

FULL REVIEW

Full Review: Kinetic Theory of Gases — Calculus-Based

Review the essential ideas, relationships, and problem-solving tools for Kinetic Theory of Gases.

 TIME 45–60 minutes	 BEST FOR A complete topic review	 FINISH WITH A readiness check
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After this full review, you'll be able to...

After this review, you'll be able to derive pressure from molecular momentum flux, use Maxwell-Boltzmann statistics and moments, and connect equipartition to molecular and molar energy.

HOW TO USE THIS GUIDE

Work through the stages in order. Write directly in the spaces provided, check your work in the Solutions section, and finish by choosing the next resource that matches your confidence.

Choose how you want to review: work through this guide, follow the online review, or watch the video review.

[Start the Review Online →](#)

[Watch the Video Review →](#)

YOU WILL NEED

Pencil or pen • Calculator if needed • Approximately 45–60 minutes

FR-02 • COURSE ALIGNMENT

Course Alignment

This Physics Sensei Unit Review is an independent learning resource. Use it to reinforce key concepts, prepare for homework, or review before a quiz or exam.

RESOURCE: Physics Sensei Unit Review
UNIT ID: THM-U07
TOPIC: Kinetic Theory of Gases
COURSE LEVEL: Calculus-Based

BEST USED

- ✓ After learning the unit
- ✓ Before starting homework
- ✓ Before a quiz or exam

FR-03 • YOUR REVIEW PLAN

Your Review Plan

Complete these six stages in order. Each stage builds on the previous one and prepares you for the final readiness check.

6 stages • Approximately 45–60 minutes

1 Warm-Up Check Activate prior knowledge.	2 Core Concepts Review the essential ideas.	3 Guided Practice Apply what you learned.
4 Confidence Check Confirm your understanding.	5 Summary Review the key ideas.	6 Next Step Continue your learning.

PRINTING TIP

For student copies, print double-sided and keep the Solutions section after the student activities so learners attempt each activity before checking their work.

FR-04 • STAGE 1 OF 6

Warm-Up Check

Before you begin, take a moment to see what you already remember. Do not worry about getting everything right. This is only a starting point.

ACTIVITY 1**Momentum Transfer**

Write the impulse delivered to a wall by one elastic collision.

For normal velocity component v_x , the wall receives $\Delta p_x = 2mv_x$.

ACTIVITY 2**Statistical Moments**

Define the quantities used by kinetic theory.

Write $\text{rms speed} = \sqrt{\text{mean-square speed}}$ and identify $\langle v \rangle$ as the first speed moment.

FR-04 • WARM-UP CHECK CONTINUED

ACTIVITY 3

Distribution Scaling

Predict how the Maxwell distribution changes.

State what increasing T does to its peak location and width for a fixed molecular species.

Ready to strengthen your understanding?

You've refreshed what you already know. Next, reinforce the essential concepts that will help you solve problems with confidence.

Continue to Core Concepts →

FR-05 • STAGE 2 OF 6

Core Concepts

Let's rebuild the key ideas one step at a time. Focus on understanding the relationships before worrying about solving problems.

KEY CONCEPT 1

Momentum-Flux Derivation of Pressure

A molecule crossing a box of length L reaches the same wall every $2L/x$ -component of velocity, so its collision rate is x -component of velocity/ $(2L)$. Multiplying that rate by impulse $2mx$ -component of velocity and summing over molecules gives force. Dividing by wall area and applying isotropy yields the standard result.

$$P = (1/3)(N/V)m\langle v^2 \rangle$$

EXAMPLE The microscopic derivation shows directly why pressure depends on a second velocity moment.

SENSEI NOTE The derivation assumes equilibrium isotropy; a directed molecular beam would not justify the $1/3$ replacement.

KEY CONCEPT 2

Maxwell-Boltzmann Speed Distribution

For a classical ideal gas in equilibrium, the speed probability density is normalized on $v \geq 0$. Moments of this distribution yield mean and rms speeds, while differentiating it locates the most probable speed.

$$f(v) = 4\pi \left(\frac{m}{2\pi k_B T} \right)^{3/2} v^2 \exp(-mv^2/(2k_B T))$$

EXAMPLE The three characteristic speeds obey most probable speed < mean speed < rms speed and all scale as $\sqrt{(T/m)}$.

