

FULL REVIEW

Full Review: Capacitance and Dielectrics — Calculus-Based

Review the essential ideas, relationships, and problem-solving tools for Capacitance and Dielectrics.

 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...

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 • 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: EME-U05
TOPIC: Capacitance and Dielectrics
COURSE LEVEL: Calculus-Based

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**Key Ideas**

State $C = Q/\Delta V$, $\Delta V = -\int \mathbf{E} \cdot d\mathbf{l}$, and the incremental charging relation $dU = V dq$. Explain what each relation contributes to a capacitance derivation.

Complete the activity in the space below.

ACTIVITY 2**Common Mistakes**

Explain why C is not obtained by substituting the instantaneous field at one point unless the geometry makes that field sufficient to evaluate the full potential difference.

Complete the activity in the space below.

FR-04 • WARM-UP CHECK CONTINUED

ACTIVITY 3

Quick Application

For uniform field between parallel plates, combine $E = Q/(\epsilon_0 A)$ with $\Delta V = Ed$ to derive C .

Complete the activity in the space below.

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

Capacitance from electrostatics

For any two-conductor configuration in a linear medium, determine E from the charge distribution, evaluate the potential difference with the line integral, and form $C = Q/\Delta V$. Geometry remains after Q cancels.

$$C = \frac{Q}{\Delta V} \quad \text{with} \quad \Delta V = - \int \mathbf{E} \cdot d\ell$$

EXAMPLE Parallel plates: $E = Q/(\epsilon_0 A)$, $\Delta V = Ed$, so $C = \epsilon_0 A/d$.

SENSEI NOTE Capacitance is a property of geometry and permittivity; Q and ΔV scale together.

KEY CONCEPT 2

Energy, field energy, and dielectrics

Incremental work $dU = V dq$ with $V = q/C$ gives $U = \int_0^Q Q(q/C) dq = Q^2/(2C)$. For a uniform linear dielectric, energy density is $u = \frac{1}{2}\epsilon E^2$ and $\epsilon = \kappa\epsilon_0$.

$$U = \int V(q) dq = \frac{Q^2}{2C} \quad u = \frac{1}{2}\epsilon E^2$$

EXAMPLE Integrating the uniform field energy density over volume Ad reproduces $\frac{1}{2}C(\Delta V)^2$.

SENSEI NOTE When a dielectric is inserted, state the boundary condition first: isolated capacitor means fixed Q ; connected battery means fixed ΔV .

FR-05 • CORE CONCEPTS CONTINUED

KEY CONCEPT 3

Nonuniform geometries and equivalent capacitance

For spherical or cylindrical conductors, use symmetry to find E , integrate to obtain ΔV , and then compute C . Network equivalent-capacitance rules remain algebraic consequences of common voltage in parallel and common charge magnitude in series.

$$\frac{C}{L} = \frac{2\pi\epsilon}{\ln(b/a)}$$

EXAMPLE A coaxial capacitor yields $C/L = 2\pi\epsilon/\ln(b/a)$.

SENSEI NOTE Do not force the parallel-plate formula onto a geometry whose field is not uniform.

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**Guided Example**

Derive the capacitance per unit length of a coaxial capacitor with inner radius a and outer radius b .

Show the governing relation, substitution or reasoning, and final conclusion.

FR-06 • GUIDED PRACTICE CONTINUED

PRACTICE 2

Independent Check

A parallel-plate capacitor is isolated and then fully filled with dielectric κ . Use the energy expression to determine $U_{\text{new}}/U_{\text{old}}$.

Show the governing relation, substitution or reasoning, and final conclusion.

PRACTICE 3

Independent Problem

For concentric spherical conductors of radii a and b , derive C .

Show the governing relation, substitution or reasoning, and final conclusion.

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**Integral Check**

Work independently, then check the solution.

If $E(r) = \lambda / (2\pi\epsilon r)$ between coaxial cylinders, what functional form must ΔV have?

QUICK CHECK 2**Energy-Density Check**

Work independently, then check the solution.

Write the electric energy density in a linear dielectric.

FR-07 • CONFIDENCE CHECK CONTINUED

QUICK CHECK 3

Spherical Limit

Work independently, then check the solution.

