

## FOCUSED REVIEW

# Focused Review: Heat Engines, Refrigerators, and Heat Pumps — Algebra-Based

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

|                                                                                                                   |                                                                                                                        |                                                                                                                                 |
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| <br><b>TIME</b><br>15–20 minutes | <br><b>BEST FOR</b><br>Focused review | <br><b>FINISH WITH</b><br>Greater confidence |
|-------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------|

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

recognize the key concepts, reinforce your problem-solving skills, and continue with greater confidence.

**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 15–20 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-U10  
**TOPIC:** Heat Engines, Refrigerators, and Heat Pumps  
**COURSE LEVEL:** Algebra-Based

**BEST USED**

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

*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 six focused stages in order. Each stage reinforces your understanding and prepares you for a final confidence check.

6 stages • Approximately 15–20 minutes

|                                                                    |                                                               |                                                              |
|--------------------------------------------------------------------|---------------------------------------------------------------|--------------------------------------------------------------|
| <b>1</b><br><b>Warm-Up Check</b><br>Refresh key ideas.             | <b>2</b><br><b>Core Concepts</b><br>Reinforce the essentials. | <b>3</b><br><b>Guided Practice</b><br>Strengthen key skills. |
| <b>4</b><br><b>Confidence Check</b><br>Confirm your understanding. | <b>5</b><br><b>Summary</b><br>Remember the essentials.        | <b>6</b><br><b>Next Step</b><br>Choose your next step.       |

**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 minute to reactivate what you already know. This quick warm-up will help you focus on the most important ideas before moving on.

**WARM-UP 1****Key Ideas**

Identify hot-source heat, rejected heat, and work for an engine.

*Draw three arrows and label the 800 J heat input, 600 J heat rejection, and unknown work output.*

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**WARM-UP 2****Common Mistakes**

Distinguish the useful output of a refrigerator from that of a heat pump.

*In the same reversed cycle, which heat flow is useful for cooling, and which for heating?*

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## FR-04 • WARM-UP CHECK CONTINUED

## WARM-UP 3

**Quick Application**

Apply the energy balance to a short cycle.

*An engine absorbs 800 J and rejects 600 J. Find its work output and efficiency.*

**Ready to strengthen your understanding?**

You've refreshed the most important ideas. Now reinforce the concepts you'll use most often.

[Continue to Core Concepts →](#)

## FR-05 • STAGE 2 OF 6

# Core Concepts

Let's reinforce the most important concepts you'll need to solve problems with confidence. Focus on the ideas that appear most often in homework, quizzes, and exams.

## KEY CONCEPT 1

### Heat engine energy balance

Using positive heat-transfer magnitudes, a cyclic heat engine satisfies  $Q_H = W_{\text{out}} + Q_C$  and  $\eta = W_{\text{out}}/Q_H = 1 - Q_C/Q_H$ . The heat rejected to the cold reservoir is part of the energy balance.

$$Q_H = W_{\text{out}} + Q_C; \eta = W_{\text{out}}/Q_H$$

**EXAMPLE** A device receives 800 J from a hot source and rejects 600 J. Its work output is 200 J and efficiency is  $200/800 = 0.25$ , or 25%.

**SENSEI NOTE** Rejected heat cannot be omitted; it accounts for energy that does not become work.

## KEY CONCEPT 2

### Refrigerators and heat pumps

A refrigerator or heat pump requires work input:  $Q_H = Q_C + W_{\text{in}}$ .  $\text{COP}_R = Q_C/W_{\text{in}}$  measures cooling;  $\text{COP}_{\text{HP}} = Q_H/W_{\text{in}}$  measures heating. Consequently  $\text{COP}_{\text{HP}} = \text{COP}_R + 1$  for the same device. For reservoirs at  $T_H$  and  $T_C$  in kelvin, an ideal reversible limit is  $\eta_{\text{Carnot}} = 1 - T_C/T_H$ . An actual engine has lower efficiency. A coefficient of performance may exceed 1 because heat is moved as well as supplied by work.

$$Q_H = Q_C + W_{\text{in}}; \text{COP}_R = Q_C/W_{\text{in}}; \text{COP}_{\text{HP}} = Q_H/W_{\text{in}}$$

**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** Cooling COP uses removed heat; heating COP uses delivered heat.

## Ready to apply these ideas?

You've reinforced the essential concepts. Now strengthen your problem-solving skills by working through a few guided examples.

