FULL REVIEW

Full Review: Momentum and Collisions — Calculus-Based

60-minute calculus-based review of momentum and collisions, emphasizing vector momentum, impulse integrals, system momentum, and collision derivations.

◷ **TIME** 60 minutes	◎ **BEST FOR** Full Review	✓ **FINISH WITH** Greater confidence

After this review, you'll be able to…

use $p = mv$ and $F = dp/dt$, evaluate impulse integrals, analyze system momentum and center-of-mass motion, and solve collision constraints with momentum and energy conservation.

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 60 minutes

FR-02 • UNIT ALIGNMENT

Unit Alignment

This Physics Sensei Unit Review covers MEC-U07 — Momentum and Collisions using the Calculus-Based treatment. Use it to reinforce the unit, prepare for homework, or review before a quiz or exam.

UNIT ID: MEC-U07 **UNIT: Momentum and Collisions** **TREATMENT: Calculus-Based** **RESOURCE: Unit Review**	**BEST USED** ✓ After reading the chapter ✓ Before starting homework ✓ Before a quiz or exam

Explore Momentum and Collisions Online →

Physics Sensei Unit Reviews use independent organization, wording, examples, and explanations.

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 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

Momentum Function

Differentiate or evaluate vector velocity before forming momentum.

A 2.0 kg particle has $v(t) = \langle 3t, 2\rangle$ m/s. Write $p(t)$.

ACTIVITY 2

Impulse Integral

Recognize impulse as the time integral of net force.

If $F_x(t) = 6t$ N from $t = 0$ to 2.0 s, what is the x-impulse?

FR-04 • WARM-UP CHECK CONTINUED

ACTIVITY 3

System Momentum

Relate total momentum to center-of-mass velocity.

For constant total mass M, what is the relation between total momentum P and center-of-mass velocity V_{cm}?

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

Momentum Dynamics for a System

For a particle of constant mass, $p = mv$ and $F_{net} = dp/dt$. For a system of particles, $dP/dt = F_{ext}$ because internal force pairs cancel in the system sum. If the external impulse is negligible, P is constant.

$$p = mv; \quad F_{net} = dp/dt; \quad dP/dt = F_{ext}$$

EXAMPLE The center of mass moves as if all mass were concentrated there and acted on by the net external force: $M A_{cm} = F_{ext}$.

SENSEI NOTE Separate internal interaction forces from external forces before invoking conservation.

KEY CONCEPT 2

Impulse as an Integral

The impulse delivered from t1 to t2 is $J = \int F_{net}(t)\, dt = p(t2) - p(t1)$. Component-by-component integration handles time-varying forces. The signed area under each force component versus time gives the corresponding impulse component.

$$J = \int_0^t F_{net}(t)\, dt = p_f - p_i$$

EXAMPLE For $F_x = 6t$ N from 0 to 2 s, $J_x = 12$ N·s.

SENSEI NOTE Integrate the force component, not its magnitude, when direction matters.

FR-05 • CORE CONCEPTS CONTINUED

KEY CONCEPT 3

Collision Constraints and the Center-of-Mass Frame

An isolated collision conserves vector momentum. Elastic collisions also conserve total kinetic energy. In the center-of-mass frame the total momentum is zero before and after; this often exposes symmetry and simplifies one-dimensional elastic collisions.

$$P_i = P_f; \text{ elastic: } K_i = K_f$$

EXAMPLE For an elastic 1D collision, momentum plus kinetic energy gives two independent equations for the two final velocities.

SENSEI NOTE Energy conservation is an additional constraint, not a replacement for momentum conservation.

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

Time-Dependent Force

Integrate the force to obtain impulse, then update momentum.

A 2.0 kg cart has $v_x(0) = 1.0$ m/s. It experiences $F_x(t) = 6t$ N from 0 to 2.0 s. Find $v_x(2.0\ \text{s})$.

FR-06 • GUIDED PRACTICE CONTINUED

PRACTICE 2

Center-of-Mass Velocity

Use $P = M V_{cm}$.

A 1.0 kg cart moves at +6.0 m/s and a 2.0 kg cart moves at -1.0 m/s. Find V_{cm}.

PRACTICE 3

One-Dimensional Elastic Collision

Use both conserved quantities.

A 1.0 kg cart at +4.0 m/s collides elastically with a 3.0 kg cart initially at rest. Find the final velocities.

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

Derivative Form

Answer without notes and justify the physical reasoning.

If $p_x(t) = 2t^3 - t$ kg·m/s, what is F_x at $t = 1.0$ s?

QUICK CHECK 2

Impulse Integral

Answer without notes and justify the physical reasoning.

If $F_x(t) = 4 - 2t$ N from 0 to 3 s, what is J_x?

FR-07 • CONFIDENCE CHECK CONTINUED

QUICK CHECK 3

Center-of-Mass Frame

Answer without notes and justify the physical reasoning.

What is the total momentum in the center-of-mass frame?

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

External Force Controls System Momentum

$dP/dt = F_{ext}$; internal forces redistribute momentum without changing the system total.

KEY TAKEAWAY 2

Impulse Is a Force Integral

$J = \int F\,dt$ provides the exact momentum change for time-dependent forces.

KEY TAKEAWAY 3

Elastic Collisions Add an Energy Constraint

Momentum conservation is universal for isolated collisions; kinetic energy conservation distinguishes the elastic model.

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. Use each answer and explanation to identify the step that supports the result.

WARM-UP • ACTIVITY 1

Momentum Function

$p(t) = <6t, 4>$ kg·m/s.

WHY IT WORKS Multiply each velocity component by the constant mass.

WARM-UP • ACTIVITY 2

Impulse Integral

12 N·s.

WHY IT WORKS $J_x = \int_0^2 6t\,dt = 3t^2|_0^2 = 12$ N·s.

WARM-UP • ACTIVITY 3

System Momentum

$P = M V_{cm}$.

WHY IT WORKS The mass-weighted sum of particle velocities equals M times the center-of-mass velocity.

SOLUTIONS • GUIDED PRACTICE

PRACTICE 1

Time-Dependent Force

7.0 m/s.

WHY IT WORKS $J_x = \int_0^2 6t\,dt = 12$ N·s. $p_f = p_i + J = 2.0 + 12 = 14$ kg·m/s, so $v_f = 7.0$ m/s.

PRACTICE 2

Center-of-Mass Velocity

+1.33 m/s.

WHY IT WORKS P = 1(6) + 2(-1) = 4 kg·m/s and M = 3 kg, so $V_{cm} = 4/3$ m/s.

PRACTICE 3

One-Dimensional Elastic Collision

v1f = -2.0 m/s and v2f = +2.0 m/s.

WHY IT WORKS Solving momentum 4 = v1f + 3v2f with kinetic energy $8 = 0.5\ v1f^2 + 1.5\ v2f^2$ gives the nontrivial collision solution.

SOLUTIONS • CONFIDENCE CHECK

QUICK CHECK 1

Derivative Form

5 N.

WHY IT WORKS $F_x = dp_x/dt = 6t^2 - 1$; at $t = 1$, $F_x = 5$ N.

QUICK CHECK 2

Impulse Integral

3 N·s.

WHY IT WORKS $\int_0^3 (4 - 2t)\,dt = [4t - t^2]\_0^3 = 12 - 9 = 3$ N·s.

QUICK CHECK 3

Center-of-Mass Frame

Zero.

WHY IT WORKS By definition, subtracting V_{cm} from every particle velocity makes $\Sigma\, m_i(v_i - V_{cm}) = P - M V_{cm} = 0$.

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