10/10 Lecture outline

• Use Carnot engine to define temperature θ: $\eta = 1 - \Theta_C/\Theta_H$. Lots of C-engines in series, defines Θ temperature scale. Agrees with previous definition, $\Theta = T$ (!).

• A system undergoes cyclic process. Absorbs heat Q_1 from reservoir at temperature T_1 and Q_2 from one at temperature T_2. Carnot says $(1 + Q_1/Q_2) \leq (1 - T_1/T_2)$. E.g. $T_1 = T_C$, $T_2 = T_H$, and $Q_1 = -|Q_C| < 0$, $Q_2 = Q_H > 0$. So $(Q_1/T_1) + (Q_2/T_2) \leq 0$, with equality holding iff the cycle is reversible.

• Arbitrary system $\mathcal{O}$ undergoing arbitrary cyclic process. Couple to lots of little Carnot engines/refrigerators, $\mathcal{C}$, whose heat output is $\mathcal{O}$'s input. In combined system, would violate Kelvin's statement unless

$$\oint \frac{đQ}{T_{ext}} \leq 0.$$

And for a reversible cycle, $T_{ext} = T$, and can reverse to get similar inequality with $đQ \to -đQ$, so

$$\oint \frac{đQ_R}{T} = 0.$$

• So $đQ_R/T = dS$ is a state variable!

• So $S(B) - S(A) = \int_A^B đQ_R/T$ over any reversible path.

• Thus $\int_A^B đQ/T \leq S(B) - S(A)$, equality iff reversible.

• Entropy of thermally isolated ($đQ = 0$) system never decreases. Thermally isolated system is in state of maximum entropy, consistent with external constraints.

• Examples