[Continue to Guided Practice →](#)

## FR-06 • STAGE 3 OF 6

## Guided Practice

Now apply the key concepts you've just reviewed. Work through these focused practice activities to reinforce your problem-solving skills before the final confidence check.

**PRACTICE 1****Guided Example**

Identify the useful transfer and calculate its ratio to the input.

For 800 J absorbed and 600 J rejected,  $W_{\text{out}} = 200 \text{ J}$ ;  $\eta = 0.25$ . Sketch the heat and work arrows before dividing.

**PRACTICE 2****Independent Check**

Solve a reversed-cycle energy balance.

*A heat pump delivers 1,200 J indoors using 300 J of work. Find outdoor heat drawn and the heating COP.*

**Ready for a confidence check?**

You've reinforced the essential skills through focused practice. Now confirm your understanding with two short questions.

[Continue to Confidence Check →](#)

FR-07 • STAGE 4 OF 6

## Confidence Check

You've reinforced the key concepts and practiced the essential skills. Now confirm you're ready to move forward by completing these short confidence checks.

### CONFIDENCE CHECK 1

#### Engine efficiency

Show the energy balance and ratio.

*An engine receives 1,000 J and rejects 700 J. Find its work output and efficiency.*

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### CONFIDENCE CHECK 2

#### Cooling versus heating

Name the useful heat transfer in each mode.

A refrigerator removes 450 J using 150 J of work. Find the heat delivered to the room,  $\text{COP}_R$ , and  $\text{COP}_{HP}$ .

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### HOW DID IT GO?

**I answered \_\_\_\_ of 2 questions correctly.**

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

**You've confirmed your understanding.**

Take one final look at the essential ideas before choosing your next step.

[Continue to Summary →](#)



## FR-08 • STAGE 5 OF 6

# Summary

Before moving on, take one final look at the essential ideas you'll want to remember.

**KEY TAKEAWAY 1****Engine**

Work output is the difference between absorbed and rejected heat; efficiency compares work to absorbed heat.

**KEY TAKEAWAY 2****Reversed cycle**

Refrigerator and heat-pump COP use different useful heat transfers for the same work input.

**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

**WARM-UP • ACTIVITY 1****Key Ideas**

Work output is 200 J.

WHY IT WORKS Subtract rejected heat from absorbed heat:  $800 - 600 = 200$  J.

**WARM-UP • ACTIVITY 2****Common Mistakes**

Refrigeration uses  $Q_C$ ; heating uses  $Q_H$ .

WHY IT WORKS The same reversed cycle can be described by which side is useful.

**WARM-UP • ACTIVITY 3****Quick Application**

A device receives 800 J from a hot source and rejects 600 J. Its work output is 200 J and efficiency is  $200/800 = 0.25$ , or 25%.

WHY IT WORKS The useful work is 200 J, then  $200/800 = 0.25$ .

## SOLUTIONS • GUIDED PRACTICE

## PRACTICE 1

**Guided Example**

A device receives 800 J from a hot source and rejects 600 J. Its work output is 200 J and efficiency is  $200/800 = 0.25$ , or 25%.

WHY IT WORKS Calculate the work first, then divide by incoming heat.

## PRACTICE 2

**Independent Check**

A heat pump delivers 1,200 J indoors while using 300 J of work. It draws 900 J from outdoors and has heating COP  $1,200/300 = 4$ .

WHY IT WORKS Outdoor heat plus work gives delivered indoor heat.

## SOLUTIONS • CONFIDENCE CHECK

## CONFIDENCE CHECK 1

**Engine efficiency**

$$W_{\text{out}} = 300 \text{ J}; \eta = 300/1,000 = 0.30, \text{ or } 30\%.$$

WHY IT WORKS Conservation gives  $1,000 - 700 = 300 \text{ J}$  before the efficiency ratio.

## CONFIDENCE CHECK 2

**Cooling versus heating**

$$Q_{\text{H}} = 600 \text{ J}; \text{COP}_{\text{R}} = 450/150 = 3; \text{COP}_{\text{HP}} = 600/150 = 4.$$

WHY IT WORKS The room receives the extracted heat plus work input.

## READINESS GUIDE

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

FR-09 • STAGE 6 OF 6

## Next Step: Continue Learning

Great work! You've completed this focused 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 focused review again to strengthen the essential concepts.<br><a href="#">Review Again →</a> | <br><b>I Need More Practice</b><br>Build confidence with additional practice problems.<br><a href="#">Go to Practice →</a> | <br><b>I'm Ready</b><br>Continue to the next topic or learning 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**