Name: ____________ Date: ____________ Period: ____________

# ROTATION DAY 12: FULL UNIT REVIEW

## MASTER EQUATION SHEET

| Concept | Linear | Rotational |
|---|---|---|
| Position | $x$ | $\theta$ |
| Velocity | $v$ | $\omega$ |
| Acceleration | $a$ | $\alpha$ |
| 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 $\alpha$.
(d) Starting from rest, find $\omega$ 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.

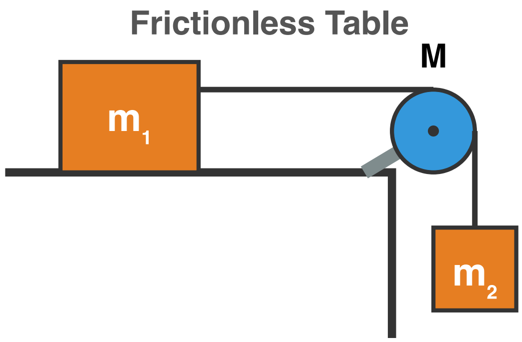
### 4 Rolling

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 ($\theta$, $\omega$, $\alpha$ 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 9 |
| Rolling without slipping | | Day 10 |
| Angular momentum conservation | | Day 11 |

### 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 $K_{\text{rot}}$, 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.