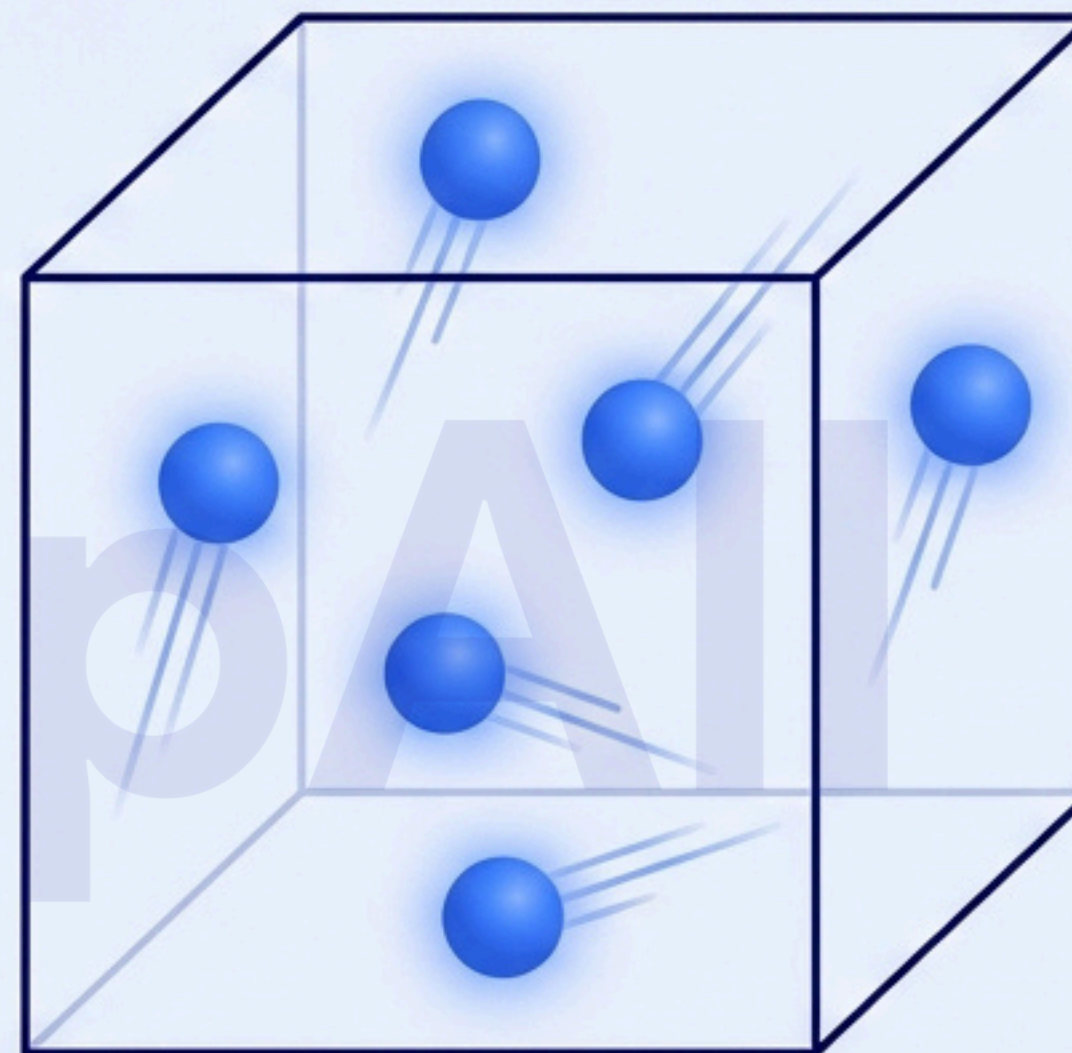


Pressure of an Ideal Gas

A Step-by-Step Derivation of the Kinetic Gas Equation

- Understanding the microscopic origins of pressure
- Momentum transfer in elastic collisions
- Deriving the master equation: $P = (1/3)nm\langle v^2 \rangle$

