

FULL REVIEW

Full Review: First Law of Thermodynamics — Calculus-Based

Review the essential ideas, relationships, and problem-solving tools for First Law of Thermodynamics.

 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-U08
TOPIC: First Law of Thermodynamics
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**Recall Activity 1**

Differential form

Write the first law for an infinitesimal change using the work-by-system convention.

ACTIVITY 2**Recall Activity 2**

Boundary work

Write the quasistatic pressure-volume work element.

FR-04 • WARM-UP CHECK CONTINUED

ACTIVITY 3

Recall Activity 3

Path integral

Write the work for a quasistatic process from initial volume to final volume.

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

First Law and Exact Differentials

For the work-by-system convention, $dU = \delta Q - \delta W$ and over a finite process $\Delta U = Q - W$. Because U is a state function, dU is exact; heat and work are process-dependent and are commonly written with inexact differentials.

$$dU = \delta Q - \delta W \quad \text{and} \quad \Delta U = Q - W$$

EXAMPLE For a complete cycle, $\Delta U = 0$, so net Q equals net W .

SENSEI NOTE Keep the sign convention fixed throughout a derivation.

KEY CONCEPT 2

Path Dependence and State Functions

Between fixed equilibrium states, ΔU is unique. Q and W may change with the path while their difference remains ΔU . This is central to interpreting P-V diagrams and thermodynamic cycles.

$$\Delta U = \int dU = U_2 - U_1$$

EXAMPLE Different paths between the same endpoints can enclose different areas and therefore produce different work.

SENSEI NOTE Endpoint data alone determine ΔU but generally not Q or W separately.

FR-05 • CORE CONCEPTS CONTINUED

KEY CONCEPT 3

Quasistatic PV Work

For simple compressible work, $\delta W = \text{external pressure } dV$; in a quasistatic process external pressure is effectively the boundary pressure and $W = \int P dV$. Constant pressure reduces to $W = P(\text{final volume} - \text{initial volume})$.

$$\delta W = P dV \quad \text{and} \quad W = \int P dV$$

EXAMPLE If $P(V) = a/V$, then $W = a \ln(\text{final volume}/\text{initial volume})$.

SENSEI NOTE Use consistent SI units so pressure-volume integrals return joules.

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**

A system absorbs 1.60 kJ and performs 0.55 kJ of work. Find ΔU .

Apply the finite first-law balance.

FR-06 • GUIDED PRACTICE CONTINUED

PRACTICE 2

Guided Problem

A quasistatic expansion follows $P(V) = a/V$ with $a = 500 \text{ J}$ from initial volume = 2.0 L to final volume = 5.0 L. Find W .

Integrate $W = \int (a/V) dV = a \ln(\text{final volume}/\text{initial volume})$.

PRACTICE 3

Independent Problem

For the expansion above, $\Delta U = 120 \text{ J}$. Find Q .

Use $Q = \Delta U + W$ after evaluating the path work.

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

Cycle relation

Solve using the first law and the stated sign convention.

For a complete cycle, what relation connects net heat and net work?

QUICK CHECK 2

Integral work

Solve using the first law and the stated sign convention.

For constant $P = 3.0 \times 10^5 \text{ Pa}$ and $\Delta V = 1.5 \times 10^{-3} \text{ m}^3$, evaluate $\int P \, dV$.

FR-07 • CONFIDENCE CHECK CONTINUED

QUICK CHECK 3

Solve for heat

Solve using the first law and the stated sign convention.

A path has $W = 620 \text{ J}$ and $\Delta U = -140 \text{ J}$. Find Q .

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

Differential first law

$dU = \delta Q - \delta W$; over a finite process, $\Delta U = Q - W$.

KEY TAKEAWAY 2

Path dependence

U is a state function; heat and work depend on the path.

KEY TAKEAWAY 3

PV integral

For quasistatic work, $W = \int P dV$, with constant pressure as a special case.

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

$$dU = \delta Q - \delta W.$$

WHY IT WORKS U is a state function, while heat and work are path-dependent transfers.

WARM-UP • ACTIVITY 2

Recall Activity 2

$$\delta W = P dV.$$

WHY IT WORKS Positive dV gives positive work by the system.

WARM-UP • ACTIVITY 3

Recall Activity 3

$$W = \int P dV \text{ from initial volume to final volume.}$$

WHY IT WORKS The value depends on the path $P(V)$, not only the endpoints.

SOLUTIONS • GUIDED PRACTICE

PRACTICE 1**Worked Example**

$$\Delta U = 1.60 \text{ kJ} - 0.55 \text{ kJ} = 1.05 \text{ kJ}.$$

WHY IT WORKS This is the integral form of $dU = \delta Q - \delta W$.

PRACTICE 2**Guided Problem**

$$W = 500 \ln(5/2) \approx 458 \text{ J}.$$

WHY IT WORKS The logarithm uses a dimensionless volume ratio.

PRACTICE 3**Independent Problem**

$$Q \approx 120 \text{ J} + 458 \text{ J} = 578 \text{ J}.$$

WHY IT WORKS Path work plus the state-function change determines the required heat transfer.

SOLUTIONS • CONFIDENCE CHECK

QUICK CHECK 1

Cycle relation

net $Q = \text{net } W$.

WHY IT WORKS Because ΔU for the cycle = 0.

QUICK CHECK 2

Integral work

$W = 450 \text{ J}$.

WHY IT WORKS Constant P factors out of the integral.

QUICK CHECK 3

Solve for heat

$Q = 480 \text{ J}$.

WHY IT WORKS $Q = \Delta U + W = -140 + 620$.

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