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 UNIT: MEC-U12 — Superposition, Standing Waves, and Sound RESOURCE: Unit Review PROFILE: University Physics • Calculus-Based	BEST USED ✓ Before homework on waves or sound ✓ Before a quiz or exam ✓ When interference, resonance, or sound relationships need reinforcement

Review Prerequisites →Review Prerequisites →

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

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

Add the wave functions, not their amplitudes in isolation.

If $y1=A \sin(kx-\omega t)$ and $y2=A \sin(kx-\omega t+\pi)$, what is $y1+y2$?

ACTIVITY 2

Recall Activity 2

Use the standing-wave function.

For $y=2A \sin(kx) \cos(\omega t)$, where are the nodes?

FR-04 • WARM-UP CHECK CONTINUED

ACTIVITY 3

Recall Activity 3

Connect two angular frequencies to the beat rate.

Two waves have frequencies 500 Hz and 506 Hz. What is the beat frequency?

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 as addition of wave functions

Because the linear wave equation is linear, sums of valid solutions are also solutions. Trigonometric identities convert equal-frequency counter-propagating waves into a standing-wave product and close frequencies into a beat envelope.

$$y_{total} = y_1 + y_2 \quad \bullet \quad \sin a + \sin b = 2 \sin[(a+b)/2] \cos[(a-b)/2]$$

KEY RELATIONSHIP Linearity permits superposition; the relative phase of component solutions determines the resulting amplitude envelope.

EXAMPLE $A \sin(kx-\omega t)+A \sin(kx+\omega t)=2A \sin(kx) \cos(\omega t)$.

SENSEI NOTE Use the actual phase in the wave functions; amplitude addition alone is only valid in special phase relationships.

KEY CONCEPT 2

Boundary conditions quantize standing-wave modes

Applying endpoint conditions to the standing-wave solution restricts k and therefore λ and f. Fixed-fixed and open-open systems give integer half-wavelengths; closed-open systems give odd quarter-wave modes.

$$k_n = n\pi/L \quad \bullet \quad f_n = nv/(2L) \quad \bullet \quad \text{closed-open: } n \text{ odd}$$

KEY RELATIONSHIP Boundary conditions quantize k; the discrete k-values determine the allowed wavelengths and resonance frequencies.

EXAMPLE For $L=0.80$ m and $v=240$ m/s, $k_3=3\pi/L$ and $f_3=450$ Hz.

SENSEI NOTE The harmonic spectrum follows from boundary conditions; it is not an arbitrary list to memorize.

FR-05 • CORE CONCEPTS CONTINUED

KEY CONCEPT 3

Sound intensity, logarithmic level, and radial spreading

For an ideal spherical wave, constant source power crossing spheres gives $I=P/(4\pi r^2)$. The logarithmic sound level compresses the enormous intensity range into decibels.

$$I = P/(4\pi r^2) \quad \bullet \quad dI/dr = -2I/r \quad \bullet \quad \beta = 10 \log_{10}(I/I_0)$$

KEY RELATIONSHIP Conservation of power gives inverse-square intensity; the derivative gives its local rate of decrease, while β maps intensity ratios logarithmically.

EXAMPLE Doubling r gives $I(2r)=I(r)/4$ and decreases level by about 6.02 dB.

SENSEI NOTE Differentiate or take ratios when comparing distances; do not treat decibels as a linear intensity scale.

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

Apply the fixed-end boundary condition to the standing-wave form.

A string of length 1.20 m has wave speed 180 m/s. Use $k_n=n\pi/L$ to find f_1 and f4.

FR-06 • GUIDED PRACTICE CONTINUED

PRACTICE 2

Guided Problem

Derive the closed-open sequence from the endpoint conditions.

A pipe of length 0.85 m is closed at x=0 and open at x=L. With v=343 m/s, find the first two allowed resonances.

PRACTICE 3

Independent Problem

Use a ratio before evaluating the logarithm.

A point source produces 72 dB at distance r. What level is expected at 2r in the ideal far field?

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

Standing-wave nodes

Use the spatial factor of the standing-wave solution.

For $y=2A\sin(kx)\cos(\omega t)$, what condition on x gives a node?

QUICK CHECK 2

Mode spacing

Use $f_n=nv/(2L)$ for a fixed-fixed string.

If adjacent harmonics differ by 120 Hz, what is $v/(2L)$?

FR-07 • CONFIDENCE CHECK CONTINUED

QUICK CHECK 3

Radial intensity derivative

Use $I=C/r^2$.

What is dI/dr in terms of I and r?

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

Linearity makes superposition powerful

Add wave functions first; identities expose interference, standing waves, and beats.

KEY TAKEAWAY 2

Boundary conditions quantize k

Allowed modes come from enforcing endpoint conditions on the spatial part of the solution.

KEY TAKEAWAY 3

Use ratios and logarithms for sound

Inverse-square intensity and logarithmic decibel changes are most efficiently handled through ratios.

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

0 everywhere the two ideal waves overlap.

WHY IT WORKS The functions differ by π in phase, so $\sin(\theta+\pi)=-\sin\theta$ and the displacements cancel point by point.

WARM-UP • ACTIVITY 2

Recall Activity 2

At $\sin(kx)=0$, so $x=n\pi/k=n\lambda/2$.

WHY IT WORKS At those positions the spatial factor is zero for all time.

WARM-UP • ACTIVITY 3

Recall Activity 3

6 Hz.

WHY IT WORKS Adding close-frequency sinusoids produces a slowly varying envelope at $|f_1-f_2|$.

SOLUTIONS • GUIDED PRACTICE

PRACTICE 1

Worked Example

f_1=75.0 Hz; f4=300 Hz.

WHY IT WORKS Since ω=vk and f=ω/(2π), f_n=v(nπ/L)/(2π)=nv/(2L).

PRACTICE 2

Guided Problem

f_1≈101 Hz; f_3≈303 Hz.

WHY IT WORKS A displacement node at x=0 and antinode at x=L require kL=(2m+1)π/2, giving odd quarter-wave modes.

PRACTICE 3

Independent Problem

About 66.0 dB.

WHY IT WORKS I2/I1=1/4, so Δβ=10$\log_{10}$(1/4)=−6.02 dB.

SOLUTIONS • CONFIDENCE CHECK

QUICK CHECK 1

Standing-wave nodes

$kx=n\pi$, or $x=n\lambda/2$.

WHY IT WORKS A node is zero for every t, so the spatial factor must vanish.

QUICK CHECK 2

Mode spacing

120 Hz.

WHY IT WORKS The harmonic spacing is the fundamental frequency $v/(2L)$.

QUICK CHECK 3

Radial intensity derivative

$dI/dr=-2I/r$.

WHY IT WORKS Differentiating Cr^{-2} gives $-2Cr^{-3}$, which equals $-2I/r$.

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