FULL REVIEW

# Full Review: Superposition, Standing Waves, and Sound

Review the essential ideas, relationships, and problem-solving tools for superposition, standing waves, and sound.

| TIME | BEST FOR | FINISH WITH |
| --- | --- | --- |
| 45–60 minutes | A complete unit review | 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 • UNIT ALIGNMENT

# Unit Alignment

This bundle is aligned to the approved Physics Sensei unit specification below. Use it to recover the unit structure, reinforce key decisions, and confirm readiness for the next study task.

| | |
|---|---|
| ARCHITECTURE: Physics Sensei Independent Mechanics<br>UNIT: MEC-U12 — Superposition, Standing Waves, and Sound<br>RESOURCE: Unit Review<br>PROFILE: Foundational • Conceptual Physics | BEST USED<br>✓ Before homework on waves or sound<br>✓ Before a quiz or exam<br>✓ When interference, resonance, or sound relationships need reinforcement |

**Review Prerequisites →**Review Prerequisites →

Physics Sensei is an independent educational resource designed to complement independently authored Physics Sensei materials. Physics Sensei content is independently authored and organized under the approved topic architecture.

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<br>**Warm-Up Check — page 4**<br>Activate prior knowledge. | 2<br>**Core Concepts — page 6**<br>Review the essential ideas. | 3<br>**Guided Practice — page 8**<br>Apply what you learned. |
| 4<br>**Confidence Check — page 10**<br>Confirm your understanding. | 5<br>**Summary — page 12**<br>Review the key ideas. | 6<br>**Next Step — page 16**<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

Think about what superposition means physically.

*Two equal upward pulses overlap completely on a string. What happens to the displacement while they overlap?*

ACTIVITY 2

## Recall Activity 2

Use the geometry of a standing wave.

*Where are the points of zero displacement in a standing wave, and where is the oscillation largest?*

FR-04 • WARM-UP CHECK CONTINUED

ACTIVITY 3

## Recall Activity 3

Connect two nearby pitches to beats.

*Two nearly equal tones are played together. What observable feature tells you that beats are occurring?*

### 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 — page 6 →**

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

## Superposition and interference

When waves overlap, the medium responds to the algebraic sum of their displacements. In-phase waves reinforce; out-of-phase waves reduce the resultant and may cancel ideally.

$$y_{total} = y_1 + y_2 \quad \bullet \quad \text{interference depends on phase}$$

KEY RELATIONSHIP Relative phase controls the result: in phase gives reinforcement; opposite phase gives cancellation.

EXAMPLE Two equal crests meeting at the same place create a larger crest; a crest meeting an equal trough can momentarily cancel.

SENSEI NOTE Interference changes the resultant while waves overlap; it does not erase the original waves.

KEY CONCEPT 2

## Standing waves and resonance

A standing wave forms from compatible waves traveling in opposite directions. Nodes and antinodes stay at fixed positions. Resonance occurs only when the system can support the required boundary pattern.

$$\text{fixed/open-open: } \lambda_n = 2L/n \quad \bullet \quad \text{closed-open: } \lambda_n = 4L/n \text{ (n odd)}$$

KEY RELATIONSHIP Boundary conditions set where nodes and antinodes must occur, which selects only certain wavelengths and resonant frequencies.

EXAMPLE A string fixed at both ends must have nodes at both ends, so only patterns that fit those endpoint conditions can persist strongly.

SENSEI NOTE Sketch the endpoint conditions before trying to remember a harmonic formula.

FR-05 • CORE CONCEPTS CONTINUED

KEY CONCEPT 3

## Sound, intensity, and sound level

Sound in air is a longitudinal pressure wave. Frequency is associated with pitch; wave amplitude and energy transport affect intensity. Spreading over a larger area reduces intensity with distance.

$$I \propto 1/r^2 \quad \bullet \quad \beta = 10 \log_{10}(I/I_0)$$

KEY RELATIONSHIP Frequency and wavelength are linked by wave speed; for radial spreading, doubling distance reduces intensity to one-fourth.