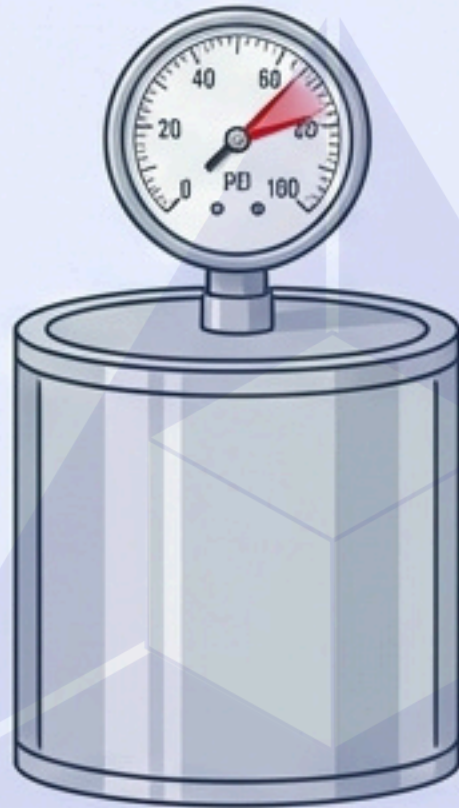
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Macroscopic Force from Microscopic Impacts

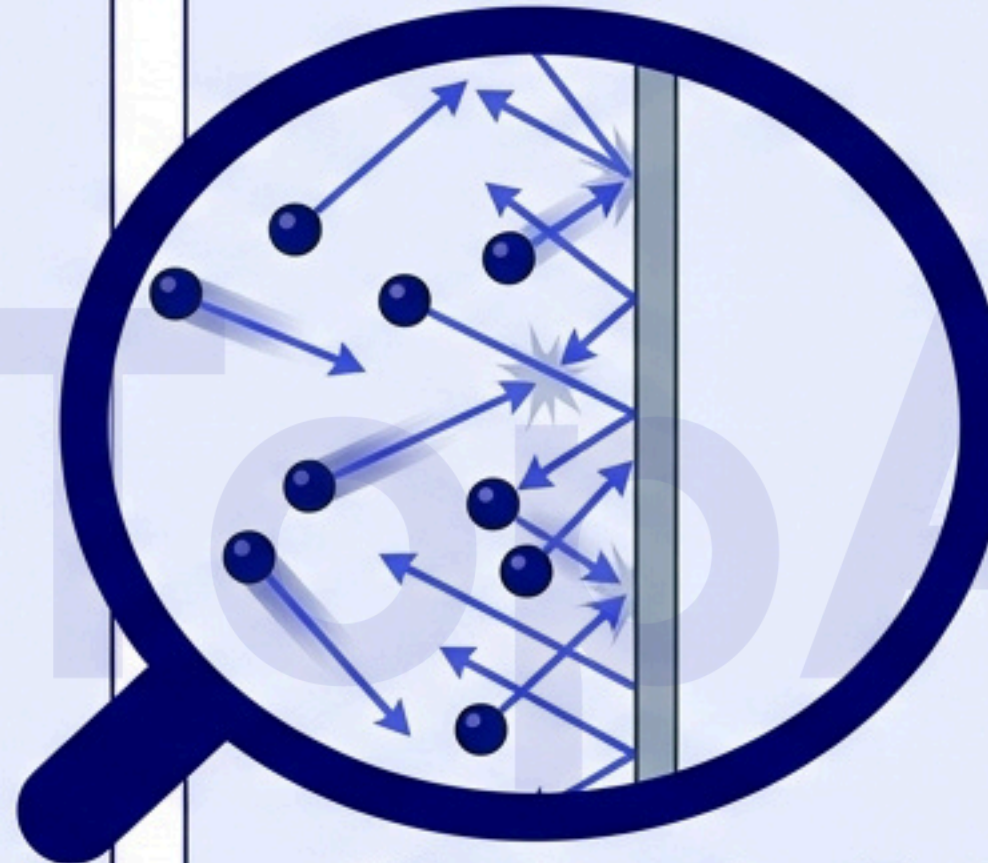
In a gas, molecules are in incessant, random motion, constantly bombarding the container walls.

UPPERCASE Plus Jakarta MACRO VIEW



- **No single big push:** Pressure isn't a continuous static force.

UPPERCASE Plus Jakarta MICRO VIEW



- **Billion tiny pushes:** It is the average macroscopic effect of countless.
 - **Perfectly Elastic:** Molecules bounce without losing kinetic energy.
- **Billion tiny pushes:** It is the average macroscopic effect of countless collisions.
 - **Perfectly Elastic:** Molecules bounce without losing kinetic energy.

