyed certain processes do not occur…; 1st TD Law→U, 2nd TD Law→ S

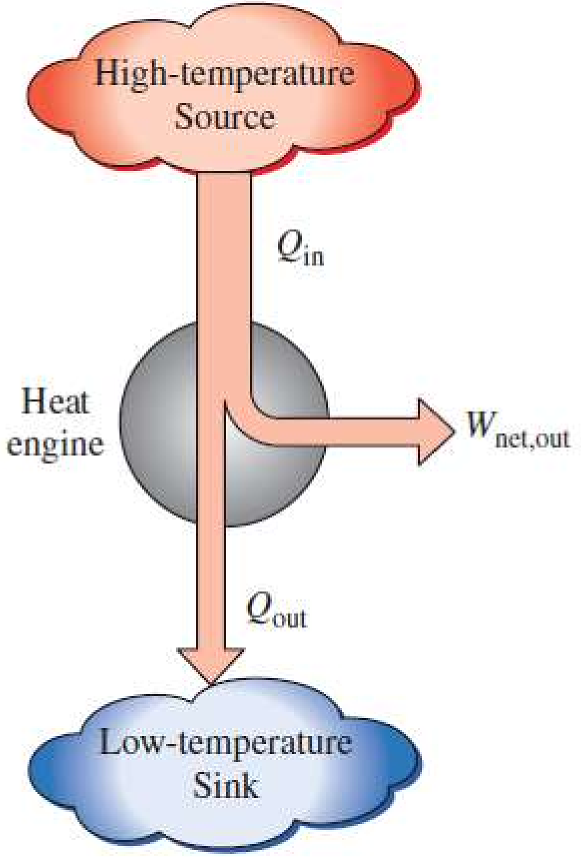
- From science to philosophy…!

