

ROTATING SYSTEMS DAY 7: FULL UNIT REVIEW

MASTER EQUATION SHEET

Concept	Linear	Rotational
Position	x	θ
Velocity	v	ω
Acceleration	a	α
Inertia	m	I
Cause	F	$\tau = rF \sin \theta$
Newton's 2nd	$\sum F = ma$	$\sum \tau = I\alpha$
Momentum	$p = mv$	$L = I\omega$
Kinetic Energy	$\frac{1}{2}mv^2$	$\frac{1}{2}I\omega^2$
Work	$W = F\Delta x$	$W = \tau\Delta\theta$
Impulse	$F\Delta t = \Delta p$	$\tau\Delta t = \Delta L$
Conservation	$\sum F_{\text{ext}} = 0$	$\sum \tau_{\text{ext}} = 0$
Bridge	—	$v = \omega r, a_t = \alpha r$

Key Insight: This single table IS the unit. Every rotation problem reduces to identifying which rotational concept parallels the linear one you already know.

Physics in the Wild: The Engineer's Rotation Toolkit

A robotics team must choose wheels for a competition bot: solid aluminum (high I , high traction, slow spin-up) or hollow plastic (low I , fast spin-up, less traction). A NASA engineer selects reaction wheels for a satellite. A Formula 1 team picks brake disc material. Every single equation on this review sheet is a tool these designers use for real. Today you practice using the whole toolkit.

1 Quick Retrieval — Fill the Gaps

- (a) $\tau =$
- (b) I for a solid disk about its center =
- (c) For rolling without slipping, $v_{\text{cm}} =$
- (d) Conditions for static equilibrium: AND
- (e) Angular momentum is conserved when
- (f) In the ramp race, the always wins because

MIXED PRACTICE PROBLEMS**2 Kinematics + Dynamics**

A solid disk (mass 3.0 kg, radius 0.20 m, $I = \frac{1}{2}MR^2$) has a string wrapped around it. A constant force of 15 N pulls on the string tangentially.

- (a) Find I .
- (b) Find the torque on the disk.
- (c) Find α .
- (d) Starting from rest, find ω after 4.0 s.
- (e) Find the rotational KE at $t = 4.0$ s.

3 Statics

A 4.0 m uniform beam (mass 20 kg) is supported by a hinge at the left wall and a cable at the right end making 50° with the beam. A 10 kg mass hangs 3.0 m from the wall.

- (a) Find cable tension.
- (b) Find hinge force components.

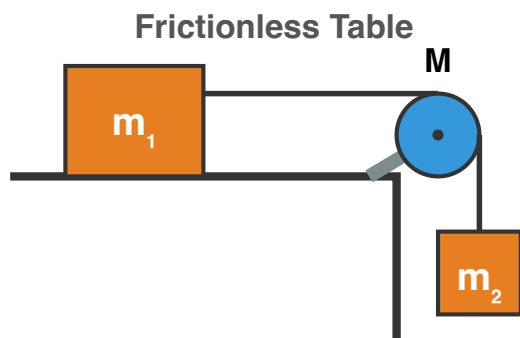
4 Rolling

A solid sphere ($I = \frac{2}{5}MR^2$) and a solid cylinder ($I = \frac{1}{2}MR^2$) (same mass and radius) roll from rest down a 2.5 m high ramp. Which reaches the bottom first? Find each speed at the bottom.

AP-STYLE FRQ PRACTICE

5 Full AP FRQ — Pulley System (15 pts)

A block of mass $m_1 = 4.0$ kg sits on a frictionless table. A string connects it over a solid cylindrical pulley (mass $M = 2.0$ kg, radius $R = 0.10$ m, $I = \frac{1}{2}MR^2$) to a hanging block of mass $m_2 = 6.0$ kg. The string does not slip on the pulley.



(a) (3 pts) Draw separate free-body diagrams for m_1 , m_2 , and the pulley.

(b) (4 pts) Write Newton's Second Law for m_1 and m_2 (using different tensions T_1 and T_2).

(c) (4 pts) Write the torque equation for the pulley. Use the constraint $a = \alpha R$ to express everything in terms of a .

(d) (2 pts) Solve for the acceleration a of the system.

(e) (2 pts) The string is cut. Describe what happens to the pulley's angular velocity. Does angular momentum apply here?

SELF-ASSESSMENT & EXAM PREPARATION

CHECK Confidence Rating

Rate each topic (confident / shaky / lost):

Topic	Rating	Review Day
Angular kinematics (θ , ω , α equations)		Day 1
$v = \omega r$, $a_t = \alpha r$ connections		Day 2
Torque calculation ($\tau = rF \sin \theta$)		Day 3
Static equilibrium ($\sum F = 0$, $\sum \tau = 0$)		Day 4
Rotational inertia ($I = \sum mr^2$)		Day 7
$\tau = I\alpha$ with coupled systems		Day 8
$K_{\text{rot}} = \frac{1}{2}I\omega^2$, $W = \tau\Delta\theta$		Day 1
Rolling without slipping		Day 2
Angular momentum conservation		Day 4

6 Common Mistakes — Error Analysis

Mistake 1: A student claims the tension is the same on both sides of a massive pulley. What's wrong with this reasoning?

Mistake 2: A student says a hoop beats a disk down a ramp because "it has more rotational inertia so more rotational KE." Identify the error.

Exam Tip: On the AP exam, rotation problems almost always require you to either (1) apply $\tau = I\alpha$ to a coupled system, (2) use energy conservation with K_{rot} , or (3) use angular momentum conservation. Identify which approach the problem is asking for BEFORE you start calculating.

Reflection: What topic from this unit are you least confident about? Write one specific question for your study session.

Tomorrow: Unit Test. Calculator allowed. Equation sheet provided. Show ALL work on FRQs for full credit.