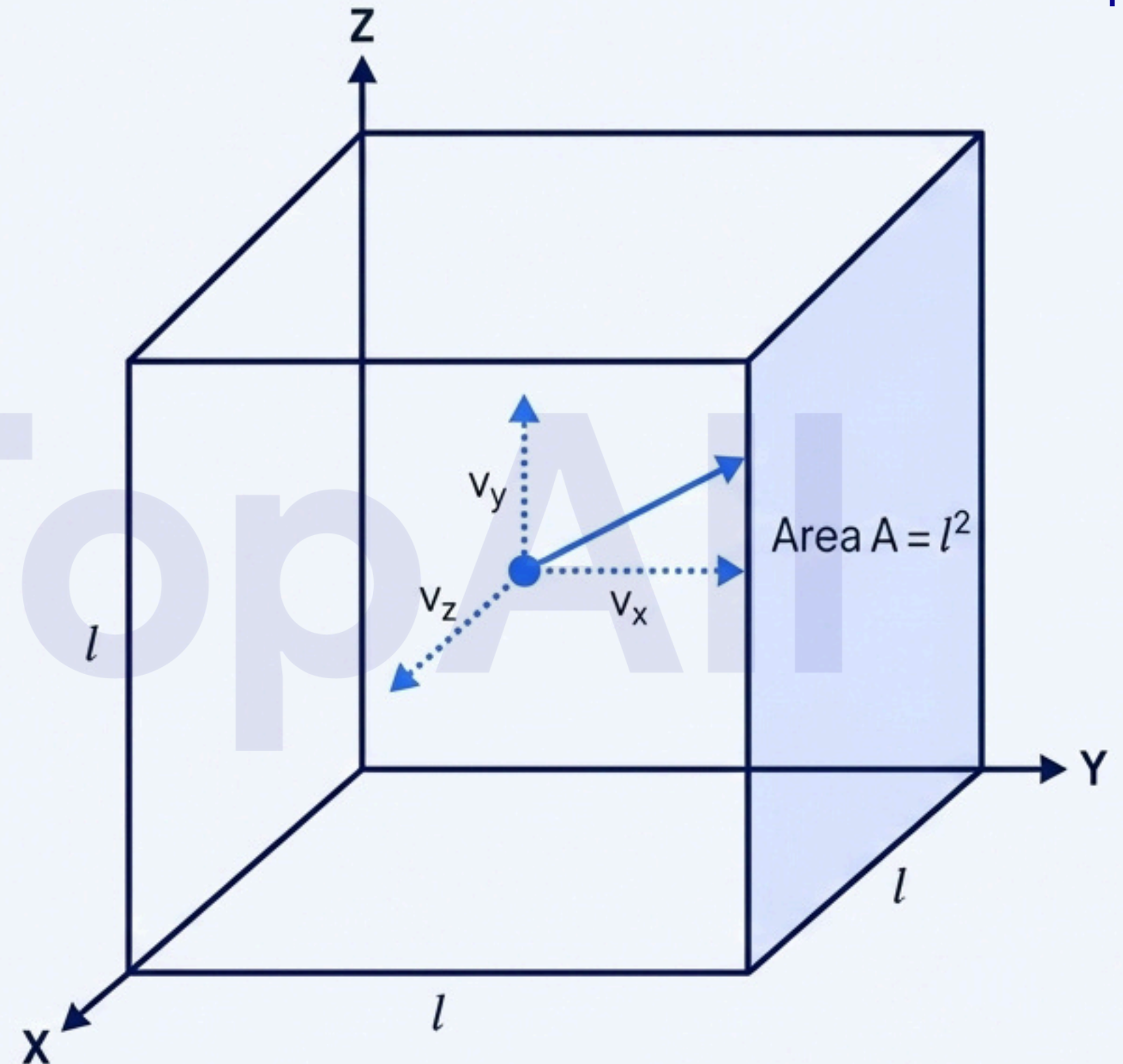
THE GOAL: How do we calculate the exact pressure exerted by these bouncing molecules?

Setting up the Geometry (Fig. 12.4)

Imagine an ideal gas enclosed in a cube. Let's isolate just one molecule moving toward the shaded wall.

- The molecule has a 3D velocity vector: (v_x, v_y, v_z) .
- It hits the shaded wall parallel to the yz -plane.
- Because the wall is flat along y and z , only the x -component (v_x) contributes to the impact force against this specific wall.

EXAM TIP: Always define your axes first!





