

FULL REVIEW

Full Review: Rolling Motion

Review the essential ideas, relationships, and problem-solving tools for rolling motion.

 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:** MEC-U22
TOPIC: Rolling Motion **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**

Write the rigid-body velocity relation for a point P on a rolling body.

Write a short response: Write the rigid-body velocity relation for a point P on a rolling body.

ACTIVITY 2**Common Mistakes**

Does $v_{\text{contact}} = 0$ imply $a_{\text{contact}} = 0$?

Write a short response: Does $v_{\text{contact}} = 0$ imply $a_{\text{contact}} = 0$?

FR-04 • WARM-UP CHECK CONTINUED

ACTIVITY 3

Quick Application

For pure rolling, differentiate $s = R\theta$ to relate speed and acceleration.

Write a short response: For pure rolling, differentiate $s = R\theta$ to relate speed and acceleration.

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

Rigid-Body Kinematics

The velocity field of a rolling rigid body is $\mathbf{v}[\mathbf{P}] = \mathbf{v}_{\text{CM}} + \boldsymbol{\omega} \times \mathbf{r}[\mathbf{P}/\text{CM}]$. At contact with a stationary surface, $\mathbf{v}_{\text{contact}} = 0$; this gives the no-slip constraint.

$$\mathbf{v}_P = \mathbf{v}_{\text{CM}} + \boldsymbol{\omega} \times \mathbf{r}_{P/\text{CM}} \quad ; \quad \mathbf{v}_{\text{contact}} = \mathbf{0}$$

EXAMPLE The top point of a wheel has instantaneous speed $2v_{\text{CM}}$.

SENSEI NOTE The contact point is an instantaneous center for velocity, not generally for acceleration.

KEY CONCEPT 2

Energy, Torque, and Constraint

Rolling dynamics combines $\Sigma \mathbf{F} = M\mathbf{a}_{\text{CM}}$, $\Sigma \boldsymbol{\tau}_{\text{CM}} = I_{\text{CM}}\boldsymbol{\alpha}$, and $\mathbf{a}_{\text{CM}} = \boldsymbol{\alpha}R$. Static friction supplies torque when required without doing work at a stationary contact point.

$$\Sigma \mathbf{F} = M\mathbf{a}_{\text{CM}} \quad ; \quad \Sigma \boldsymbol{\tau}_{\text{CM}} = I_{\text{CM}}\boldsymbol{\alpha} \quad ; \quad \mathbf{a}_{\text{CM}} = \boldsymbol{\alpha}R$$

EXAMPLE For $I = kMR^2$, eliminating friction and $\boldsymbol{\alpha}$ gives $a = g \sin\theta / (1+k)$ on an incline.

SENSEI NOTE Choose the torque origin carefully; about the center of mass, gravity may have zero torque while friction supplies the rotational torque.

FR-05 • CORE CONCEPTS CONTINUED

KEY CONCEPT 3

Instantaneous Center and Acceleration

For velocity analysis, the contact point of a pure-rolling body on a fixed surface can be treated as an instantaneous center. Acceleration requires the full rigid-body relation $\mathbf{a}[\mathbf{P}] = \mathbf{a}_{\text{CM}} + \boldsymbol{\alpha} \times \mathbf{r}[\mathbf{P}/\text{CM}] + \boldsymbol{\omega} \times (\boldsymbol{\omega} \times \mathbf{r}[\mathbf{P}/\text{CM}])$. The contact point generally has nonzero centripetal acceleration.

$$\mathbf{a}_P = \mathbf{a}_{\text{CM}} + \boldsymbol{\alpha} \times \mathbf{r}_{P/\text{CM}} + \boldsymbol{\omega} \times (\boldsymbol{\omega} \times \mathbf{r}_{P/\text{CM}})$$

EXAMPLE For constant-speed rolling, the contact point has upward acceleration of magnitude $\omega^2 R$ even though its instantaneous velocity is zero.

SENSEI NOTE Do not extend the instantaneous-center shortcut from velocity directly to acceleration.

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 speed of a rolling body after descending height h using $I = kMR^2$.

Derive the speed of a rolling body after descending height h using $I = kMR^2$.

FR-06 • GUIDED PRACTICE CONTINUED

PRACTICE 2

Independent Check

A wheel rolls right with $v_{CM} = v$. Use $v[P] = v_{CM} + \omega \times r$ to find the velocity of the top point.