SENSEI NOTE $f(v)$ is a probability density in speed, so probabilities come from areas under the curve, not from $f(v)$ at one point.

FR-05 • CORE CONCEPTS CONTINUED

KEY CONCEPT 3

Equipartition and Translational Energy

Each quadratic translational degree of freedom contributes $(1/2)k_B T$ to the average molecular energy. Three translational dimensions therefore give average translational kinetic energy = $(3/2)k_B T$ and, for a monatomic ideal gas, $U = (3/2)nRT$.

$$K_{\text{avg}} = \frac{3}{2} k_B T$$

EXAMPLE Differentiating U with respect to T at fixed volume gives the monatomic molar heat capacity constant-volume heat capacity = $(3/2)R$.

SENSEI NOTE Additional rotational or vibrational quadratic degrees of freedom change the energy and heat-capacity result when they are active.

Ready to apply these ideas?

You've reinforced the essential concepts. Now put them into practice by working through guided examples and building your problem-solving confidence.

[Continue to Guided Practice](#) →

FR-06 • STAGE 3 OF 6

Guided Practice

Now it's time to apply what you've reviewed. Work through each activity in order. The examples become gradually more challenging, and each prepares you for the final readiness check.

PRACTICE 1**Derive Pressure**

Carry the single-particle collision argument to the ensemble result.

Starting with $\Delta p_x = 2mv_x$ and collision rate $v_x/(2L)$, derive P in terms of N/V and mean-square speed.

FR-06 • GUIDED PRACTICE CONTINUED

PRACTICE 2**Locate the Maxwell Peak**

Use calculus on the distribution.

For $f(v) \propto \text{speed squared} \exp[-\text{aspeed squared}]$, differentiate $\ln f$ and express the maximizing speed in terms of a , then substitute $a = m/(2\text{Boltzmann constant}T)$.

PRACTICE 3**Second Moment and RMS Speed**

Connect a distribution moment to the standard speed.

Using the Maxwell result mean-square speed = $3\text{Boltzmann constant}T/m$, obtain rms speed and compare it with most probable speed.

Ready to check your understanding?

You've practiced the essential skills with guidance. Now solve a few short problems on your own and confirm you're ready to move forward.

Continue to Confidence Check →

FR-07 • STAGE 4 OF 6

Confidence Check

You've rebuilt the key ideas and practiced them with guidance. Now try these short questions on your own to check your understanding before moving on.

QUICK CHECK 1

Normalization Meaning

Interpret an integral.

What does the integral of $f(v)$ from zero to infinity equal, and what does the integral from a to b represent?

QUICK CHECK 2

Pressure Moment

Identify the mathematical quantity.

Which moment of speed enters P , and what physical feature produces it?

FR-07 • CONFIDENCE CHECK CONTINUED

QUICK CHECK 3

Equipartition Result

Count quadratic degrees of freedom.

What average translational kinetic energy corresponds to three independent quadratic translational terms?

HOW DID IT GO?

I answered ____ of 3 questions correctly.

Use the Solutions section to check your reasoning, then take one final look at the essential ideas.

You've checked your understanding.

Take one final look at the essential ideas before deciding what to do next.

Continue to Summary →

FR-08 • STAGE 5 OF 6

Summary

Before moving on, take one final look at the most important ideas from this review.

KEY TAKEAWAY 1

Pressure measures molecular momentum flux

The wall-collision derivation produces a velocity second moment and the isotropic 1/3 factor.

KEY TAKEAWAY 2

Maxwell statistics defines characteristic speeds

The mode, mean, and rms come from different operations on the same normalized distribution.

KEY TAKEAWAY 3

Equipartition links temperature to energy

Three translational quadratic degrees give average translational kinetic energy = $(3/2)k_B T$ and $U = (3/2)nRT$ for a monatomic ideal gas.

MY ONE-SENTENCE SUMMARY

In my own words, the most important idea is:

Ready for your next step?