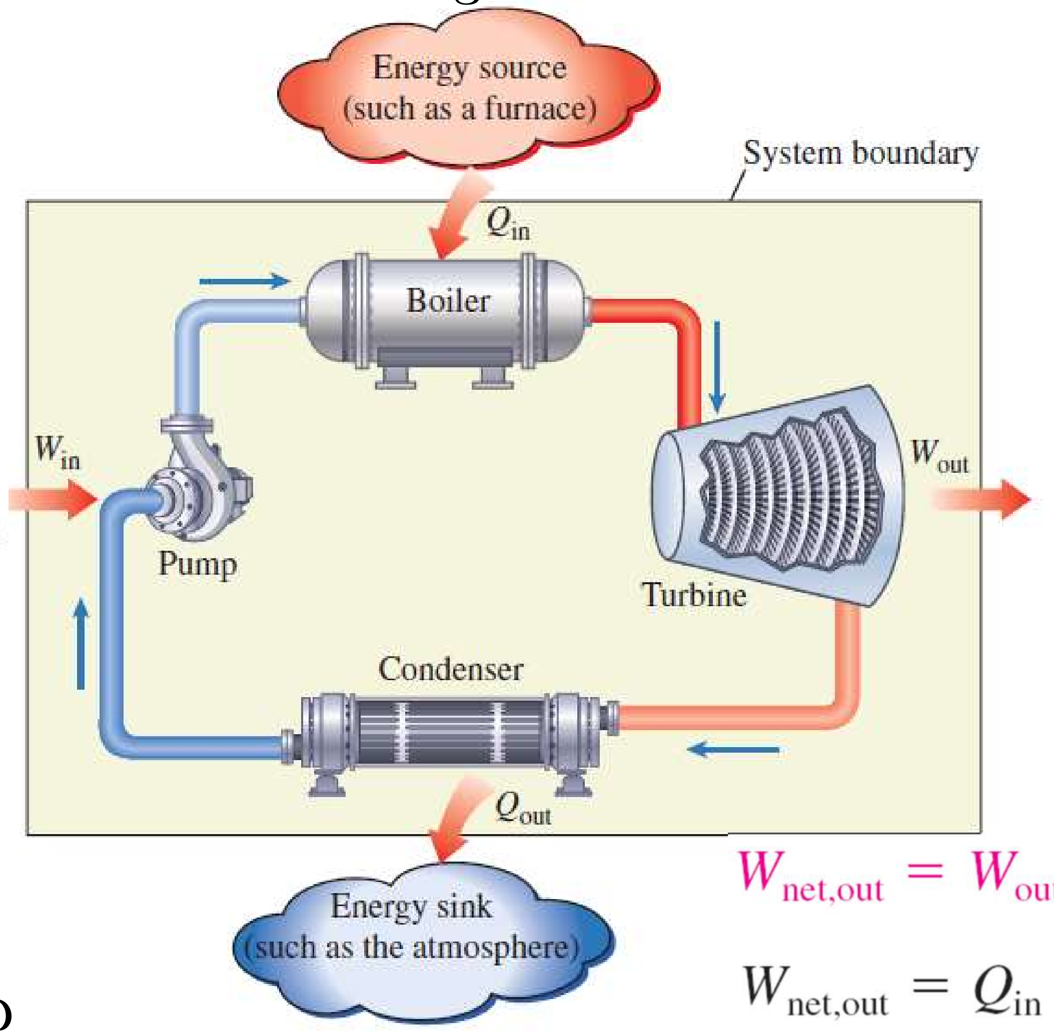


Figs: Cengel & Boles: TD

Why Heat Engines?

- Heat generated from burning fuels is converted to work: How much of the heat be converted to work?
- Cyclical devices generating work while exchanging heat with two “heat reservoirs”; “External” combustion engine





$$W_{net,out} = W_{out} - W_{in}$$

$$W_{net,out} = Q_{in} - Q_{out}$$

Figs: Cengel & Boles: TD

Heat Reservoirs have large thermal energy capacity

- Thermal energy capacity=Mass*Specific heat capacity
- Addition/subtraction of thermal energy does not change temperature
- Ocean/Atmosphere…
- Human body (w.r.t thermometer)…
- 2-phase system, Industrial furnace…

External vs. Internal combustion engine

- Mechanical cycle
- No TD cycle
- Working fluid is purged & not recycled

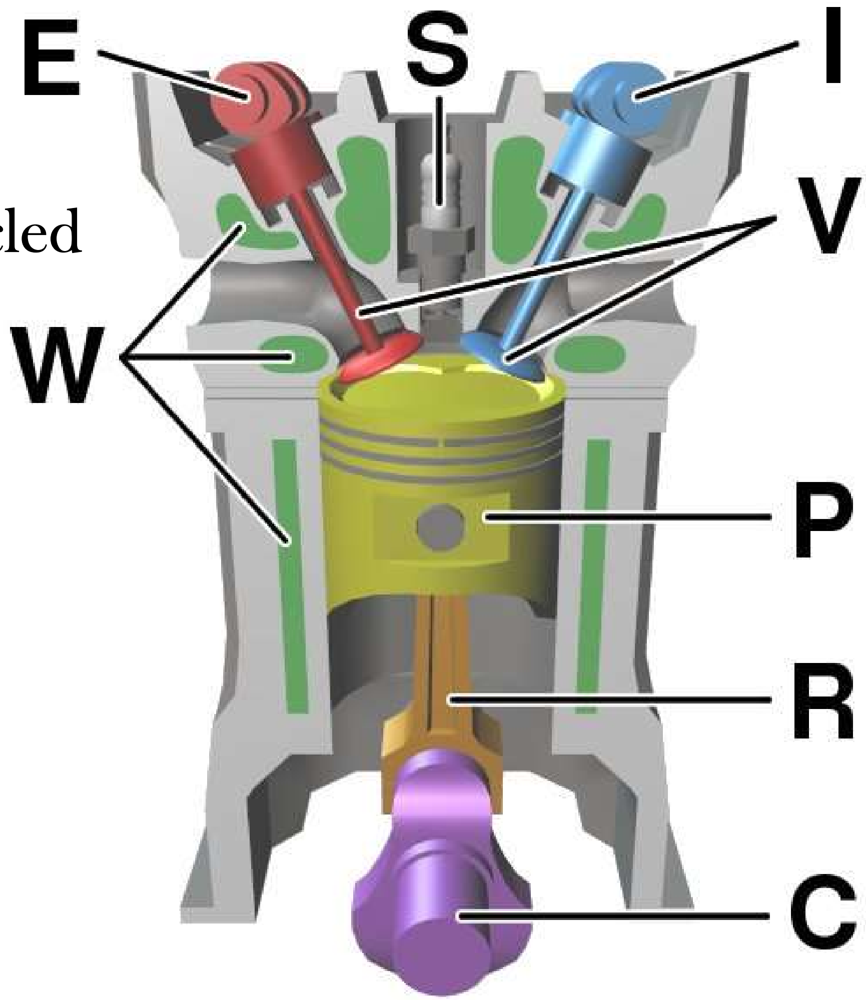
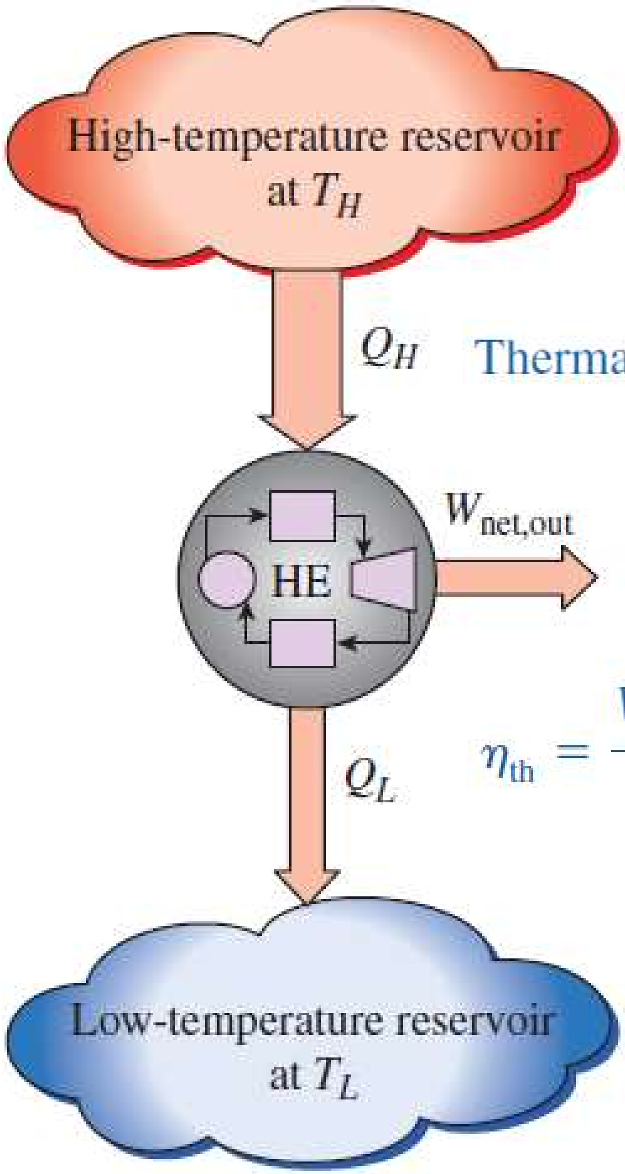


