

FULL REVIEW

Full Review: Current, Resistance, and Ohm's Law — Calculus-Based

Review the essential ideas, relationships, and problem-solving tools for Current, Resistance, and Ohm's Law.

 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-U06
TOPIC: Current, Resistance, and Ohm's Law
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

Derivative

Recall the relevant definition or relationship, then answer in your own words.

If $Q(t) = 3t^2$ C (t in seconds), find $I(t)$.

ACTIVITY 2

Integral

Recall the relevant definition or relationship, then answer in your own words.

A wire carries $I(t) = 2t$ A, t in seconds. Calculate charge from 0 to 2 s.

FR-04 • WARM-UP CHECK CONTINUED

ACTIVITY 3

Vector flux

Recall the relevant definition or relationship, then answer in your own words.

For constant uniform J normal to area A , write the surface-integral reduction.

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

Instantaneous current and charge

Instantaneous current is $I(t) = \frac{dQ}{dt}$. The charge transported during an interval is

$\Delta Q = \int_{t_1}^{t_2} I(t) dt$ over the chosen time interval. Current is signed relative to the selected surface normal.

$$I(t) = \frac{dQ}{dt}; \Delta Q = \int_{t_1}^{t_2} I(t) dt$$

EXAMPLE For $I(t) = (2t)$ A with t in seconds, charge transported from 0 to 3 s is 9 C.

SENSEI NOTE Average current is not automatically equal to the instantaneous current at an endpoint.

KEY CONCEPT 2

Microscopic current and field

Current density $\vec{J}$ relates to charge transport: $I = \int_S \vec{J} \cdot d\vec{A}$. In an ohmic isotropic conductor,

$\vec{J} = \sigma \vec{E}$ and $\rho = \frac{1}{\sigma}$. The lumped relation $V = IR$ follows under steady, uniform geometry assumptions.

$$I = \int_S \vec{J} \cdot d\vec{A}; \vec{J} = \sigma \vec{E}$$

EXAMPLE For uniform $\vec{J}$ aligned with a wire's cross section, $I = J A$.

SENSEI NOTE $\vec{J}$ is a vector; do not replace the surface integral with $J A$ when field or orientation varies.

FR-05 • CORE CONCEPTS CONTINUED

KEY CONCEPT 3

Resistance, power, and limits

For a uniform wire $R = \frac{\rho L}{A}$. Nonuniform conduction instead requires local electric-field/current-density reasoning. Instantaneous delivered power is $p(t) = v(t)i(t)$; for a fixed ohmic resistor $p = i^2 R$.

$$R = \frac{\rho L}{A}; p(t) = v(t)i(t)$$

EXAMPLE If $i(t) = t$ A through $2\ \Omega$, $p(t) = 2t^2$ W with t numerically in seconds.

SENSEI NOTE The relation $V = IR$ assumes the component behaves ohmically under the conditions considered.

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**Time-varying current**

The net charge transported is $Q(t) = (2t^2 + 1)$ C, with t in seconds. Determine $I(3 \text{ s})$.

Worked method: $I(t) = \frac{dQ}{dt} = 4t$ A, so $I(3 \text{ s}) = 12$ A. Check: verify the units and physical assumptions.

FR-06 • GUIDED PRACTICE CONTINUED

PRACTICE 2

Charge integration

Current is $I(t) = 3t^2$ A with t in seconds. Find the charge moved from 0 to 2 s.

Your turn: solve independently. Record the formula, substitution, and units before checking the Solutions section.

PRACTICE 3

Current density

A circular wire of radius 1.0 mm carries a uniform axial current density 2.0×10^6 A/m². Find current.

Your turn: solve independently. Record the formula, substitution, and units before checking the Solutions section.

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**Derivative sign**

Work independently before consulting the solutions section.

$Q(t) = (5 - t^2) \text{ C}$ with t in seconds. Find I at $t = 2 \text{ s}$.

QUICK CHECK 2**Integral of current**

Work independently before consulting the solutions section.

$I(t) = 4t \text{ A}$ with t in seconds. Find charge moved between 1 and 3 s.

FR-07 • CONFIDENCE CHECK CONTINUED

QUICK CHECK 3

Ohmic heating

Work independently before consulting the solutions section.

At an instant $i = 2 \text{ A}$ through a $5 \, \Omega$ resistor. Find power.