EXAMPLE Moving twice as far from an ideal point source spreads the same power over four times the area, so the intensity becomes one-fourth.

SENSEI NOTE A decibel is a logarithmic level, not a direct measure of amplitude or perceived loudness.

**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 — page 8 →**

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

Reason from the endpoint pattern before calculating.

*A string fixed at both ends shows three loops in its standing-wave pattern. Which harmonic is present, and how many antinodes are there?*

PRACTICE 2

## Guided Problem

Use node and antinode spacing.

*Adjacent nodes in a standing wave are 0.35 m apart. Find the wavelength.*

PRACTICE 3

## Independent Problem

Use the inverse-square idea qualitatively and quantitatively.

*The intensity from an ideal point source is I at distance r. What is the intensity at 3r?*

**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 — page 10 →**

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

## Interference pattern

Classify the interference from phase.

*Two equal waves arrive exactly half a cycle out of phase. What kind of interference occurs?*

QUICK CHECK 2

## Standing-wave spacing

Use the fixed geometry of nodes and antinodes.

*How far is the nearest antinode from a node?*

QUICK CHECK 3

## Sound spreading

Use the area argument.

*If distance from an ideal point sound source doubles, what happens to intensity?*

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 — page 12 →**

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

### Add the displacements

Superposition means overlapping wave displacements add at each place and time.

KEY TAKEAWAY 2

### Let boundaries choose the modes

Standing-wave resonances are fixed by endpoint conditions, which determine nodes, antinodes, and allowed wavelengths.

KEY TAKEAWAY 3

### Separate frequency from intensity

Frequency controls the wave cycle rate; intensity describes energy transfer per area and changes with distance.

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 — page 16 →**

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

The displacement is twice as large upward.

WHY IT WORKS Superposition adds the instantaneous displacements. The pulses later continue through one another.

WARM-UP • ACTIVITY 2

### Recall Activity 2

Nodes have zero displacement; antinodes oscillate with the largest amplitude.

WHY IT WORKS A standing wave separates space into fixed nodes and strongly oscillating antinodes.

WARM-UP • ACTIVITY 3

### Recall Activity 3

The loudness rises and falls periodically.

WHY IT WORKS The waves repeatedly move into and out of phase, creating an amplitude envelope.

SOLUTIONS • GUIDED PRACTICE

PRACTICE 1

## Worked Example

Third harmonic; three antinodes.

WHY IT WORKS  Each loop corresponds to one antinode. For a fixed-fixed string, the number of loops equals the harmonic number.

PRACTICE 2

## Guided Problem

$\lambda = 0.70$ m.

WHY IT WORKS  Adjacent nodes are separated by half a wavelength, so $\lambda/2 = 0.35$ m.

PRACTICE 3

## Independent Problem

I/9.

WHY IT WORKS  Spherical area grows as $r^2$, so tripling distance increases area by 9 and reduces intensity by 9.

SOLUTIONS • CONFIDENCE CHECK

QUICK CHECK 1

### Interference pattern

Destructive interference.

WHY IT WORKS Half a cycle corresponds to a phase difference of π, so equal displacements oppose one another.

QUICK CHECK 2

### Standing-wave spacing

λ/4.

WHY IT WORKS An antinode lies halfway between adjacent nodes, and adjacent nodes are λ/2 apart.

QUICK CHECK 3

### Sound spreading

It becomes one-fourth as large.

WHY IT WORKS The same power is spread over four times the spherical area.

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** | **I Need More Practice** | **I'm Ready** |
| Review the key ideas and examples again. | Continue with additional practice for this topic. | Continue to the next recommended resource. |
| **Review again: return to Warm-Up Check on page 4.** | **Go to Practice →** | **Continue →** |

RECOMMENDED LINKS

**Review again: return to Warm-Up Check on page 4.**

**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**