FOCUSED REVIEW

Focused Review: Center of Mass and Systems of Particles

Reinforce the highest-leverage center-of-mass calculations and system-motion relationships.

TIME	BEST FOR	FINISH WITH
15 minutes	Focused review	Greater confidence

After this focused review, you'll be able to…

calculate center of mass for discrete particles, use P = M VCM, and determine center-of-mass acceleration from net external force.

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 15 minutes

FR-02 • PHYSICS SENSEI UNIT REVIEW

Physics Sensei Unit Review

Use this Physics Sensei Unit Review to reinforce key concepts, prepare for homework, and review before a quiz or exam.

UNIT: MEC-U19
TOPIC FAMILY: Mechanics
TOPIC: Center of Mass and Systems of Particles
COURSE LEVEL: Algebra-based introductory college physics

BEST USED

- ✓ **To reinforce key concepts**
- ✓ Before starting homework
- ✓ Before a quiz or exam

Continue with Physics Sensei →

Physics Sensei is an independent educational resource organized around core college-physics ideas, problem-solving models, and study workflows.

FR-03 • YOUR REVIEW PLAN

Your Review Plan

Complete these six focused stages in order. Each stage reinforces your understanding and prepares you for a final confidence check.

6 stages • Approximately 15 minutes

1 **Warm-Up Check — page 4** Refresh key ideas.	2 **Core Concepts — page 6** Reinforce the essentials.	3 **Guided Practice — page 7** Strengthen key skills.
4 **Confidence Check — page 9** Confirm your understanding.	5 **Summary — page 10** Remember the essentials.	6 **Next Step — page 14** Choose your next step.

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 minute to reactivate what you already know. This quick warm-up will help you focus on the most important ideas before moving on.

WARM-UP 1

Key Ideas

Recall the mass-weighted-average formula for center of mass.

For masses 2.0 kg at x = 1.0 m and 3.0 kg at x = 5.0 m, find xCM.

WARM-UP 2

Common Mistakes

Recall the system-level momentum relation.

A system has total mass 5.0 kg and total momentum +10 kg·m/s. Find VCM.

FR-04 • WARM-UP CHECK CONTINUED

WARM-UP 3

Quick Application

Connect net external force to center-of-mass acceleration.

A 4.0 kg system experiences a net external force of 12 N. Find ACM.

Ready to strengthen your understanding?

You've refreshed the most important ideas. Now reinforce the concepts you'll use most often.

Continue to Core Concepts — page 6 →

FR-05 • STAGE 2 OF 6

Core Concepts

Let's reinforce the most important concepts you'll need to solve problems with confidence. Focus on the ideas that appear most often in homework, quizzes, and exams.

KEY CONCEPT 1

Discrete Center of Mass

For discrete particles, calculate the center of mass as a mass-weighted average. In two dimensions, evaluate xCM and yCM separately using the same total mass.

$$x_{CM} = \frac{\sum_i m_i x_i}{\sum_i m_i} \qquad y_{CM} = \frac{\sum_i m_i y_i}{\sum_i m_i}$$

EXAMPLE For 2.0 kg at x = 1.0 m and 3.0 kg at x = 5.0 m, xCM = [2(1) + 3(5)]/5 = 3.4 m.

SENSEI NOTE Do not average positions unless the masses are equal. Center of mass is a mass-weighted average.

KEY CONCEPT 2

System Momentum and External Force

Total momentum is connected to center-of-mass velocity by P = M VCM. The acceleration of the center of mass is determined by the net external force: net external force = M ACM.

$$\frac{d\mathbf{P}}{dt} = \sum \mathbf{F}_{ext} = M\mathbf{A}_{CM}$$

EXAMPLE If a system has M = 5.0 kg and P = +10 kg·m/s, then VCM = +2.0 m/s. If a 4.0 kg system experiences net external force = 12 N, then ACM = 3.0 m/s^2.

SENSEI NOTE Internal forces can redistribute momentum among particles, but only the net external force determines center-of-mass acceleration.

Ready to apply these ideas?

You've reinforced the essential concepts. Now strengthen your problem-solving skills by working through a few guided examples.

Continue to Guided Practice — page 7 →

FR-06 • STAGE 3 OF 6

Guided Practice

Now apply the key concepts you've just reviewed. Work through these focused practice activities to reinforce your problem-solving skills before the final confidence check.