Diagram of a cylinder as found in 4-stroke gasoline engines.:
C – crankshaft **E** – exhaust camshaft **I** – inlet camshaft **P** – piston **R** – connecting rod
S – spark plug **V** – valves. red: exhaust, blue: intake.
W – cooling water jacket *gray structure* – engine block
https://commons.wikimedia.org/wiki/File:Four_stroke_engine_diagram.jpg

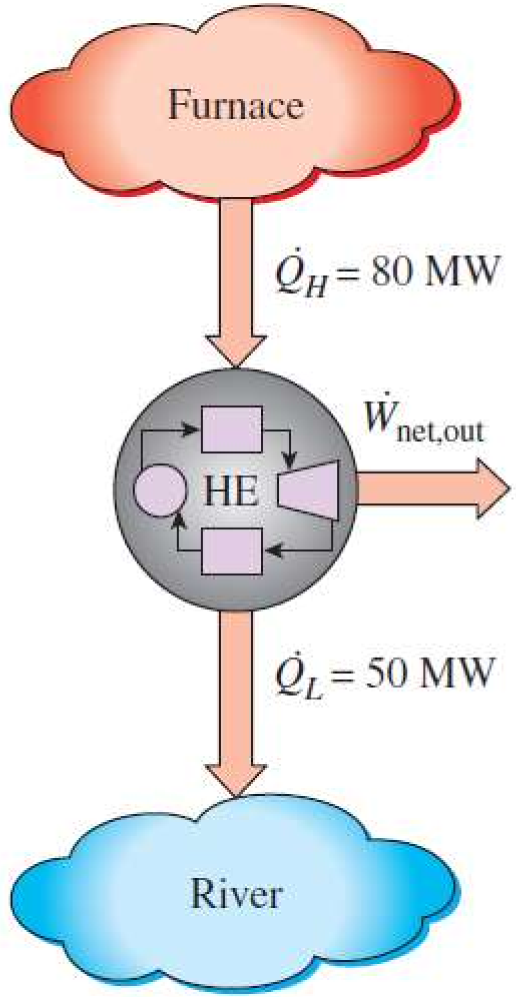
Thermal efficiency



$$\text{Thermal efficiency} = \frac{\text{Net work output}}{\text{Total heat input}}$$

$$W_{\text{net,out}} = Q_H - Q_L$$

$$\eta_{\text{th}} = \frac{W_{\text{net,out}}}{Q_H} \qquad \eta_{\text{th}} = 1 - \frac{Q_L}{Q_H}$$

