

FULL REVIEW

Full Review: Temperature and Thermal Equilibrium

Review the essential ideas, relationships, and problem-solving tools for Temperature and Thermal Equilibrium.

 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...

recall the essential ideas, apply them to representative problems, and determine what to study next.

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-U01
TOPIC: Temperature and Thermal Equilibrium
COURSE LEVEL: Calculus-Based University Physics

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**Recall Activity 1**

Recall absolute temperature, heat transfer, and equilibrium.

State the equilibrium conditions for two systems in thermal contact.

ACTIVITY 2**Recall Activity 2**

Identify local sensor sensitivity from $X(T)$.

For $X(T)$, explain the physical meanings of X , dX/dT , and d^2X/dT^2 .

FR-04 • WARM-UP CHECK CONTINUED

ACTIVITY 3

Recall Activity 3

Apply a differential approximation near an operating point.

At T_0 , $dX/dT=5$ units/K. Estimate ΔT for $\Delta X=1.5$ units.

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

Temperature and Thermal Equilibrium

Temperature is a thermodynamic state variable. A temperature difference establishes a direction for spontaneous heat transfer. At equilibrium, interacting systems share a common temperature and exhibit no net heat transfer.

At equilibrium: $T(A) = T(B)$; internally uniform T gives $\nabla T = 0$

EXAMPLE Two bodies that independently equilibrate with the same thermometer share the same value of the state variable T .

SENSEI NOTE Do not confuse zero temperature gradient with zero molecular motion.

KEY CONCEPT 2

Microscopic Meaning of Absolute Temperature

For a classical monatomic ideal gas, absolute temperature is proportional to average translational kinetic energy per particle. This relationship is a model-specific microscopic interpretation, not a universal formula for every material degree of freedom.

Average translational kinetic energy = $(3/2)kT$ for a classical monatomic ideal gas, where k is Boltzmann's constant

EXAMPLE Doubling absolute temperature doubles the model's average translational kinetic energy.

SENSEI NOTE Use kelvins in proportional relationships involving absolute temperature.

FR-05 • CORE CONCEPTS CONTINUED

KEY CONCEPT 3

Calibration, Derivatives, and Sensitivity

A thermometric property $X(T)$ must be calibrated. Its derivative dX/dT gives local sensitivity, while the second derivative indicates how sensitivity changes. A first-order differential approximation is reliable only over a sufficiently small interval.

$$dX \approx (dX/dT)dT; \quad dT \approx dX/(dX/dT)$$

EXAMPLE For $R(T)=R_0[1+\alpha(T-T_0)]$, $dR/dT=R_0\alpha$.

SENSEI NOTE For nonlinear sensors, evaluate sensitivity at the operating point and check that the change is small.

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**Worked Example**

Connect absolute temperature to a microscopic model.

For a classical monatomic ideal gas, find the ratio of average translational kinetic energies at 600 K and 300 K.

FR-06 • GUIDED PRACTICE CONTINUED

PRACTICE 2

Guided Problem

Differentiate a nonlinear thermometer response.

A sensor obeys $X(T)=2T+0.010T^2$, with X in units and T in kelvins. Find dX/dT at 300 K and estimate ΔX for $\Delta T=0.50$ K.

PRACTICE 3

Independent Problem

Propagate a small measurement uncertainty through sensitivity.

Near 290 K, $dR/dT=0.40 \Omega/\text{K}$ and the resistance uncertainty is $\pm 0.06 \Omega$. Estimate the temperature uncertainty.

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

Uniform Equilibrium

Interpret the spatial derivative.

What is ∇T inside an object whose equilibrium temperature is uniform?

QUICK CHECK 2

Kinetic-Energy Ratio

Use absolute temperature.

In the ideal-gas model, what is the ratio of average translational kinetic energies at 450 K and 300 K?

FR-07 • CONFIDENCE CHECK CONTINUED

QUICK CHECK 3

Local Linearization

Differentiate before estimating.

For $X(T)=aT+bT^2$, estimate ΔT from a small measured ΔX near T_0 .

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**Temperature Is a State Variable**

Thermal equilibrium requires a common temperature and no net heat transfer between interacting systems.

KEY TAKEAWAY 2**Absolute Temperature Supports Microscopic Ratios**

Kelvin temperature enters proportional microscopic relations because it is an absolute scale.

KEY TAKEAWAY 3**Sensitivity Is Local**

A derivative-based thermometer conversion is a local approximation evaluated at the operating point.

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.

WARM-UP • ACTIVITY 1

Recall Activity 1

At equilibrium, $T(A)=T(B)$ and there is no net heat transfer; uniform internal temperature gives $\nabla T=0$.

WHY IT WORKS Equal temperature and zero gradient remove the imbalance that drives net transfer.

WARM-UP • ACTIVITY 2

Recall Activity 2

X is the sensor property; dX/dT is sensitivity; d^2X/dT^2 describes how sensitivity changes with temperature.

WHY IT WORKS The first derivative measures slope; the second measures curvature of the calibration curve.

WARM-UP • ACTIVITY 3

Recall Activity 3

$\Delta T \approx 1.5/5 = 0.30 \text{ K}$.

WHY IT WORKS The local inverse sensitivity converts the small property change into temperature change.

SOLUTIONS • GUIDED PRACTICE

PRACTICE 1

Worked Example

The kinetic-energy ratio is $600/300=2$.

WHY IT WORKS Average translational kinetic energy is proportional to absolute temperature in this model.

PRACTICE 2

Guided Problem

$dX/dT=2+0.020T$, so at 300 K the sensitivity is 8 units/K; $\Delta X \approx 8(0.50)=4$ units.

WHY IT WORKS Differentiation supplies the local slope used by the tangent-line approximation.

PRACTICE 3

Independent Problem

The temperature uncertainty is approximately $\pm 0.06/0.40=\pm 0.15$ K.

WHY IT WORKS First-order uncertainty propagation divides the measurement uncertainty by sensitivity.

SOLUTIONS • CONFIDENCE CHECK

QUICK CHECK 1

Uniform Equilibrium

$\nabla T = 0$ because the equilibrium temperature is spatially constant.

WHY IT WORKS The gradient of a constant scalar field is zero.

QUICK CHECK 2

Kinetic-Energy Ratio

The ratio is $450/300 = 1.5$.

WHY IT WORKS The model gives a direct ratio of absolute temperatures.

QUICK CHECK 3

Local Linearization

dX/dT at T_0 is $a + 2bT_0$, so $\Delta T \approx \Delta X / (a + 2bT_0)$.

WHY IT WORKS Differentiate the calibration function and invert the local linear relationship.

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.

[PhysicsSensei.com](https://www.physicssensei.com)