Department of Physics

Problem Set 3: Rotational Dynamics

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Due date: *August 27, 2026*

A uniform solid disk of mass M and radius R rolls without slipping down an incline of angle θ. Find the linear acceleration of the disk's center of mass.

Solution

The disk has moment of inertia $I = \frac{1}{2}MR^2$ about its center. With rolling without slipping, $a = R\alpha$. Newton's second law along the incline and the rotational equation about the center give:

$$Mg\sin\theta - f = Ma,$$
$$fR = I\alpha = \tfrac{1}{2}MR^2 \cdot \frac{a}{R}.$$

Solving the pair for a:

$$a = \frac{2}{3}g\sin\theta.$$

Two blocks of mass m_1 and m_2 are connected by a massless string over a frictionless, massless pulley. Derive the acceleration of the system and the tension in the string.

Solution

Let $m_1 > m_2$, so m_1 descends. Newton's second law for each block:

$$m_1 g - T = m_1 a,$$
$$T - m_2 g = m_2 a.$$

Adding the two equations eliminates T:

$$a = \frac{(m_1 - m_2)g}{m_1 + m_2}, \qquad T = \frac{2m_1 m_2 g}{m_1 + m_2}.$$

1. Conceptual questions

1. Why does the rolling disk in Problem 1 accelerate more slowly than a block sliding down the same frictionless incline ($a = g\sin\theta$)?
2. What happens to the tension T in Problem 2 in the limit $m_1 = m_2$? Does that match your physical intuition?