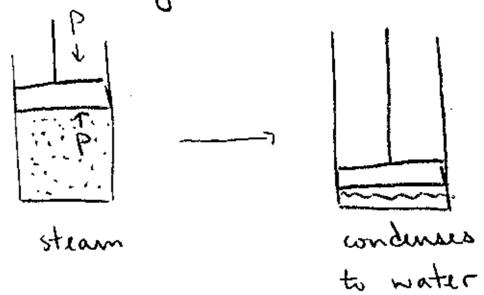
4/10

Thermodynamics of Steam Engines

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



Work = Force × Distance
↓
change in pressure when steam condenses

↓
pressure of steam balances pressure of atmosphere

[Pressure:

pressure = Force / Area

units: 1 atm = atmospheric pressure = 14 psi (pounds/square inch)

⇒ every square inch feels 14 lbs pressure

(equivalent of being under 10 m water!)]

So Work = Force × distance

= Pressure of atmosphere × Area of cylinder × length of cylinder

Work = Pressure of atmosphere × Volume of cylinder

Power = Work / time = Work / time of each cycle
↓
limited by time to condense water

[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

} increase power, too (see slides)

↳ 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

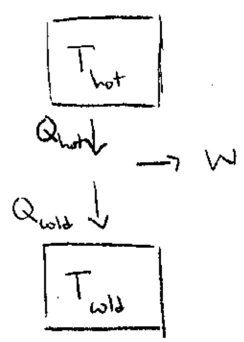
How to measure Work:

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?



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

2^{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.

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

What is the limit of engine efficiency?