You've reviewed the essential ideas one last time. Now choose the resource that best matches how confident you feel.

Continue to Next Step →

ANSWER KEY • CHECK AFTER ATTEMPTING

Solutions and Explanations

Use these solutions to check your reasoning—not only your final answer. Replace each placeholder with a concise answer and the essential explanation.

WARM-UP • ACTIVITY 1

Recall Activity 1

The wall receives $+2m_x$ -component of velocity in an elastic reversal of the molecule's normal momentum.

WHY IT WORKS Tangential momentum is unchanged for an ideal specular wall collision.

WARM-UP • ACTIVITY 2

Recall Activity 2

rms speed = $\sqrt{\text{mean-square speed}}$; the mean speed is the first moment of a normalized speed density.

WHY IT WORKS Different moments summarize different features of the speed distribution.

WARM-UP • ACTIVITY 3

Recall Activity 3

Increasing T shifts the distribution toward higher speeds and broadens it.

WHY IT WORKS All characteristic speeds scale as $\sqrt{T}$ for fixed molecular mass.

SOLUTIONS • GUIDED PRACTICE

PRACTICE 1**Worked Example**

One molecule contributes average force $\langle m v_x^2 \rangle / L$; summing gives $F = (m/L) \sum \langle v_x^2 \rangle$. With $V = AL$, $P = F/A = (Nm/V) \langle v_x^2 \rangle$.
 $= (1/3)(N/V)m \langle v^2 \rangle$ = mean-square speed.

WHY IT WORKS The final equality uses isotropy of the equilibrium velocity components.

PRACTICE 2**Guided Problem**

In $f = 2 \ln v - a v^2 + \text{constant}$, so $2/v - 2av = 0$ and speed squared $= 1/a$. With $a = m/(2 \text{Boltzmann constant } T)$, most probable speed $= \sqrt{2 \text{Boltzmann constant } T/m}$.

WHY IT WORKS Log differentiation preserves the maximum while simplifying products and exponentials.

PRACTICE 3**Independent Problem**

rms speed $= \sqrt{\langle v^2 \rangle} = \sqrt{3 \text{Boltzmann constant } T/m}$, while most probable speed $= \sqrt{2 \text{Boltzmann constant } T/m}$, so rms speed divided by most probable speed $= \sqrt{3/2}$.

WHY IT WORKS The rms value exceeds the most probable speed because it weights the high-speed tail more strongly.

SOLUTIONS • CONFIDENCE CHECK

QUICK CHECK 1

Normalization Meaning

The integral from zero to infinity equals 1; the integral from a to b is the probability that a molecule's speed lies between a and b.

WHY IT WORKS A continuous probability density must be integrated over an interval to produce a probability.

QUICK CHECK 2

Pressure Moment

The second moment mean-square speed enters pressure.

WHY IT WORKS Impulse scales with velocity and collision rate also scales with velocity, producing the square before averaging.

QUICK CHECK 3

Equipartition Result

average translational kinetic energy = $3(1/2 \text{ Boltzmann constant}T) = (3/2)\text{Boltzmann constant}T$.

WHY IT WORKS Each independent quadratic translational degree contributes one-half Boltzmann constantT to the mean energy.

READINESS GUIDE

3 correct: You're ready to continue. • 2 correct: Review the missed idea, then continue. • 0–1 correct: Revisit Core Concepts or choose more practice.

FR-09 • STAGE 6 OF 6

Next Step: Continue Learning

Great work! You've completed this review. Choose the next resource that best matches how confident you feel.

 I'm Still Unsure Review the key ideas and examples again. Review Again →	 I Need More Practice Continue with additional practice for this topic. Go to Practice →	 I'm Ready Continue to the next recommended resource. Continue →
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RECOMMENDED LINKS

[Review this topic again →](#)[Find additional practice →](#)[Choose another type of physics help →](#)

Continue reviewing with these companion resources.

[Start the Review Online →](#)[Watch the Video Review →](#)

PHYSICS HELP THAT MAKES SENSE

A Physics Sensei review never ends at the last question. It always guides you toward the next useful step.

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