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

Instantaneous current

$I(t) = \frac{dQ}{dt}$; accumulated charge is the time integral of current.

KEY TAKEAWAY 2

Microscopic transport

$I = \int_s \vec{J} \cdot d\vec{A}$; $\vec{J} = \sigma \vec{E}$ for an isotropic ohmic material.

KEY TAKEAWAY 3

Lumped limit

$R = \frac{\rho L}{A}$ for a uniform wire; $p(t) = v(t)i(t)$.

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

$$I(t) = \frac{dQ}{dt} = 6t \text{ A (t measured in seconds).}$$

WHY IT WORKS Instantaneous current is the time derivative of charge: $I(t) = \frac{dQ}{dt}$. Differentiating $3t^2$ gives $6t$; with charge in coulombs and time in seconds, the result is in amperes.

WARM-UP • ACTIVITY 2

Integral

$$\Delta Q = \int_0^2 2t \, dt = [t^2]_0^2 = 4 \text{ C}$$

WHY IT WORKS The net charge transported over a time interval is the definite integral of current. Integrating $2t$ from 0 to 2 s gives the difference t^2 at the limits, $4 \text{ C} - 0 \text{ C} = 4 \text{ C}$.

WARM-UP • ACTIVITY 3

Vector flux

$$I = \int_S \vec{J} \cdot d\vec{A} = JA \text{ for uniform } \vec{J} \text{ perpendicular to the surface.}$$

WHY IT WORKS Current through a surface is the flux of current density, $I = \int_S \vec{J} \cdot d\vec{A}$. If $\vec{J}$ is uniform and normal to a flat cross-section, the dot product is $J \, dA$ everywhere and integrates to JA .

SOLUTIONS • GUIDED PRACTICE

PRACTICE 1

Time-varying current

$$I(t) = \frac{dQ}{dt} = 4t \text{ A, so } I(3 \text{ s}) = 12 \text{ A.}$$

WHY IT WORKS Current is the instantaneous rate of change of transported charge. Differentiating $Q(t) = 2t^2 + 1$ eliminates the constant and gives $I(t) = 4t \text{ A}$; evaluating at $t = 3 \text{ s}$ yields 12 A.

PRACTICE 2

Charge integration

$$\Delta Q = \int_0^2 3t^2 dt = [t^3]_0^2 = 8 \text{ C}$$

WHY IT WORKS Charge transported is the area under the signed current–time curve:

$$\Delta Q = \int_0^2 3t^2 dt. \text{ Its antiderivative is } t^3, \text{ so the difference of endpoint values is } 8 \text{ C.}$$

PRACTICE 3

Current density

$$I = J\pi r^2 = (2.0 \times 10^6 \text{ A/m}^2)\pi(0.001 \text{ m})^2 \approx 6.28 \text{ A.}$$

WHY IT WORKS Uniform axial current density is constant and perpendicular to the circular cross-section, so $I = \int S \vec{J} \cdot d\vec{A} = J\pi r^2$. Converting 1.0 mm to 0.001 m before squaring gives $I \approx 6.28 \text{ A}$.

SOLUTIONS • CONFIDENCE CHECK

QUICK CHECK 1

Derivative sign

$I = dQ/dt = -2t$ A; at $t = 2$ s, $I = -4$ A relative to the chosen orientation.

WHY IT WORKS Current is the derivative $\frac{dQ}{dt}$, not charge divided by time at one instant.

Differentiating $5 - t^2$ gives $-2t$ A; the negative sign at 2 s indicates flow opposite the chosen positive orientation.

QUICK CHECK 2

Integral of current

$$\Delta Q = \int_1^3 4t \, dt = [2t^2]_1^3 = 16 \, \text{C}$$

WHY IT WORKS Net transported charge is the definite time integral of signed current. Integrating $4t$ yields $2t^2$; evaluating from 1 to 3 s gives $18 - 2 = 16$ C.

QUICK CHECK 3

Ohmic heating

$$p = i^2 R = 20 \, \text{W}.$$

WHY IT WORKS At the stated instant an ohmic resistor dissipates power $p = i^2 R$, obtained from $p = vi$ and $v = iR$. Substituting $i = 2$ A and $R = 5 \, \Omega$ gives $4 \times 5 = 20$ W.

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