FOCUSED REVIEW

Focused Review: Newton's Laws and Free-Body Diagrams

Express Newton's laws as vector differential equations and use integration or differential-equation models when forces vary with time, position, or velocity.

◷ TIME	◎ BEST FOR	✓ FINISH WITH
15–20 minutes	Focused unit review	Greater confidence

After this focused review, you'll be able to…
move fluently between free-body diagrams, vector differential equations, impulse, and variable-force motion models while preserving the physical meaning of every 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 15–20 minutes

FR-02 • UNIT ALIGNMENT

Unit Alignment

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

ARCHITECTURE: Physics Sensei Independent Mechanics UNIT: MEC-U05 — Newton's Laws and Free-Body Diagrams SCOPE: Unit Review PHYSICS LEVEL: Calculus-Based	BEST USED ✓ Before calculus-based dynamics homework ✓ When forces vary with time or velocity ✓ When you need to connect FBDs to differential equations

Review Prerequisites →

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 15–20 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 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

State Newton second law in differential form.

For constant mass, write Newton's second law using velocity and using momentum.

WARM-UP 2

Common Mistakes

Recognize what an ODE solution needs.

After a free-body diagram gives m dv/dt = F(t), what additional information is needed to determine a unique velocity function?

FR-04 • WARM-UP CHECK CONTINUED

WARM-UP 3

Quick Application

Connect steady motion to zero net force.

For linear drag with downward positive, $m\,dv/dt = mg - bv$. What condition defines terminal speed?

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

The free-body diagram becomes a vector differential equation

Choose a system and write $\Sigma F\_ext = dp/dt$. For constant mass, each component gives $m\ d^2r/dt^2 = \Sigma F(r,v,t)$. The FBD supplies the physics; calculus evolves the state.

$$\Sigma F\_ext = dp/dt$$

EXAMPLE If $F(t) = (6t\ i + 4\ j)$ N on a 2 kg particle, then $dv_x/dt = 3t$ and $dv_y/dt = 2$.

SENSEI NOTE Do not begin with integration before the force model and coordinate directions are correct.

KEY CONCEPT 2

Integrals connect force, momentum, velocity, and position

Integrating net force over time gives impulse and momentum change. Integrating acceleration gives velocity; integrating velocity gives position, with constants fixed by initial conditions.

$$m\ d^2r/dt^2 = \Sigma F(r,v,t)$$

EXAMPLE $J = \int \Sigma F\ dt = \Delta p$. For constant mass, $\Delta v = (1/m)\int \Sigma F\ dt$.

SENSEI NOTE An integral is not decorative calculus; it is required when the force or acceleration varies over the interval.

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

Worked Example

Integrate a time-dependent vector force twice.

A 2.0 kg particle starts from rest at the origin under $F(t) = (6t\ i + 4\ j)$ N. Find $v(2\ s)$ and $r(2\ s)$.

PRACTICE 2

Guided Problem

Solve a first-order drag equation and identify its time scale.

A 1.5 kg object falls from rest with linear drag $b = 3.0$ N·s/m. Take downward positive and use $g = 9.8\ m/s^2$. Find terminal speed and speed at $t = 1.0$ s.

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 8 →

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

Momentum form

Identify the general law.

What is the most general compact form of Newton's second law for a particle system with momentum p?

CONFIDENCE CHECK 2

Impulse from variable force

Integrate force over time.

A 2.0 kg particle initially at rest experiences $F_x = 4t$ *N from t=0 to 3.0 s. What is its final x-velocity?*

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

FBD first, differential equation second

Calculus evolves a correct physical model; it cannot repair a missing or misdirected force.

KEY TAKEAWAY 2

Integrals encode accumulated force effects

Impulse is the time integral of net force and determines momentum change.

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. Replace each placeholder with a concise answer and the essential explanation.

WARM-UP • ACTIVITY 1

Key Ideas

$\Sigma F = m\, dv/dt$ and, more generally, $\Sigma F = dp/dt$.

WHY IT WORKS Force determines the time rate of change of momentum. For constant mass, $dp/dt = m\, dv/dt$.

WARM-UP • ACTIVITY 2

Common Mistakes

An initial velocity (or another equivalent velocity condition).

WHY IT WORKS Integrating acceleration introduces a constant of integration that is fixed by the initial condition.

WARM-UP • ACTIVITY 3

Quick Application

$dv/dt = 0$, so $mg - bv_t = 0$.

WHY IT WORKS Terminal speed is the steady state of the differential equation: acceleration vanishes even though gravity and drag remain nonzero and balanced.

SOLUTIONS • GUIDED PRACTICE

PRACTICE 1

Worked Example

$v(2) = (6\,i + 4\,j)$ m/s; $r(2) = (4\,i + 4\,j)$ m.

WHY IT WORKS $a = F/m = (3t\,i + 2\,j)$ m/s^2. Integrating with $v(0)=0$ gives $v = (1.5t^2\,i + 2t\,j)$. Integrating again with $r(0)=0$ gives $r = (0.5t^3\,i + t^2\,j)$. At $t=2$ s these are (6,4) m/s and (4,4) m.

PRACTICE 2

Guided Problem

$v_t = 4.90$ m/s; $v(1.0\text{ s}) = 4.24$ m/s downward.

WHY IT WORKS $m\,dv/dt = mg - bv$ gives $v(t)=v_t[1-e^{-t/\tau}]$, where $v_t=mg/b=4.90$ m/s and $\tau=m/b=0.50$ s. Thus $v(1)=4.90(1-e^{-2})=4.24$ m/s.

SOLUTIONS • CONFIDENCE CHECK

CONFIDENCE CHECK 1

Momentum form

$\Sigma F_{ext} = dp/dt$.

WHY IT WORKS The momentum form remains the fundamental statement; $m\, dv/dt$ follows for constant mass.

CONFIDENCE CHECK 2

Impulse from variable force

9.0 m/s.

WHY IT WORKS Impulse $J = \int_0^3 4t\, dt = 18$ N·s $= \Delta p$. With $m=2.0$ kg and initial velocity zero, $v = 18/2 = 9.0$ m/s.

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