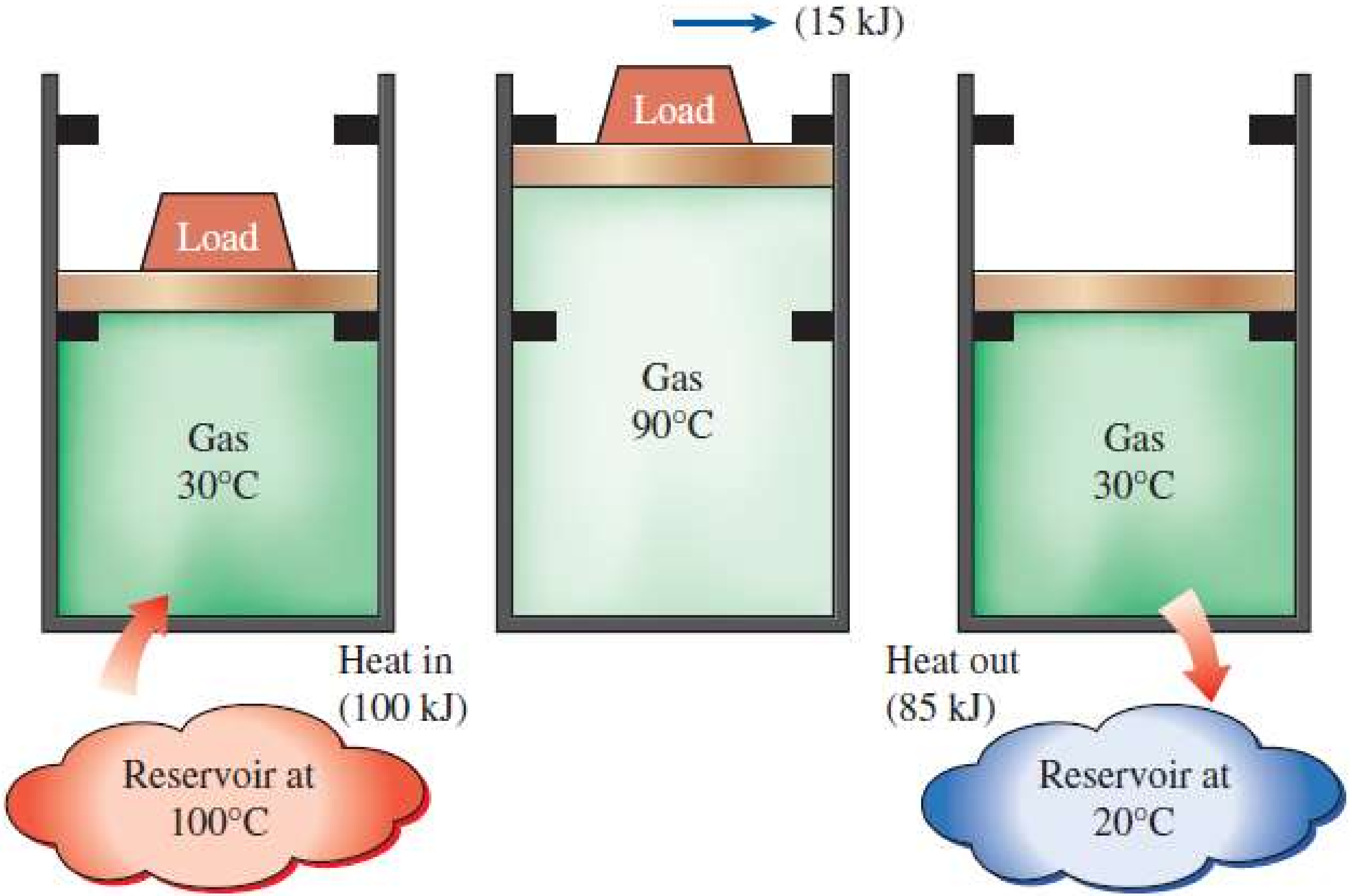


$$\dot{W}_{\text{net,out}} = \dot{Q}_H - \dot{Q}_L = (80 - 50)\ \text{MW} = \mathbf{30\ MW}$$

$$\eta_{\text{th}} = \frac{\dot{W}_{\text{net,out}}}{\dot{Q}_H} = \frac{30\ \text{MW}}{80\ \text{MW}} = \mathbf{0.375}\ (\text{or } 37.5\%)$$

