Ideal Gas Model

- Molecules may be treated as point masses relative to the volume of the system.
- Molecular collisions are elastic, i.e. kinetic energy is conserved.
- Intermolecular forces of attraction and repulsion have negligible on the molecular motion.

Ideal Gas Assumptions

- The number of molecules in the gas is large, and the average separation between the molecules is large compared with their dimensions
  - The molecules occupy a negligible volume within the container
  - This is consistent with the macroscopic model where we assumed the molecules were point-like

Ideal Gas Assumptions, 2

- The molecules obey Newton’s laws of motion, but as a whole they move randomly
  - Any molecule can move in any direction with any speed
  - At any given moment, a certain percentage of molecules move at high speeds
  - Also, a certain percentage move at low speeds

Ideal Gas Assumptions, 3

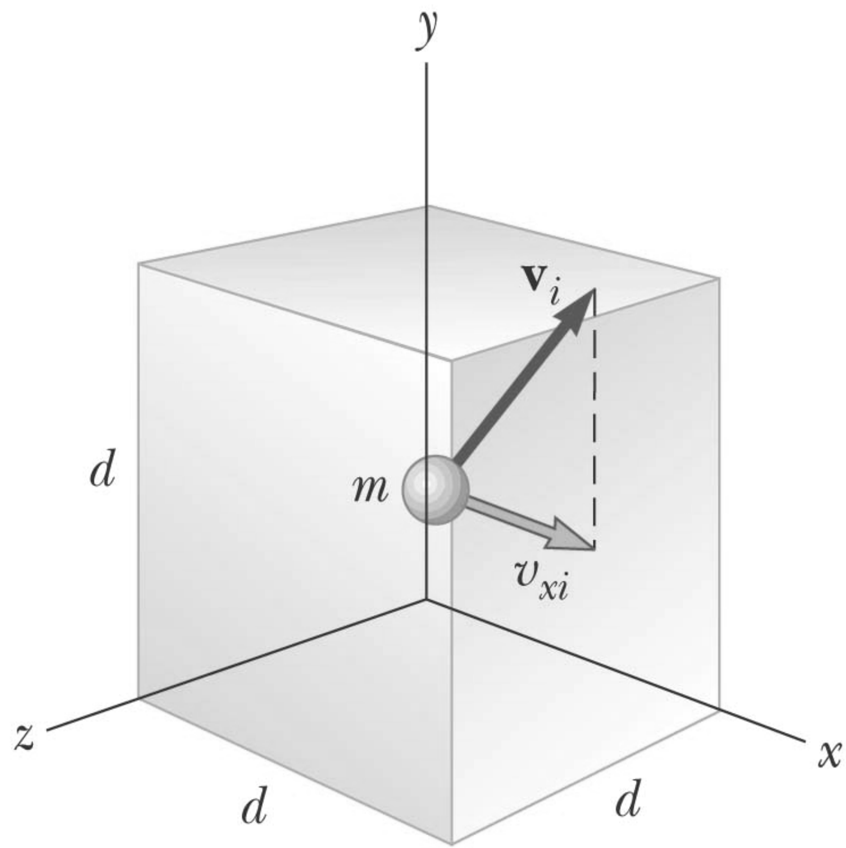
- The molecules interact only by short-range forces during elastic collisions
  - This is consistent with the macroscopic model, in which the molecules exert no long-range forces on each other
- The molecules make elastic collisions with the walls
- The gas under consideration is a pure substance
  - All molecules are identical

Ideal Gas Notes

- An ideal gas is often pictured as consisting of single atoms
- However, the behavior of molecular gases approximate that of ideal gases quite well
  - Molecular rotations and vibrations have no effect, on average, on the motions considered

Pressure and Kinetic Energy

- Assume a container is a cube
  - Edges are length *d*
- Look at the motion of the molecule in terms of its velocity components
- Look at its momentum and the average force