PRACTICE 1

Guided Example

Calculate xCM and yCM using mass-weighted coordinates.

Particles of 1.0 kg, 2.0 kg, and 3.0 kg are at (0,0), (3,0), and (0,4) m. Find xCM and yCM.

PRACTICE 2

Independent Check

Find total momentum, then use it to determine VCM.

A 3.0 kg cart moves at +2.0 m/s and a 2.0 kg cart moves at -1.0 m/s. Find P and VCM.

Ready for a confidence check?

You've reinforced the essential skills through focused practice. Now confirm your understanding with two short questions.

Continue to Confidence Check — page 9 →

FR-07 • STAGE 4 OF 6

Confidence Check

You've reinforced the key concepts and practiced the essential skills. Now confirm you're ready to move forward by completing these short confidence checks.

CONFIDENCE CHECK 1

Center-of-Mass Calculation

Use the mass-weighted average, not the geometric midpoint.

Two masses, 4.0 kg at x = 0 and 6.0 kg at x = 5.0 m, form a system. Find xCM.

CONFIDENCE CHECK 2

System Motion

Connect total momentum to center-of-mass velocity.

A 10 kg system has VCM = +0.60 m/s. Find the total momentum. If net external force = 0, what happens to VCM?

HOW DID IT GO?

I answered ____ of 2 questions correctly.

Use the Solutions section to check your reasoning, then take one final look at the essential ideas.

You've confirmed your understanding.

Take one final look at the essential ideas before choosing your next step.

Continue to Summary — page 10 →

FR-08 • STAGE 5 OF 6

Summary

Before moving on, take one final look at the essential ideas you'll want to remember.

KEY TAKEAWAY 1

Use Mass-Weighted Coordinates

Compute each center-of-mass coordinate from the weighted position sum divided by total mass.

KEY TAKEAWAY 2

Use System-Level Momentum and Force Relations

Use P = M VCM and net external force = M ACM to connect particle behavior to system motion.

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 14 →

ANSWER KEY • CHECK AFTER ATTEMPTING

Solutions and Explanations

Use these solutions to check your reasoning—not only your final answer. Use each answer and explanation to check both the setup and the physical interpretation.

WARM-UP • ACTIVITY 1

Key Ideas

xCM = 3.4 m.

WHY IT WORKS xCM = [2.0(1.0) + 3.0(5.0)]/(5.0) = 17/5 = 3.4 m.

WARM-UP • ACTIVITY 2

Common Mistakes

VCM = +2.0 m/s.

WHY IT WORKS Use P = M VCM, so VCM = P/M = 10/5.0 = +2.0 m/s.

WARM-UP • ACTIVITY 3

Quick Application

ACM = 3.0 m/s^2.

WHY IT WORKS net external force = M ACM, so ACM = 12/4.0 = 3.0 m/s^2.

SOLUTIONS • GUIDED PRACTICE

PRACTICE 1

Guided Example

xCM = 1.0 m; yCM = 2.0 m.

WHY IT WORKS The total mass is 6.0 kg. xCM = [1(0)+2(3)+3(0)]/6 = 1.0 m and yCM = [1(0)+2(0)+3(4)]/6 = 2.0 m.

PRACTICE 2

Independent Check

P = +4.0 kg·m/s; VCM = +0.80 m/s.

WHY IT WORKS P = 3.0(+2.0) + 2.0(-1.0) = +4.0 kg·m/s. With M = 5.0 kg, VCM = P/M = +0.80 m/s.

SOLUTIONS • CONFIDENCE CHECK

CONFIDENCE CHECK 1

Center-of-Mass Calculation

xCM = 3.0 m.

WHY IT WORKS xCM = [4.0(0) + 6.0(5.0)]/(10.0) = 3.0 m.

CONFIDENCE CHECK 2

System Motion

P = +6.0 kg·m/s, and VCM remains +0.60 m/s if net external force = 0.

WHY IT WORKS P = M VCM = 10(0.60) = +6.0 kg·m/s. With zero net external force, total momentum and therefore VCM remain constant.

READINESS GUIDE

2 correct: You're ready to continue. • 1 correct: Review the missed idea, then continue. • 0 correct: Revisit Core Concepts or choose more practice.

FR-09 • STAGE 6 OF 6

Next Step: Continue Learning

Great work! You've completed this focused 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 focused review again to strengthen the essential concepts.	Build confidence with additional practice problems.	Continue to the next topic or learning 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