

## FULL REVIEW

# Full Review: Entropy and the Second Law — Foundational

Review the essential ideas, relationships, and problem-solving tools for entropy and the second law.

|                                                                                                                   |                                                                                                                                 |                                                                                                                                |
|-------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------|
| <br><b>TIME</b><br>45–60 minutes | <br><b>BEST FOR</b><br>A complete topic review | <br><b>FINISH WITH</b><br>A readiness check |
|-------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------|

**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-U11  
**TOPIC:** Entropy and the Second Law  
**COURSE LEVEL:** Foundational

**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

|                                                                    |                                                                 |                                                               |
|--------------------------------------------------------------------|-----------------------------------------------------------------|---------------------------------------------------------------|
| <b>1</b><br><b>Warm-Up Check</b><br>Activate prior knowledge.      | <b>2</b><br><b>Core Concepts</b><br>Review the essential ideas. | <b>3</b><br><b>Guided Practice</b><br>Apply what you learned. |
| <b>4</b><br><b>Confidence Check</b><br>Confirm your understanding. | <b>5</b><br><b>Summary</b><br>Review the key ideas.             | <b>6</b><br><b>Next Step</b><br>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**

State in words what entropy tells you about the number of microscopic arrangements available to a system.

*Write the key relationship and explain its physical meaning.*

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**ACTIVITY 2****Recall Activity 2**

For an isolated system, decide whether total entropy can decrease, stay constant, or increase.

*Write the key relationship and explain its physical meaning.*

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## FR-04 • WARM-UP CHECK CONTINUED

## ACTIVITY 3

**Recall Activity 3**

A hot object touches a cold object. Predict the spontaneous direction of heat transfer and the sign of the total entropy change.

*Write the key relationship and explain its physical meaning.*

**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****Entropy and multiplicity**

Entropy measures how many microscopic arrangements are compatible with the same macroscopic state. More accessible arrangements correspond to greater entropy.

$$S = k_B \ln \Omega$$

A gas spreading through a larger available volume has more possible molecular arrangements. Entropy is not simply "disorder"; focus on accessible microstates and energy dispersal.

**KEY CONCEPT 2****Second Law of Thermodynamics**

For an isolated system, spontaneous processes do not reduce total entropy. Reversible idealizations keep total entropy unchanged; irreversible processes increase it.

$$\Delta S_{\text{total}} \geq 0$$

Heat flowing naturally from hot to cold increases the total entropy of the combined system and surroundings. A local entropy decrease is allowed when the surroundings gain enough entropy that the total does not decrease.

## FR-05 • CORE CONCEPTS CONTINUED

## KEY CONCEPT 3

**Reversible and irreversible processes**

A reversible process is an ideal limit that can be undone with no net change to system plus surroundings. Real spontaneous processes are irreversible and generate entropy.

$$\Delta S_{\text{universe}} = \Delta S_{\text{system}} + \Delta S_{\text{surroundings}} \geq 0$$

Friction, free expansion, and heat transfer across a finite temperature difference are irreversible.

“Reversible” means more than merely being able to run a device backward.

**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**

Solve the problem and justify the entropy relation used.

*Classify each process as reversible idealization or irreversible: slow frictionless compression; free expansion; heat transfer through a finite temperature difference.*

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## FR-06 • GUIDED PRACTICE CONTINUED

## PRACTICE 2

**Guided Problem**

Solve the problem and justify the entropy relation used.

*Two bodies at different temperatures are placed in thermal contact in an insulated enclosure. Explain why equilibrium is the spontaneous final state using entropy.*

## PRACTICE 3

**Independent Problem**

Solve the problem and justify the entropy relation used.

*A refrigerator decreases the entropy of its cold interior. Explain why this does not violate the second law.*

**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****Entropy Check**

Solve or explain briefly.

*Can an isolated system spontaneously move to a state with lower total entropy? Explain.*

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**QUICK CHECK 2****Entropy Check**

Solve or explain briefly.

*A process returns a system to its initial state but leaves the surroundings changed. Is that enough to call the process reversible?*

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## FR-07 • CONFIDENCE CHECK CONTINUED

## QUICK CHECK 3

**Entropy Check**

Solve or explain briefly.

*Name one common irreversible process and identify what makes it irreversible.*

## 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****Entropy and accessible states**

Entropy measures how many microscopic arrangements are compatible with the same macroscopic state.

**KEY TAKEAWAY 2****Second-law direction**

For an isolated system, spontaneous processes do not reduce total entropy.

**KEY TAKEAWAY 3****Local vs total entropy**

A reversible process is an ideal limit that can be undone with no net change to system plus surroundings.

**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**

Entropy reflects the number of accessible microscopic arrangements; larger multiplicity means larger entropy.

This is the governing entropy principle for the activity.

**WARM-UP • ACTIVITY 2****Recall Activity 2**

Total entropy of an isolated system cannot decrease. It is unchanged only in the reversible ideal limit and increases for irreversible processes.

This is the governing entropy principle for the activity.

**WARM-UP • ACTIVITY 3****Recall Activity 3**

Heat flows from hot to cold. The hot object loses entropy, the cold object gains entropy, and the total entropy increases until equilibrium.

This is the governing entropy principle for the activity.

## SOLUTIONS • GUIDED PRACTICE

**PRACTICE 1****Worked Example**

Slow frictionless compression can approach reversible behavior; free expansion and finite-temperature-difference heat transfer are irreversible.

Verify the integral/sign convention and interpret the result physically.

**PRACTICE 2****Guided Problem**

The two-body system evolves toward thermal equilibrium because that macrostate has greater total entropy; once equilibrium is reached there is no spontaneous net heat flow.

Verify the integral/sign convention and interpret the result physically.

**PRACTICE 3****Independent Problem**

The refrigerator exports entropy to the surroundings while consuming work. The total entropy change of refrigerator plus surroundings is nonnegative.

Verify the integral/sign convention and interpret the result physically.

## SOLUTIONS • CONFIDENCE CHECK

## QUICK CHECK 1

**Entropy Check**

Slow frictionless compression can approach reversible behavior; free expansion and finite-temperature-difference heat transfer are irreversible.

A correct result must also satisfy the second-law entropy balance.

## QUICK CHECK 2

**Entropy Check**

The two-body system evolves toward thermal equilibrium because that macrostate has greater total entropy; once equilibrium is reached there is no spontaneous net heat flow.

A correct result must also satisfy the second-law entropy balance.

## QUICK CHECK 3

**Entropy Check**

The refrigerator exports entropy to the surroundings while consuming work. The total entropy change of refrigerator plus surroundings is nonnegative.

A correct result must also satisfy the second-law entropy balance.

## 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.

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|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <br><b>I'm Still Unsure</b><br>Review the key ideas and examples again.<br><a href="#">Review Again →</a> | <br><b>I Need More Practice</b><br>Continue with additional practice for this topic.<br><a href="#">Go to Practice →</a> | <br><b>I'm Ready</b><br>Continue to the next recommended resource.<br><a href="#">Continue →</a> |
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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**