You've Learned the Theory. Let's Test Them Now.

$$E=mc^2$$



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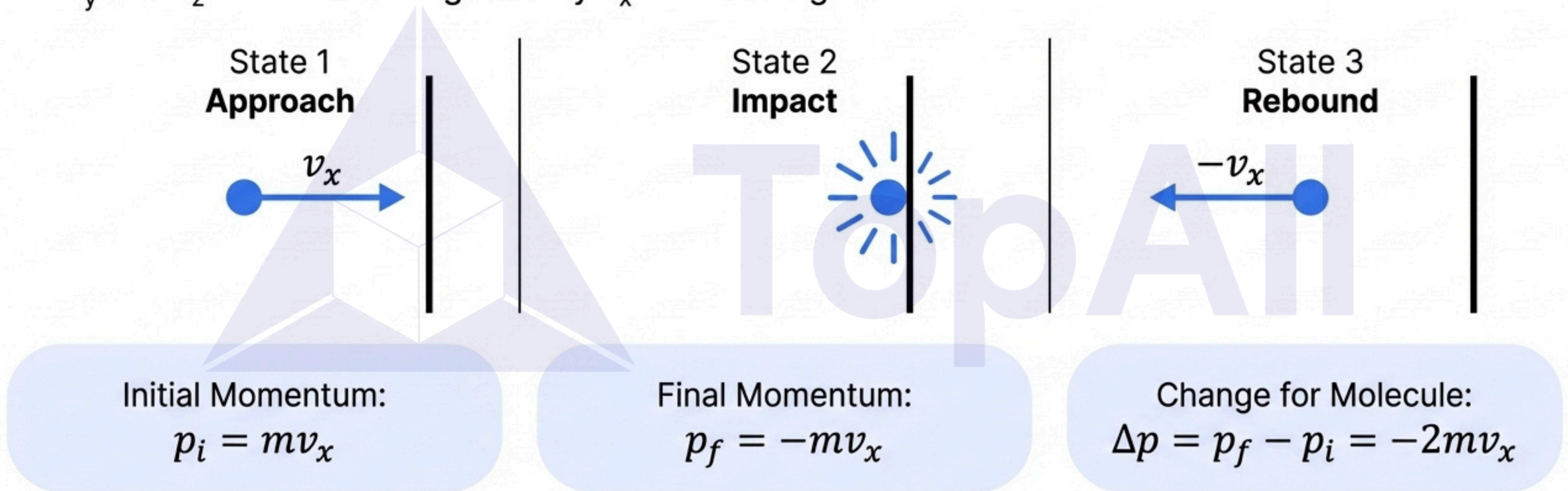
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Calculating Momentum Transfer

- Because the collision is elastic, the molecule rebounds with the exact same speed, but in the opposite direction.
- v_y and v_z remain unchanged. Only v_x reverses sign.

