

FULL REVIEW

Full Review: Thermal Expansion

Review thermal expansion from physical meaning through representative calculations and applications.

 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...

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explain thermal expansion, select and apply linear, area, and volume models, and analyze constrained expansion.

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-U02
TOPIC: Thermal Expansion
COURSE LEVEL: Calculus-based college physics

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**Derivative definition**

Write α in terms of L and dL/dT .

ACTIVITY 2**First-order relation**

Starting from $V \propto L^3$, predict β/α for an isotropic solid.

FR-04 • WARM-UP CHECK CONTINUED

ACTIVITY 3

Stress sign

With tension positive, predict the sign of stress in a fully constrained bar that is heated.

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

Expansion Coefficient as a Derivative

The instantaneous linear expansion coefficient is $\alpha(T) = (1/L)(dL/dT)$. If α varies with temperature, integrate: $\ln(L/L_0) = \int \alpha(T) dT$. For nearly constant α and small fractional change, $L \approx L_0(1 + \alpha\Delta T)$.

$$\alpha(T) = (1/L)(dL/dT); \ln(L/L_0) = \int \alpha(T) dT$$

EXAMPLE For constant α , the exact integrated form is $L = L_0 e^{\alpha\Delta T}$; the familiar linear formula is its first-order approximation.

SENSEI NOTE State when the constant- α approximation is being used.

KEY CONCEPT 2

Multidimensional Expansion

For isotropic scaling, $A \propto L^2$ and $V \propto L^3$. Differentiation gives $(1/A)(dA/dT) = 2\alpha$ and $(1/V)(dV/dT) = 3\alpha$, so $\beta = 3\alpha$ for an isotropic solid to first order.

$$(1/A)(dA/dT) = 2\alpha; (1/V)(dV/dT) = 3\alpha$$

EXAMPLE The products $(\alpha\Delta T)^2$ and higher are discarded in the usual small-expansion approximation.

SENSEI NOTE The relations 2α and 3α assume isotropy.

FR-05 • CORE CONCEPTS CONTINUED

KEY CONCEPT 3

Thermoelastic Constraint

Free thermal strain is $\epsilon_{th} = \alpha\Delta T$. In one-dimensional linear thermoelasticity, $\sigma = Y(\epsilon_{total} - \epsilon_{th})$. If a bar is fully constrained so $\epsilon_{total} = 0$, then $\sigma = -Y\alpha\Delta T$ for heating.

$$\sigma = Y(\epsilon_{total} - \alpha\Delta T)$$

EXAMPLE The negative sign denotes compression under the tensile-positive convention.

SENSEI NOTE Separate imposed total strain from free thermal strain before applying Hooke's law.

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**Variable coefficient**

Let $\alpha(T) = a + bT$. Derive $L(T)$ relative to L_0 at T_0 .

FR-06 • GUIDED PRACTICE CONTINUED

PRACTICE 2**First-order volume**

Use $L = L_0(1 + x)$, with $x = \alpha\Delta T$, to derive the first-order volume change of a cube.

PRACTICE 3**Constrained rod**

A steel rod has $Y = 200 \text{ GPa}$, $\alpha = 12 \times 10^{-6}/\text{K}$, and $\Delta T = 40 \text{ K}$. Find the stress if expansion is fully prevented.

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

Exact versus linear

For constant α , give the exact integrated expression for L and its first-order approximation.

QUICK CHECK 2

Anisotropy

Why can $\beta = 3\alpha$ fail for a crystal?

FR-07 • CONFIDENCE CHECK CONTINUED

QUICK CHECK 3

Partial constraint

Write the one-dimensional stress relation when total strain ϵ_{total} is prescribed.

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

Expansion Coefficient as a Derivative

The instantaneous linear expansion coefficient is $\alpha(T) = (1/L)(dL/dT)$. If α varies with temperature, integrate: $\ln(L/L_0) = \int \alpha(T) dT$. For nearly constant α and small fractional change, $L \approx L_0(1 + \alpha\Delta T)$.

KEY TAKEAWAY 2

Multidimensional Expansion

For isotropic scaling, $A \propto L^2$ and $V \propto L^3$. Differentiation gives $(1/A)(dA/dT) = 2\alpha$ and $(1/V)(dV/dT) = 3\alpha$, so $\beta = 3\alpha$ for an isotropic solid to first order.

KEY TAKEAWAY 3

Thermoelastic Constraint

Free thermal strain is $\epsilon_{th} = \alpha\Delta T$. In one-dimensional linear thermoelasticity, $\sigma = Y(\epsilon_{total} - \epsilon_{th})$. If a bar is fully constrained so $\epsilon_{total} = 0$, then $\sigma = -Y\alpha\Delta T$ for heating.

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

Derivative definition

Use the definitions and relationships from the review.

WHY IT WORKS Identify the dimension, temperature change, and coefficient before calculating.

WARM-UP • ACTIVITY 2

First-order relation

Use the definitions and relationships from the review.

WHY IT WORKS Identify the dimension, temperature change, and coefficient before calculating.

WARM-UP • ACTIVITY 3

Stress sign

Use the definitions and relationships from the review.

WHY IT WORKS Identify the dimension, temperature change, and coefficient before calculating.

SOLUTIONS • GUIDED PRACTICE

PRACTICE 1**Variable coefficient**

Integrate $dL/L = (a + bT)dT$: $L = L_0 \exp[a(T - T_0) + (b/2)(T^2 - T_0^2)]$.

WHY IT WORKS The model connects fractional size change to temperature change.

PRACTICE 2**First-order volume**

$V/V_0 = (1 + x)^3 = 1 + 3x + 3x^2 + x^3$. Keeping first order gives $\Delta V/V_0 \approx 3\alpha\Delta T$, so $\beta \approx 3\alpha$.

WHY IT WORKS The model connects fractional size change to temperature change.

PRACTICE 3**Constrained rod**

$\sigma = -Y\alpha\Delta T = -(200 \times 10^9)(12 \times 10^{-6})(40) \text{ Pa} = -9.6 \times 10^7 \text{ Pa} = -96 \text{ MPa}$.

WHY IT WORKS The model connects fractional size change to temperature change.

SOLUTIONS • CONFIDENCE CHECK

QUICK CHECK 1

Exact versus linear

Exact: $L = L_0 e^{\alpha \Delta T}$. First order: $L \approx L_0(1 + \alpha \Delta T)$.

WHY IT WORKS Apply the stated approximation and interpret the sign physically.

QUICK CHECK 2

Anisotropy

A crystal can have direction-dependent expansion coefficients, so equal fractional expansion in all three directions is not guaranteed.

WHY IT WORKS Apply the stated approximation and interpret the sign physically.

QUICK CHECK 3

Partial constraint

$\sigma = Y(\epsilon_{\text{total}} - \alpha \Delta T)$.

WHY IT WORKS Apply the stated approximation and interpret the sign physically.

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