FULL REVIEW

Full Review: Torque and Rotational Dynamics — Calculus-Based

Review the essential calculus-based ideas, relationships, and problem-solving tools for Torque and Rotational Dynamics.

◷ TIME	◎ BEST FOR	✓ FINISH WITH
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 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-U20** **TOPIC: Torque and Rotational Dynamics** **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

Vector Foundations

State the magnitude and direction rules for $\vec{\tau} = \vec{r} \times \vec{F}$.

Write your response in the space below.

ACTIVITY 2

Calculus Definitions

State α and I in differential/integral form.

Write your response in the space below.

FR-04 • WARM-UP CHECK CONTINUED

ACTIVITY 3

Angular-Momentum Connection

For fixed I about a fixed axis, relate net torque to the rate of change of angular momentum.

Write your response in the space below.

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

Vector Torque

Torque about an origin is $\vec{\tau} = \vec{r} \times \vec{F}$. In component form, the cross product identifies the rotational axis and sign. For planar problems, the z-component often carries the full rotational information.

$$\vec{\tau} = \vec{r} \times \vec{F} \quad \bullet \quad I = \int r^2\, dm \quad \bullet \quad \Sigma\tau = dL/dt$$

EXAMPLE $\vec{r} = x\hat{\imath}$ and $\vec{F} = F_y\hat{\jmath}$ gives $\tau_z = xF_y$.

SENSEI NOTE Choose the origin deliberately; torque is defined about a point or axis.

KEY CONCEPT 2

Deriving Rotational Inertia

For discrete masses, $I = \Sigma m_i r_i^2$. For a continuous body, $I = \int r^2\, dm$, with dm expressed using the appropriate linear, surface, or volume density. The result depends on the chosen axis.

$$\vec{\tau} = \vec{r} \times \vec{F} \quad \bullet \quad I = \int r^2\, dm \quad \bullet \quad \Sigma\tau = dL/dt$$

EXAMPLE For a slender rod, one may write $dm = \lambda\, dx$ and integrate $r^2 dm$ over its length for the specified axis.

SENSEI NOTE Set the coordinate origin at the rotation axis when possible; it simplifies r.

FR-05 • CORE CONCEPTS CONTINUED

KEY CONCEPT 3

Dynamics and Time Evolution

The general rotational statement is $\sum \tau = dL/dt$. For a rigid body about a fixed principal axis with constant I, $L = I\omega$ and $\sum \tau = I\alpha$. If torque varies with time, $\alpha(t) = \tau(t)/I$ and ω changes according to $d\omega/dt = \alpha(t)$.

$$\vec{\tau} = \vec{r} \times \vec{F} \quad \bullet \quad I = \int r^2\, dm \quad \bullet \quad \Sigma\tau = dL/dt$$

EXAMPLE For $\tau(t)=kt$ and constant I, $\omega(t)=\omega_0+(k/2I)t^2$.

SENSEI NOTE Do not apply $\Sigma\tau = I\alpha$ without checking that the fixed-axis, constant-I model is appropriate.

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

Worked Example

Compute the torque for $\vec{r} = (0.40\hat{\imath} + 0.20\hat{\jmath})$ m and $\vec{F} = 10\hat{\jmath}$ N.

Show your setup and reasoning in the space below.

FR-06 • GUIDED PRACTICE CONTINUED

PRACTICE 2

Guided Problem

For constant I, a torque $\tau(t)=4t$ N·m acts from $t=0$ to 3 s on a body with $I=2$ kg·m^2 and $\omega_0=0$. Find $\omega(3)$.

Show your setup and reasoning in the space below.

PRACTICE 3

Independent Problem

A ring and disk have the same M and R about their symmetry axes. The ring has $I=MR^2$ and disk $I=(1/2)MR^2$. If the same torque acts, compare their angular accelerations.

Show your setup and reasoning in the space below.

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

Component Torque

Solve or explain without looking back.

If $\vec{r}$ and $\vec{F}$ are parallel, evaluate $\vec{r} \times \vec{F}$.

QUICK CHECK 2

Variable Torque

Solve or explain without looking back.

For constant I, if $\tau(t)$ increases linearly with time, what is the qualitative shape of $\omega(t)$?

FR-07 • CONFIDENCE CHECK CONTINUED

QUICK CHECK 3

General Law

Solve or explain without looking back.

What rotational law remains valid when angular momentum is the more natural variable?

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

Use the Cross Product

$\vec{\tau} = \vec{r} \times \vec{F}$ determines both the magnitude and axis of the rotational effect.

KEY TAKEAWAY 2

Build I from the Mass Distribution

$I = \int r^2\, dm$ requires a specified axis and an appropriate expression for dm.

KEY TAKEAWAY 3

Torque Changes Angular Momentum

$\sum\tau = dL/dt$ is general; for fixed-axis constant-I rotation it reduces to $\sum\tau = I\alpha$.

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

Vector Foundations

Magnitude is $rF \sin\theta$; direction is perpendicular to the r–F plane by the right-hand rule.

WHY IT WORKS This restores a prerequisite idea used later in the review.

WARM-UP • ACTIVITY 2

Calculus Definitions

$\alpha = d\omega/dt$ and, for a continuous distribution, $I = \int r^2\, dm$ about the chosen axis.

WHY IT WORKS This restores a prerequisite idea used later in the review.

WARM-UP • ACTIVITY 3

Angular-Momentum Connection

$\sum\tau = dL/dt$, and when $L = I\omega$ with constant I, $\sum\tau = I\, d\omega/dt = I\alpha$.

WHY IT WORKS This restores a prerequisite idea used later in the review.

SOLUTIONS • GUIDED PRACTICE

PRACTICE 1

Worked Example

$\vec{\tau} = \vec{r} \times \vec{F}$. The $0.20\hat{j}$ term gives zero cross product with $10\hat{j}$. The $0.40\hat{i}$ term gives $4.0\hat{k}$ N·m, so $\vec{\tau} = 4.0\hat{k}$ N·m.

WHY IT WORKS The solution follows the Unit 20 rotational-dynamics model and a consistent axis/sign convention.

PRACTICE 2

Guided Problem

$\alpha(t)=\tau/I=2t$. Integrate: $\omega(3)=\int_0^3 2t\,dt = [t^2]_0^3 = 9$ rad/s.

WHY IT WORKS The solution follows the Unit 20 rotational-dynamics model and a consistent axis/sign convention.

PRACTICE 3

Independent Problem

$\alpha=\tau/I$. Therefore $\alpha_{disk} = 2\tau/(MR^2)$ while $\alpha_{ring} = \tau/(MR^2)$; the disk has twice the angular acceleration.

WHY IT WORKS The solution follows the Unit 20 rotational-dynamics model and a consistent axis/sign convention.

SOLUTIONS • CONFIDENCE CHECK

QUICK CHECK 1

Component Torque

Zero vector.

WHY IT WORKS The cross product magnitude includes $\sin\theta$, which is zero for parallel vectors.

QUICK CHECK 2

Variable Torque

Quadratic in time, assuming the torque begins from zero and no other torque terms alter the form.

WHY IT WORKS $\alpha(t)=\tau(t)/I$ is linear, and integrating a linear function gives a quadratic $\omega(t)$.

QUICK CHECK 3

General Law

$\sum\tau = dL/dt$.

WHY IT WORKS This is the general torque–angular-momentum relation; $\sum\tau = I\alpha$ is a special fixed-axis form.

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 →	**Go to Practice →**	**Continue →**

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