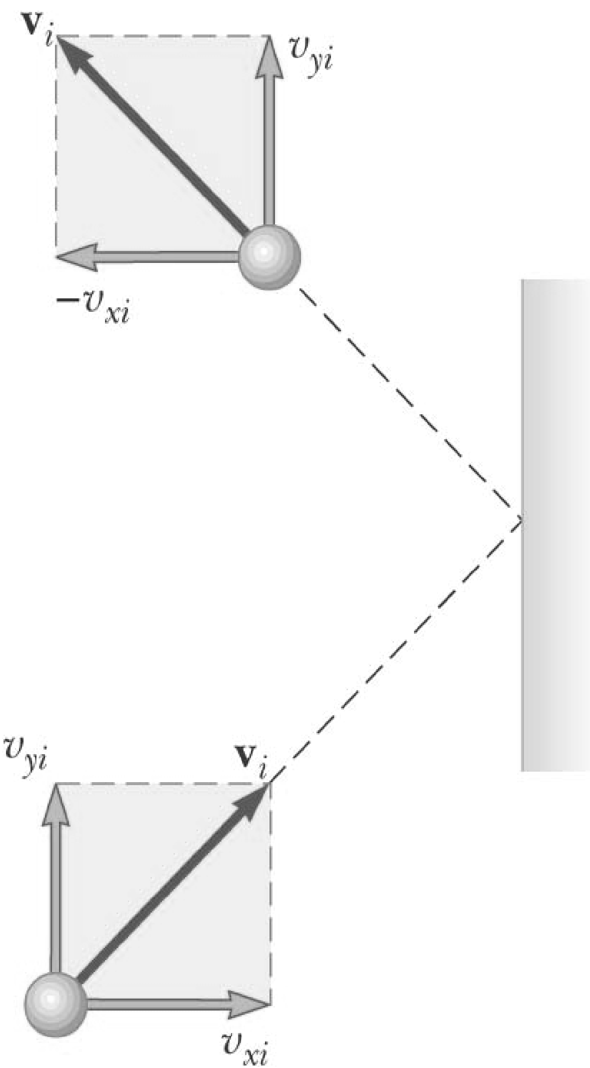


Pressure is the amount of momentum that crosses a unit area of the surface per unit time:

$$\mathbf{P = 1/A \times d(mv)/dt}$$

Pressure and Kinetic Energy, 2

- Assume perfectly elastic collisions with the walls of the container
- The relationship between the pressure and the molecular kinetic energy comes from momentum and Newton's Laws



Pressure and Kinetic Energy, 3

- The relationship is

$$P = \frac{2}{3}\left(\frac{N}{V}\right)\left(\frac{1}{2}m\overline{v^2}\right)$$

- This tells us that pressure is proportional to the number of molecules per unit volume (*N*/*V*) and to the average translational kinetic energy of the molecules

Pressure and Kinetic Energy, final

- This equation also relates the macroscopic quantity of pressure with a microscopic quantity of the average value of the square of the molecular speed
- One way to increase the pressure is to increase the number of molecules per unit volume
- The pressure can also be increased by increasing the speed (kinetic energy) of the molecules

Molecular Interpretation of Temperature

- We can take the pressure as it relates to the kinetic energy and compare it to the pressure from the equation of state for an ideal gas

$$P = \frac{2}{3}\left(\frac{N}{V}\right)\left(\frac{1}{2}m\overline{v^2}\right) = Nk_{\mathrm{B}}T$$

- Therefore, the **temperature** is a direct measure of the **average molecular kinetic energy**

Molecular Interpretation of Temperature, cont

- Simplifying the equation relating temperature and kinetic energy gives

$$\frac{1}{2} m \overline{v^2} = \frac{3}{2} k_B T$$

- This can be applied to each direction,

$$\frac{1}{2} m \overline{v_x^2} = \frac{1}{2} k_B T$$

with similar expressions for v_y and v_z