What happens to the spherical-capacitor expression as $b \rightarrow \infty$?

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

Capacitance from field and potential

Capacitance follows from the relation between charge and potential difference; for a chosen geometry, obtain ΔV from the electric field and then form $C = Q/\Delta V$.

KEY TAKEAWAY 2

Energy from incremental charging

The work to charge a capacitor is the integral of $V(q)dq$, giving equivalent energy expressions and the field-energy density.

KEY TAKEAWAY 3

Dielectric response

Linear dielectrics replace ϵ_0 by $\epsilon = \kappa\epsilon_0$ in the ideal parallel-plate model. Boundary conditions determine whether Q or ΔV is fixed and therefore how energy changes.

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. Focus on the governing idea and the essential explanation.

WARM-UP • ACTIVITY 1

Key Ideas

$C = Q/\Delta V$ defines capacitance; $\Delta V = -\int \mathbf{E} \cdot d\mathbf{l}$ converts the field of the charge distribution into a potential difference; $dU = V dq$ gives the work needed to build the charge and therefore the stored energy.

WHY IT WORKS A field calculation supplies E , the line integral supplies ΔV , and the ratio $Q/\Delta V$ removes the arbitrary charge scale and leaves the geometry/permittivity dependence.

WARM-UP • ACTIVITY 2

Common Mistakes

The potential difference depends on the line integral of E between conductors, not generally on E at one point.

WHY IT WORKS Only when symmetry or a uniform-field geometry makes the full integral reducible to a simple expression can a local field value alone determine ΔV .

WARM-UP • ACTIVITY 3

Quick Application

$E = Q/(\epsilon_0 A)$ and $\Delta V = Ed$ give $\Delta V = Qd/(\epsilon_0 A)$. Therefore $C = Q/\Delta V = \epsilon_0 A/d$.

WHY IT WORKS The field-to-potential step introduces the plate spacing, then Q cancels from $Q/\Delta V$, leaving only geometry and permittivity.

SOLUTIONS • GUIDED PRACTICE

PRACTICE 1**Guided Example**

Using $E(r) = \lambda / (2\pi\epsilon r)$, $\Delta V = \int_a^b E \, dr = \lambda \ln(b/a) / (2\pi\epsilon)$. Thus $C/L = 2\pi\epsilon / \ln(b/a)$.

WHY IT WORKS For coaxial symmetry, Gauss's law gives E proportional to $1/r$; integrating E from a to b produces $\ln(b/a)$, and C/L follows from $\lambda/\Delta V$.

PRACTICE 2**Independent Check**

With Q fixed and $C_{\text{new}} = \kappa C_{\text{old}}$, $U = Q^2 / (2C)$, so $U_{\text{new}} / U_{\text{old}} = 1/\kappa$.

WHY IT WORKS Isolation fixes Q . Since a full dielectric multiplies C by κ and $U = Q^2 / (2C)$, the energy falls by the factor κ .

PRACTICE 3**Independent Problem**

$E(r) = Q / (4\pi\epsilon r^2)$. $\Delta V = \int_a^b E \, dr = Q(1/a - 1/b) / (4\pi\epsilon)$, so $C = 4\pi\epsilon ab / (b - a)$.

WHY IT WORKS Spherical symmetry gives E proportional to $1/r^2$; integrating from a to b produces the potential difference and then $C = Q/\Delta V$.

SOLUTIONS • CONFIDENCE CHECK

QUICK CHECK 1

Integral Check

It is proportional to $\ln(b/a)$.

WHY IT WORKS Integrating $1/r$ gives a logarithm, so the coaxial potential difference must contain $\ln(b/a)$.

QUICK CHECK 2

Energy-Density Check

$$u = \frac{1}{2}\epsilon E^2.$$

WHY IT WORKS In a linear dielectric, the field-energy density is $u = \frac{1}{2}\epsilon E^2$.

QUICK CHECK 3

Spherical Limit

It becomes the isolated-sphere capacitance $C = 4\pi\epsilon a$.

WHY IT WORKS Taking the outer radius to infinity leaves the potential relative to infinity and yields the isolated-sphere result $C = 4\pi\epsilon a$.

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](https://www.physicssensei.com)