A wheel rolls right with $v_{CM} = v$. Use $v[P] = v_{CM} + \omega \times r$ to find the velocity of the top point.

PRACTICE 3

Independent Problem

A wheel rolls at constant speed v . Find the acceleration magnitude of the instantaneous contact point.

A wheel rolls at constant speed v . Find the acceleration magnitude of the instantaneous contact point.

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**Contact Acceleration**

Solve or explain without looking back.

Can the contact point have nonzero acceleration in pure rolling?

QUICK CHECK 2**Energy Result**

Solve or explain without looking back.

For $I = kMR^2$, write the speed after a vertical drop h .

FR-07 • CONFIDENCE CHECK CONTINUED

QUICK CHECK 3

Contact-Point Acceleration

Solve or explain without looking back.

For constant-speed pure rolling, what is the magnitude of the contact point's acceleration?

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**Velocity Field**

Pure rolling follows from the vector velocity field plus the zero-contact-velocity constraint.

KEY TAKEAWAY 2**Coupled Dynamics**

Translation, rotation, and the no-slip constraint must be solved together.

KEY TAKEAWAY 3**Instantaneous Center and Acceleration**

For velocity analysis, the contact point of a pure-rolling body on a fixed surface can be treated as an instantaneous center.

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

Key Ideas

$$\mathbf{v}[\mathbf{P}] = \mathbf{v}_{\text{CM}} + \boldsymbol{\omega} \times \mathbf{r}[\mathbf{P}/\text{CM}].$$

WHY IT WORKS $\mathbf{v}[\mathbf{P}] = \mathbf{v}_{\text{CM}} + \boldsymbol{\omega} \times \mathbf{r}[\mathbf{P}/\text{CM}].$

WARM-UP • ACTIVITY 2

Common Mistakes

No. The contact point can have nonzero acceleration even when its instantaneous velocity is zero.

WHY IT WORKS No. The contact point can have nonzero acceleration even when its instantaneous velocity is zero.

WARM-UP • ACTIVITY 3

Quick Application

$$v_{\text{CM}} = R\omega \text{ and } a_{\text{CM}} = R\alpha \text{ for tangential motion.}$$

WHY IT WORKS $v_{\text{CM}} = R\omega \text{ and } a_{\text{CM}} = R\alpha \text{ for tangential motion.}$

SOLUTIONS • GUIDED PRACTICE

PRACTICE 1

Guided Example

$Mgh = \frac{1}{2} Mv^2 + \frac{1}{2} (kMR^2)(v^2/R^2)$. Thus $v = \sqrt{2gh/(1+k)}$.

WHY IT WORKS $Mgh = \frac{1}{2} Mv^2 + \frac{1}{2} (kMR^2)(v^2/R^2)$. Thus $v = \sqrt{2gh/(1+k)}$.

PRACTICE 2

Independent Check

The rotational contribution at the top is $+v$ in the direction of translation, so $v_{\text{top}} = 2v$.

WHY IT WORKS The rotational contribution at the top is $+v$ in the direction of translation, so $v_{\text{top}} = 2v$.

PRACTICE 3

Independent Problem

With $a_{\text{CM}} = 0$ and $\alpha = 0$, $\mathbf{a} = \boldsymbol{\omega} \times (\boldsymbol{\omega} \times \mathbf{r})$. At the bottom point its magnitude is $\omega^2 R = v^2/R$, directed upward.

WHY IT WORKS With $a_{\text{CM}} = 0$ and $\alpha = 0$, $\mathbf{a} = \boldsymbol{\omega} \times (\boldsymbol{\omega} \times \mathbf{r})$. At the bottom point its magnitude is $\omega^2 R = v^2/R$, directed upward.

SOLUTIONS • CONFIDENCE CHECK

QUICK CHECK 1

Contact Acceleration

Yes. Zero instantaneous velocity does not require zero acceleration.

WHY IT WORKS Yes. Zero instantaneous velocity does not require zero acceleration.

QUICK CHECK 2

Energy Result

$$v = \sqrt{2gh/(1+k)}.$$

WHY IT WORKS $v = \sqrt{2gh/(1+k)}.$

QUICK CHECK 3

Contact-Point Acceleration

v^2/R , directed upward.

WHY IT WORKS v^2/R , directed upward.

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. <u>Go to Practice →</u>	✓ 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)