The Box Model

Ins and Outs of Budgeting
Box Model

• The Box Model
  → Introduction
  → Steady-state Concentration Formula
  → Application to Pollution Control
A defined system receives something (input or source) and simultaneously has this stuff removed (output or sink).

Steady-state: when the source rate = sink rate, resulting in a constant amount or concentration of material inside the box.
Source rate = Sink rate
Source rate > Sink rate
**Steady-state Box Model Concentration**

V = volume of box

S = source rate ( = sink rate L at steady-state)

$\tau = \text{residence time ("tau")}$

$q = \text{steady-state concentration of pollutant in the box}$

$q = \frac{S\tau}{V}$
Air Pollution Sources and Sinks

- **Sources: origin of pollution**
  - Direct emission
  - Winds
  - Chemical processes
  - Resuspension

- **Sinks: removal processes**
  - Winds
  - Chemical processes
  - Deposition
Residence Time

• $\tau \equiv$ average period of time a molecule of an air pollutant stays inside a box before it is removed by some sink process

• Controlled by sinks:
  \[ \rightarrow \text{More efficient sink process} \]
  \[ \rightarrow \text{smaller residence time} \]
Pollution Control Analysis

Reduction of ambient, steady-state air pollution concentration achieved by:

• Reducing $S$
  → Easy to eliminate source or decrease source rate

• Reducing $\tau$
  → Somewhat more difficult to add more sink processes or increase sink efficiency

• Increasing $V$
  → Most difficult—how does one add on volume?
The Sun and The Earth
Sun, Earth, and Radiation

• Sun and Earth Radiation
  ➔ Origins
  ➔ Electromagnetic Radiation
  ➔ Blackbody Radiation Emission
  ➔ Solar vs. Terrestrial Radiation
The Sun

• A condensed, extremely large mass of hydrogen (90%) and helium (9.9%)

• Fusion of hydrogen into helium produces energy to drive sunlight-producing reactions

  → Most of the radiation eventually emitted to space is visible light
Electromagnetic Radiation (EMR)

Wavelength

\[ \lambda \]
Blackbody Radiation Emission

- Blackbody: an object that absorbs all wavelengths of EMR that fall on it
  - Also emits radiation at all wavelengths
  - Emission spectrum is temperature-dependent
Wien’s Law: the wavelength at which a blackbody emits the most radiation is inversely proportional to the blackbody’s temperature

\[ \lambda_{\text{max}} (\mu m) = \frac{2897}{T \ (K)} \]
Solar/terrestrial Radiation

Radiative equilibrium: The rate at which an object emits electromagnetic radiation is equal to the rate at which it absorbs electromagnetic radiation.

Stefan-Boltzmann Law: The emitted radiation power flux from a blackbody is directly proportional to its temperature.
Sun and Earth are both “near-blackbodies”

Sunlight

Terrestrial radiation

Sun, 6000K: emits mostly visible light
Earth, 255K: emits mostly infrared radiation