Physics 122 — Thermal Physics

Lecture Notes: Week 3, Day 3

1 Adiabatic Processes

Definition

An **adiabatic process** is a thermodynamic process in which **no heat is exchanged** with the surroundings:

$$Q = 0$$

1.1 First Law of Thermodynamics (Course Convention)

Sign convention: Work done *by the environment on the system* is positive.

$$\boxed{\Delta E = Q + W}$$

For an adiabatic process:

$$\boxed{\Delta E = W}$$

1.2 Physical Examples

- Opening a soda bottle (rapid gas expansion)
- Spraying deodorant
- Diesel engine compression (no spark plug)

Rapid expansion or compression occurs too quickly for heat transfer.

1.3 Temperature Change

- Expansion $\rightarrow W < 0 \rightarrow$ internal energy decreases $\rightarrow$ gas cools
- Compression $\rightarrow W > 0 \rightarrow$ internal energy increases $\rightarrow$ gas heats

2 Adiabatic vs Isothermal Processes

2.1 Ideal Gas Law

$$PV = nRT$$

2.2 Isothermal Process

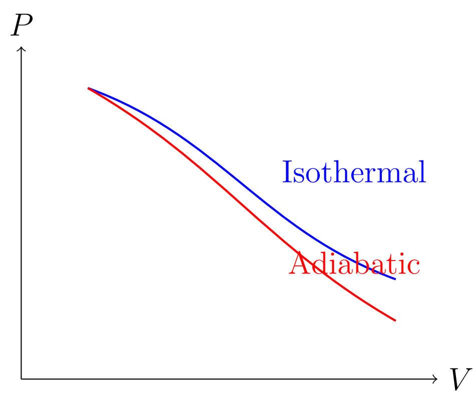
$$T = \text{constant}, \qquad P = \frac{nRT}{V}$$

2.3 Adiabatic Process

$$\boxed{PV^\gamma = \text{constant}}$$

where

$$\gamma = \frac{C_P}{C_V}$$



Adiabatic curves are steeper than isothermal curves.

3 Thermal Expansion

3.1 Linear Expansion

Linear Expansion

$$\boxed{\Delta L = \alpha L_0 \Delta T}$$

- α has units of K^{-1}
- Depends on material

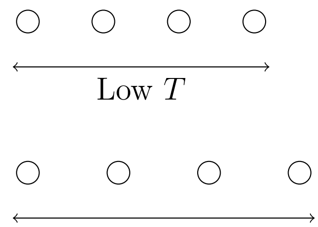
3.2 Volume Expansion

$$\boxed{\Delta V = \beta V_0 \Delta T}$$

For isotropic solids:

$$\boxed{\beta \approx 3\alpha}$$

3.3 Microscopic Picture



Higher temperature increases atomic vibration amplitude, increasing average spacing.

4 Example: Warming a Frozen Popsicle

Problem: A 50 g popsicle is removed from a freezer at $-10°$C and warmed to $20°$C.
Given:

$$c_{\text{ice}} = 2100\,\text{J}/(\text{kg}\cdot\text{K})$$
$$c_{\text{water}} = 4200\,\text{J}/(\text{kg}\cdot\text{K})$$
$$L_f = 3 \times 10^5\ \text{J}/\text{kg}$$

Steps

$$\begin{aligned} Q_1 &= mc_{\text{ice}}(0-(-10)) \\ Q_2 &= mL_f \\ Q_3 &= mc_{\text{water}}(20-0) \end{aligned}$$

Total Heat

$$\boxed{Q = Q_1 + Q_2 + Q_3 \approx 1.93 \times 10^4\ \text{J}}$$