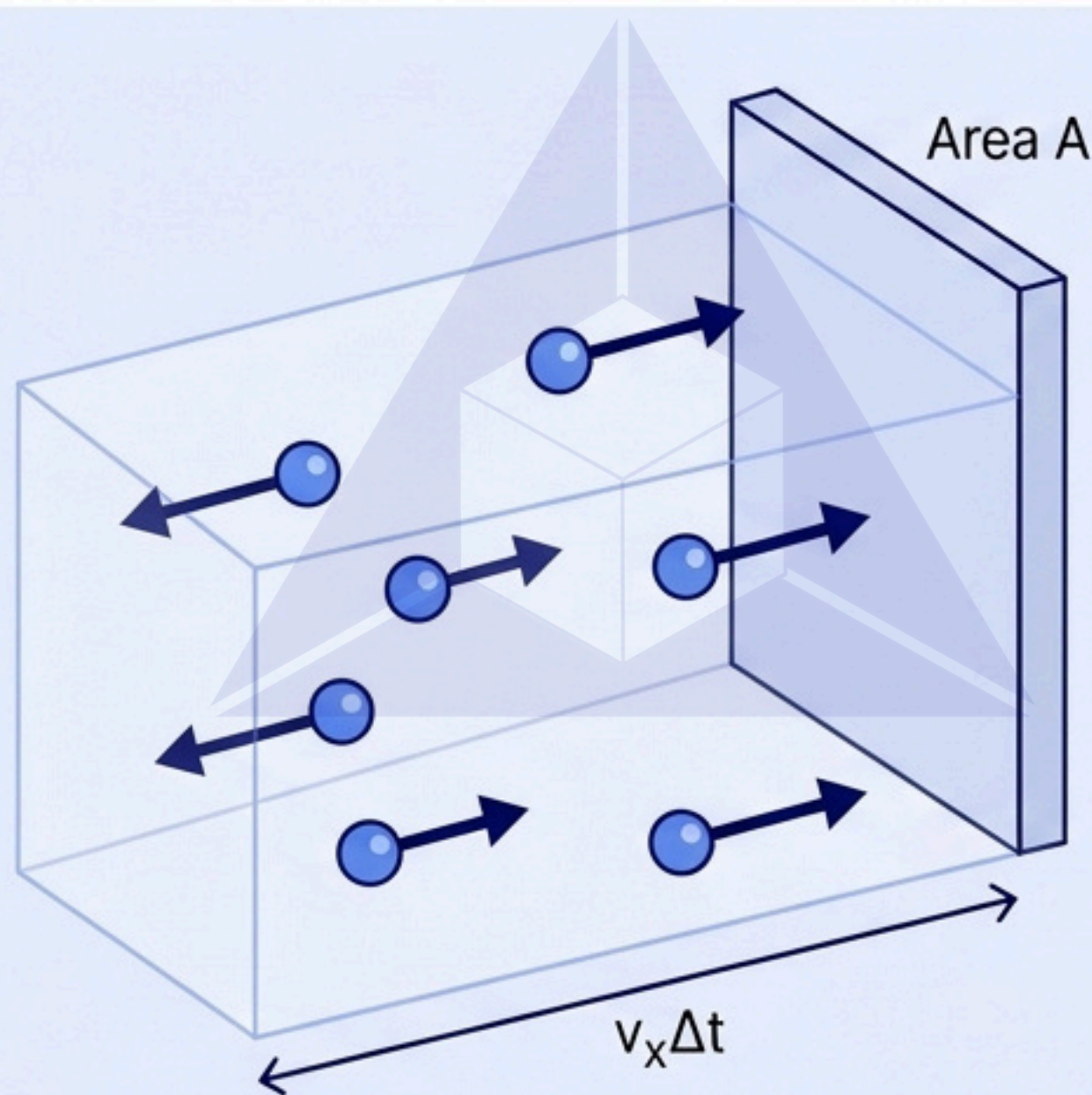


Highlight Box

→ By Newton's Third Law (conservation of momentum), the momentum imparted TO the wall is $+2mv_x$.

H1. From One Molecule to a Continuous Force

In a small time interval Δt , only molecules within a distance $v_x \Delta t$ can reach the wall. Let n be the number density (molecules per unit volume).


 Δp

 F

 P

1. Volume swept: $V = A \cdot v_x \Delta t$

2. Molecules inside: $n \cdot V$

3. Hitting the wall: Only $1/2$ are moving towards the wall.

Equation Build

Total Momentum (Q) = (Hits) $\times$ (Momentum per hit)

$$Q = \left(\frac{1}{2}\right) n A v_x \Delta t \times (2mv_x) = n m A v_x^2 \Delta t$$

[EQ. 12.11]

$$\text{Pressure (P)} = \frac{F}{A} = \frac{Q / \Delta t}{A} = n m v_x^2$$

3D Symmetry & The Final Equation

Because the gas is isotropic (random, no preferred direction), molecules behave identically across all three spatial axes.

X-Axis

$$\langle v_x^2 \rangle$$

Y-Axis

$$\langle v_y^2 \rangle$$

Z-Axis

$$\langle v_z^2 \rangle$$

By symmetry: $\langle v_x^2 \rangle = \langle v_y^2 \rangle = \langle v_z^2 \rangle$

Total mean squared speed: $\langle v^2 \rangle = \langle v_x^2 \rangle + \langle v_y^2 \rangle + \langle v_z^2 \rangle$

Therefore: $\langle v_x^2 \rangle = (1/3) \langle v^2 \rangle$

[EQ. 12.14]

$$P = \frac{1}{3} n m \langle v^2 \rangle$$

(Where n is number density, m is mass of one molecule, $\langle v^2 \rangle$ is mean squared speed)

Key Takeaways for Exams

- ✓ **Origin:** Pressure is the rate of momentum transfer from elastic collisions with container walls.
- ✓ **Single Impact:** One molecule transfers $2mv_x$ momentum to the wall.
- ✓ **Symmetry Rule:** Isotropic motion guarantees that $\langle v_x^2 \rangle = (1/3) \langle v^2 \rangle$.
- ✓ **Master Formula:** $P = (1/3) n m \langle v^2 \rangle$.



**Ready to test
your
knowledge?**

Now that you understand the microscopic origin of pressure, let's apply the math.

→ Try Chapter 12 MCQs Next



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