10/3 Lecture outline

• Finish up some stuff from end of last lecture: Ideal gas, and adiabatic: $PdV = -C_V dT$, $VdP = C_P dT$, $C_V VdP = -C_P PdV$. $dP/P = -\gamma dV/V$, so $PV^\gamma = constant$. $\left(\frac{\partial P}{\partial V}\right)_{adi} = -\gamma P/V = \gamma\left(\frac{\partial P}{\partial V}\right)_T > \left(\frac{\partial P}{\partial V}\right)_T$. So adiabatic curve has steeper slope than isothermal curve in P/V diagram. See here $\kappa_T = \gamma\kappa_{adi}$ (and more generally too).

• Examples of ΔW for ideal gasses and various processes (segue into today's topic: inter-conversion of heat and work – theory of heat engines):

1. isothermal: $\Delta U = 0$. $\Delta Q = \Delta W = nRT\ln(V_f/V_i)$
2. isochoric: $\Delta W = 0$. $\Delta Q = \Delta U = C_V\Delta T$
3. isobaric: $\Delta W = P\Delta V = nR\Delta T$. $\Delta Q = C_P\Delta T = (C_V + nR)\Delta T$
4. adiabatic: $\Delta Q = 0$. $\Delta W = -\Delta U = -C_V\Delta T$.

• Efficiency $\eta \equiv |W|/|Q_H|$. E.g. isothermal expansion of ideal gas: $|W| = |Q| = nRT\ln(P_i/P_f)$ has $\eta = 1$, but this is a one-shot process. Final state differs from initial.

• For an engine, want cyclic process, coming back to starting state, i.e. closed loop in P/V diagram. For complete cycle, $\Delta U = 0$ (state variable). Total work of process $= |W| =$ area enclosed by cycle in P/V diagram. In process, some heat $|Q_H|$ is taken out of some hot working substance (e.g. boiler), and then some heat is ejected into cold area (e.g. the smoke going out into the atmosphere). $|W| = |Q_H| - |Q_C|$, so $\eta = 1 - |Q_C|/|Q_H$. To maximize η, want to minimize ΔQ. But this is generally impossible!

• Refrigerator performance: $\omega = |Q_C|/|W|$.

• Preview of 2nd law: (Clauius) *no device can be made that operates in a cycle and whose* **SOLE** *effect is to transfer heat from cooler to hotter body.* Relate to the statement that every engine has to deliver some wasted heat to the colder body, i.e. that $\eta < 1$ for cyclic process.