Thermodynamics of Steam Engines

First steam engine: Newcomen, 1712, 0.5% efficiency.

\[ \text{Work} = \text{Force} \times \text{Distance} \]

\[ \text{change in pressure when steam condenses} \]

\[ \text{Pressure:} \]

\[ \text{pressure} = \frac{\text{Force}}{\text{Area}} \]

\[ \text{units: 1 atm = atmospheric pressure = 14 psi} \]

\[ \Rightarrow \text{every square inch feels 14 lbs pressure with} \]

\[ \text{(equivalent of being under 10 m water!)} \]

So \( \text{Work} = \text{Force} \times \text{distance} \)

\[ = \text{Pressure of atmosphere} \times \text{Area of cylinder} \times \text{length of cylinder} \]

\[ \text{Work} = \text{Pressure of atmosphere} \times \text{Volume of cylinder} \]

\[ \text{Power} = \frac{\text{Work}}{\text{time}} = \frac{\text{Work}}{\text{time of each cycle}} \]

\[ \text{limited by time to condense water} \]

\[ \text{[Why did they use steam? It's faster to evaporate water than to heat air.]} \]
Watt's Steam Engine: 1769, 2% efficiency
Watt's Improved Steam Engine: 1783, 3% efficiency

- push - pull engine!
- Double-action steam engine
- throw away steam in favor of time
  => waste: work that could be done with steam, but higher power

How to measure work:
- measure steam pressure & position of piston throughout stroke
  (see PV diagram on slides) Area of indicator is the work done per cycle
  *must balance maximizing work * efficiency*

But what is a heat engine, anyway?

$$\begin{array}{c}
T_{hot} \\
Q_{out}
\end{array} \Rightarrow \begin{array}{c}
Q_{in} \downarrow
T_{cold}
\end{array}$$

$$\epsilon = \frac{W}{Q_{hot}}$$

2\text{nd} Law of Thermodynamics: disorder always increases
(unless you put work into the system)

Moving heat from hot to cold makes more disorder.
Work is ordered energy.

$$\Rightarrow$$ cannot have perfectly efficient engine.
If $\epsilon = 1$, $W = Q_{hot}$, disorder doesn't increase.
Violates 2\text{nd} Law.

What is the limit of engine efficiency?