FULL REVIEW

Full Review: Uniform Circular Motion — Calculus-Based

Review the essential ideas, relationships, and problem-solving tools for Uniform Circular Motion.

◷ TIME	◎ BEST FOR	✓ FINISH WITH
45–60 minutes	A complete topic 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 • TOPIC ALIGNMENT

Topic Alignment

This bundle is aligned to the approved Physics Sensei topic specification below. Use it to recover the topic structure, reinforce key decisions, and confirm readiness for the next study task.

TEXTBOOK: Independent Physics Sensei Unit Review **CHAPTER: Mechanics • MEC-U16** **TOPIC: Uniform Circular Motion** **COURSE LEVEL: Calculus-Based**	**BEST USED** ✓ **After learning the unit** ✓ **Before starting homework** ✓ **Before a quiz or exam**

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

Use the circular position function and its derivatives.

For $r(t)=r\cos(\omega t)i+r\sin(\omega t)j$, determine v and a at $t=0$.

ACTIVITY 2

Recall Activity 2

Connect angular position, period, and frequency.

If $\theta(t)=\omega t$, relate ω, T, and f.

FR-04 • WARM-UP CHECK CONTINUED

ACTIVITY 3

Recall Activity 3

Write Newton's second law in radial vector form.

Starting with $a=-\omega^2 r$ in radial vector form, write Newton's second law.

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

Circular kinematics: period, frequency, angular speed, and linear speed

Represent the motion with $r(t)=r\cos(\omega t)i+r\sin(\omega t)j$. Differentiation gives tangent velocity with constant magnitude $v=\omega r$.

$$r(t)=r\cos(\omega t)i+r\sin(\omega t)j;\ v(t)=-\omega r\sin(\omega t)i+\omega r\cos(\omega t)j;\ |v|=\omega r.$$

EXAMPLE The dot product $r(t)\cdot v(t)=0$, showing radial position and tangent velocity are perpendicular.

SENSEI NOTE Linear speed and angular speed are related but not identical. Points at different radii can share the same angular speed while having different linear speeds.

KEY CONCEPT 2

Centripetal acceleration: changing direction at constant speed

Differentiating velocity gives $a(t)=-\omega^2 r\cos(\omega t)i-\omega^2 r\sin(\omega t)j$. The minus sign shows that acceleration is opposite the outward radial direction.

$$a(t)=-\omega^2 r(t);\ |a|=\omega^2 r=v^2/r.$$

EXAMPLE The second derivative of the circular position function is proportional to $-r(t)$.

SENSEI NOTE A statement about how acceleration changes with radius is incomplete unless you also state what is held constant: speed, angular speed, or period.

FR-05 • CORE CONCEPTS CONTINUED

KEY CONCEPT 3

Radial force modeling: the inward net force

Use the vector relation $\Sigma F = -m\omega^2 r$ in the radial direction and combine it with independent vertical or tangential component equations when needed.

$$\Sigma F = -m\omega^2 r \text{ in radial vector form.}$$

EXAMPLE For a conical pendulum, vertical balance and radial acceleration are separate component conditions.

SENSEI NOTE "Centripetal" describes the required inward net-force direction. It is not the name of an additional physical interaction.

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

Connect period, angular speed, and linear speed; keep units visible.

For $r(t)=R\cos(\omega t)i+R\sin(\omega t)j$, show that $r(t)\cdot v(t)=0$.

FR-06 • GUIDED PRACTICE CONTINUED

PRACTICE 2

Guided Problem

Draw the free-body diagram, identify the inward direction, and then apply the radial equation.

Using outward radial unit direction, write the friction-force vector required for the same car.

PRACTICE 3

Independent Problem

Separate vertical balance from radial acceleration.

Write the two independent component equations for a conical pendulum and explain why they can be solved together.

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

Direction check

Answer without drawing a separate centripetal-force arrow.

What does the minus sign in $a=-\omega^2 r$ mean geometrically?

QUICK CHECK 2

Scaling check

State what is held constant before giving the factor.

At fixed angular speed, what happens to a_c if radius doubles?

FR-07 • CONFIDENCE CHECK CONTINUED

QUICK CHECK 3

Force-model check

Name the real interaction and the radial equation.

Write the radial vector form of Newton's second law for UCM.

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

Connect T, f, ω, and v before calculating

One revolution is 2π radians and a distance $2\pi r$. Use $f=1/T$, $\omega=2\pi/T$, and $v=\omega r$ to translate between cycle, angular, and linear descriptions.

KEY TAKEAWAY 2

Velocity is tangent; acceleration is inward

Constant speed can coexist with nonzero acceleration because velocity direction changes. Use $a_c=v^2/r=\omega^2 r$ and always identify the center first.

KEY TAKEAWAY 3

Model the real forces, then impose the radial requirement

Draw the free-body diagram with actual interactions. Their inward components must satisfy $\Sigma F_r=mv^2/r$; never add a duplicate “centripetal force.”

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.

WARM-UP • ACTIVITY 1

Recall Activity 1

$v(0)=\omega r\, j$; $a(0)=-\omega^2 r\, i$.

WHY IT WORKS Differentiation rotates the velocity direction and gives a second derivative opposite the radial position.

WARM-UP • ACTIVITY 2

Recall Activity 2

$\omega=2\pi/T=2\pi f$.

WHY IT WORKS One revolution is 2π radians, so $\omega T=2\pi$ and $f=1/T$.

WARM-UP • ACTIVITY 3

Recall Activity 3

$\Sigma F=-m\omega^2 r$ in the radial direction.

WHY IT WORKS The acceleration vector is opposite the outward radial position vector.

SOLUTIONS • GUIDED PRACTICE

PRACTICE 1

Worked Example

$r \cdot v = 0$.

WHY IT WORKS The radial position and tangent velocity are perpendicular at every instant.

PRACTICE 2

Guided Problem

$F_f = -5400$ N in the outward-radial coordinate convention.

WHY IT WORKS The negative sign indicates inward direction relative to an outward radial axis.

PRACTICE 3

Independent Problem

$T\cos\theta = mg$ and $T\sin\theta = mv^2/r = m\omega^2 r$.

WHY IT WORKS The component equations express different acceleration constraints for the same force vector.

SOLUTIONS • CONFIDENCE CHECK

QUICK CHECK 1

Direction check

Acceleration is opposite the outward radial position, so it points toward the center.

WHY IT WORKS Velocity is tangent to the path; centripetal acceleration is radial and inward.

QUICK CHECK 2

Scaling check

It doubles.

WHY IT WORKS Use $a_c = v^2/r$ when speed is controlled and $a_c = \omega^2 r$ when angular speed is controlled.

QUICK CHECK 3

Force-model check

$\Sigma F = -m\omega^2 r$ in radial vector form.

WHY IT WORKS Centripetal force is not an additional interaction; it is the inward net-force requirement.

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