

## QUICK REVIEW

# Quick Review: Heat Engines, Refrigerators, and Heat Pumps — Calculus-Based

Review how heat engines produce work and how refrigerators and heat pumps move heat in a cycle.

|                                                                                                                  |                                                                                                                         |                                                                                                                                  |
|------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------|
| <br><b>TIME</b><br>5–10 minutes | <br><b>BEST FOR</b><br>A rapid refresh | <br><b>FINISH WITH</b><br>Key ideas refreshed |
|------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------|

**After this quick review, you'll be able to...**

quickly recall the essential concepts, formulas, and problem-solving strategies needed to move forward with confidence.

**HOW TO USE THIS GUIDE**

Work through the four stages in order. Write directly in the spaces provided, check your work in the Quick Answers 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 5–10 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.

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| <b>RESOURCE:</b> Physics Sensei Unit Review<br><b>UNIT ID:</b> THM-U10<br><b>TOPIC:</b> Heat Engines, Refrigerators, and Heat Pumps<br><b>COURSE LEVEL:</b> Calculus-Based | <b>BEST USED</b> <ul style="list-style-type: none"><li>✓ After learning the unit</li><li>✓ Before starting homework</li><li>✓ Before a quiz or exam</li></ul> |
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*Replace every double-brace placeholder, update all topic-specific links, and test every hyperlink before publishing. This includes the online review, video review, practice bundle, next recommended resource, and additional-help links.*

## FR-03 • YOUR REVIEW PLAN

# Your Review Plan

Complete these four stages to quickly refresh the essential ideas and confirm you're ready to continue.

4 stages • Approximately 5–10 minutes

|                                                                         |                                                                         |
|-------------------------------------------------------------------------|-------------------------------------------------------------------------|
| <b>1</b><br><b>Quick Recall</b><br>Refresh what you already know.       | <b>2</b><br><b>Essential Idea</b><br>Review the most important concept. |
| <b>3</b><br><b>Confidence Check</b><br>Confirm you're ready to move on. | <b>4</b><br><b>Next Step</b><br>Continue your learning.                 |

**PRINTING TIP**

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

FR-04 • STAGE 1 OF 4

## Quick Recall

Let's quickly refresh what you already know. This short recall activity will bring the most important ideas back to mind before you review them.

### QUICK RECALL

#### Recall Activity

Name the three energy flows in a heat engine, refrigerator, and heat pump.

*For each device, draw arrows for heat entering, heat leaving, and work; circle the useful output.*

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### Ready to refresh the essentials?

Great! Now review the most important idea you'll want to remember.

[Review the Essential Idea →](#)

## FR-05 • STAGE 2 OF 4

## Essential Idea

Take one last look at the most important concept from this topic. If you remember this idea, the rest will come back much more easily.

### ESSENTIAL IDEA

#### One cycle, three useful outputs

For a cyclic engine,  $\Delta U = 0$ , so  $W_{\text{net}} = Q_H - Q_C$  with  $Q_H$  and  $Q_C$  positive magnitudes. The enclosed area on a  $P$ - $V$  diagram is  $\oint P \, dV$ ; clockwise traversal gives positive net work by the gas. For a reversed cycle,  $W_{\text{in}} = Q_H - Q_C$ . Refrigeration performance is  $\text{COP}_R = Q_C/W_{\text{in}}$ ; heating performance is  $\text{COP}_{\text{HP}} = Q_H/W_{\text{in}} = \text{COP}_R + 1$ . These relations are energy balances, not ideal-cycle assumptions. The reversible upper bound between thermal reservoirs is  $\eta_{\text{Carnot}} = 1 - T_C/T_H$  and  $\text{COP}_{R,\text{Carnot}} = T_C/(T_H - T_C)$ , with absolute temperatures. No cyclic device can exceed its corresponding reversible bound.

$$Q_H = Q_C + W_{\text{in}} \text{ (reversed cycle); } Q_H = Q_C + W_{\text{out}} \text{ (engine, with opposite work direction)}$$

**EXAMPLE** A refrigerator removes 300 J from a cold compartment using 100 J of work. It delivers 400 J to the room;  $\text{COP}_R = 300/100 = 3$  and  $\text{COP}_{\text{HP}} = 400/100 = 4$ .

**SENSEI NOTE** Do not call a COP above 1 an efficiency above 100%; the device moves heat.

### Ready to check your memory?

You've refreshed the essential idea. Now see how much you remember before moving on.

[Start the Confidence Check →](#)

FR-06 • STAGE 3 OF 4

## Confidence Check

You've refreshed the essential idea. Now answer this quick confidence check to confirm you're ready to move on.

### CONFIDENCE CHECK

#### Track all three energy flows

Use the energy balance before a performance ratio.

*A refrigerator removes 300 J from a cold space using 100 J of work. How much heat reaches the room, and what are its cooling and heating COP values?*

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### Ready for your next step?

Great work! You've refreshed the essential idea. Now choose the resource that best matches what you'd like to do next.

[Choose Your Next Step →](#)

## QUICK ANSWERS • CHECK AFTER ATTEMPTING

## Quick Answers and Explanations

Use these concise answers to check your recall and confidence—not only your final response.

## QUICK RECALL

### Recall Activity

Engine:  $Q_H = W_{\text{out}} + Q_C$ . Refrigerator/heat pump:  $Q_H = Q_C + W_{\text{in}}$ . The useful quantity changes with the job.

WHY IT WORKS Each device obeys conservation of energy; identify whether work leaves or enters.

## CONFIDENCE CHECK

## CONFIDENCE CHECK

### Track all three energy flows

A refrigerator removes 300 J from a cold compartment using 100 J of work. It delivers 400 J to the room;  $\text{COP}_R = 300/100 = 3$  and  $\text{COP}_{HP} = 400/100 = 4$ .

WHY IT WORKS The room receives both the removed heat and the electrical work. Cooling and heating divide different useful heat transfers by the same work input.

## READINESS GUIDE

1 correct: You're ready to continue. • 0 correct: Revisit the Essential Idea or choose more practice.

FR-07 • STAGE 4 OF 4

## Next Step: Continue Learning

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

|                                                                                                                       |                                                                                                                                              |                                                                                                                      |
|-----------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------|
| <p>?</p> <p><b>I'm Still Unsure</b></p> <p>Review the essential idea again.</p> <p><a href="#">Review Again →</a></p> | <p>🎯</p> <p><b>I Need More Practice</b></p> <p>Continue with additional practice for this topic.</p> <p><a href="#">Go to Practice →</a></p> | <p>✓</p> <p><b>I'm Ready</b></p> <p>Continue to the next recommended resource.</p> <p><a href="#">Continue →</a></p> |
|-----------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------|

### 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)