Figs: Cengel & Boles: TD

Can we get 100% thermal efficiency?-No!, cycle…



Figs: Cengel & Boles: TD

Molecular interpretation of "wasted" heated

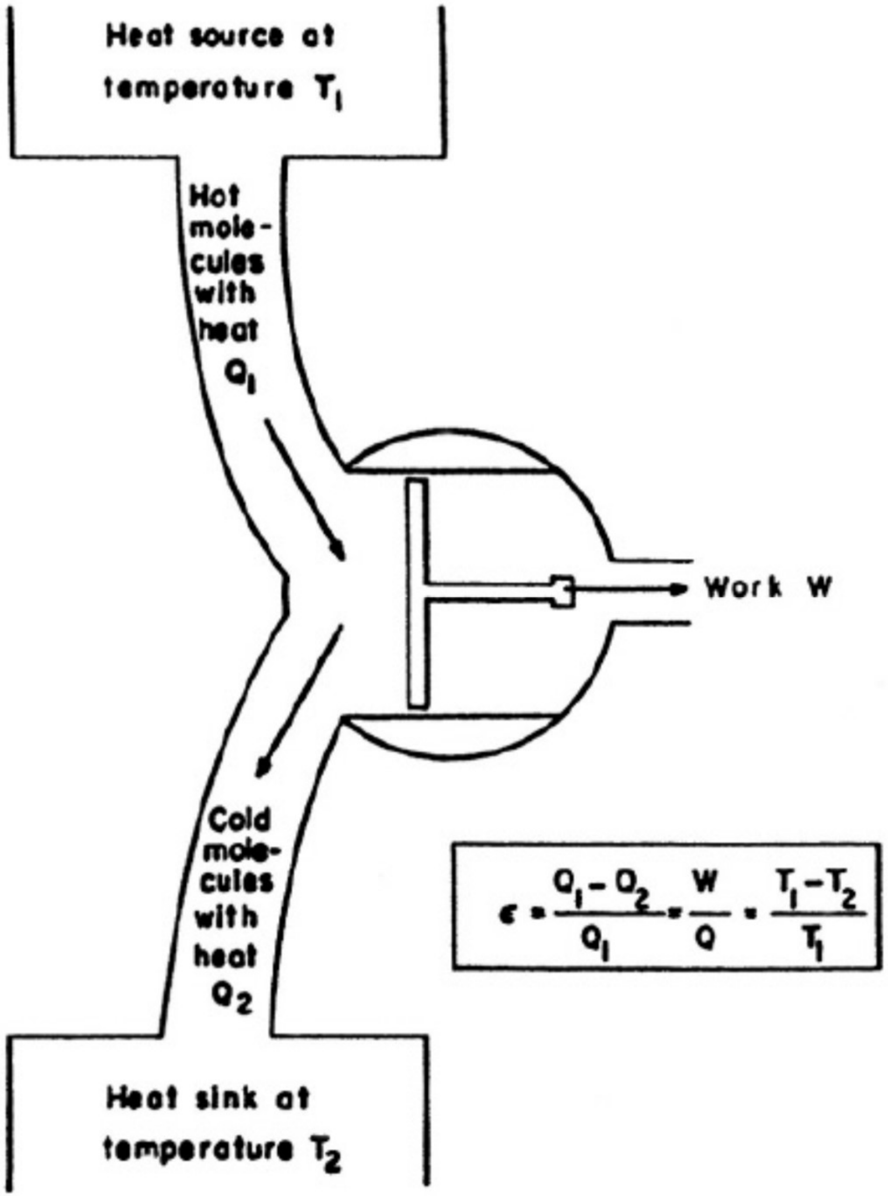


Fig: Modern Electrochemistry 2B, Bockris & Reddy

What's next?

- Kelvin-Planck statement of 2nd law of TD