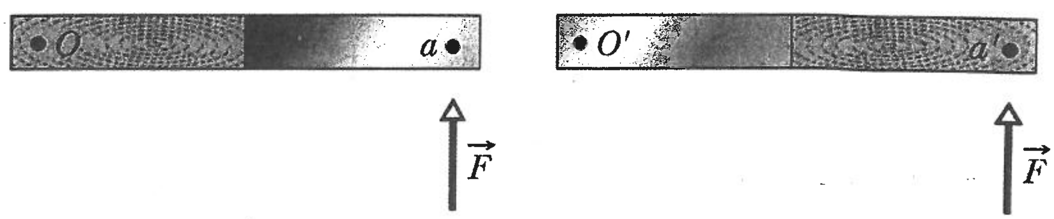
Physics 4A
Fall 2023

Name Answer Key

Lab: 8:00 am 11:15 am 2:30 pm (circle one)

Quiz #10: Rotation of a Rigid Body

Problem 1 (2 points)
The figure below shows two overhead views of a meter stick that is lying on a frictionless surface. In figure (a), a meter stick that is half wood and half steel is pivoted at the wood end at point O. A force $\vec{F}$ is applied to the steel end at point a. In figure (b), the stick is reversed and pivoted at the steel end at point O', and the same force is applied at the wooden end at point a'. Is the resulting angular acceleration of figure (a) greater than, less than, or the same as that of figure (b)?



(a) (b)

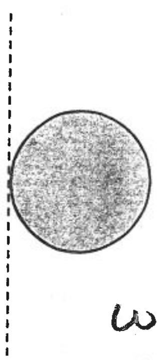
B

(a) greater than
(b) less than
(c) the same as

τ is the same in each case but $I_a > I_b$

so $\alpha_A < \alpha_B$

Problem 2 (3 points)
A solid sphere of mass 1.25 kg and radius 0.40 m is rotated around a vertical axis about one end (see the figure below) at an angular speed of 25.0 rev/min. What is the rotational kinetic energy of the sphere?



$I_{\text{solid sphere}} = \frac{2}{5}MR^2$ (about the COM)

for an axis at one end $I = \frac{2}{5}MR^2 + MR^2 = \frac{7}{5}MR^2$

$I = \frac{7}{5}(1.25\text{ kg})(0.40\text{ m})^2 = 0.28\text{ kg m}^2$

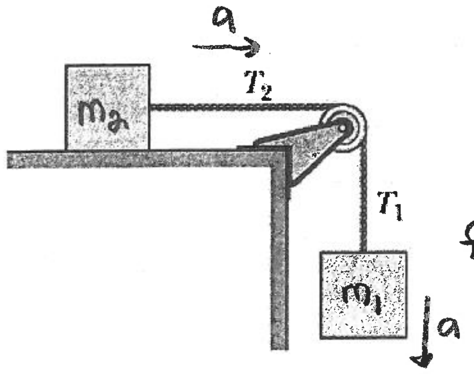
$\omega = 25.0\text{ rev/min}\left(\frac{2\pi\text{ rad}}{1\text{ rev}}\right)\left(\frac{1\text{ min}}{60\text{ s}}\right) = 2.62\text{ rad/s}$

$K_{rot} = \frac{1}{2}I\omega^2$

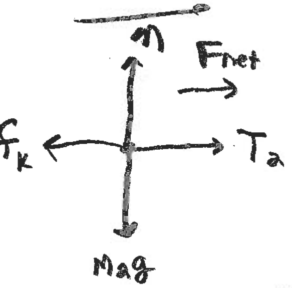
$= \frac{1}{2}(0.28\text{ kg m}^2)(2.62\text{ rad/s})^2$

$K_{rot} = 0.960\text{ J}$

Problem 3 (5 points)
In the figure below, block 2 of mass $m_2 = 5.75$ kg rests on a surface. The coefficient of kinetic friction between block 2 and the surface is 0.45. Block 2 is attached to block 1 ($m_1 = 3.50$ kg) by a massless, stretchless string that passes over a frictionless pulley of mass 2.0 kg and radius R = 15.0 cm. What is the magnitude of the acceleration of each block and the magnitudes of T_1 and T_2? (Note: you must draw FBDs and show all work to get full credit.)



block 2:



$\sum_i F_y = ma_y = 0$

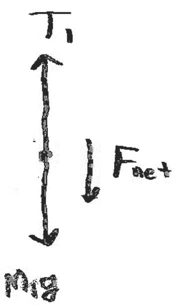
$n = m_2 g$

$\sum_i F_x = ma_x$

$T_2 - f_k = m_2 a_x \qquad f_k = \mu_k n = \mu_k m_2 g$

$T_2 = m_2 a + \mu_k m_2 g \qquad (1)$

block 1:

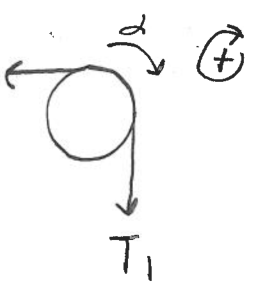


define down as +:

$\sum_i F_y = ma_y$

$m_1 g - T_1 = m_1 a \rightarrow T_1 = m_1 g - m_1 a \qquad (2)$

pulley:



$\sum_i \tau = I\alpha$

$T_1 R \sin 90 - T_2 R \sin 90 = (\frac{1}{2} MR^2)(a/R)$

$T_1 - T_2 = \frac{1}{2} Ma \qquad (3)$

put (1) + (2) → (3) $\quad (m_1 g - m_1 a) - (m_2 a + \mu_k m_2 g) = \frac{1}{2} Ma$

$$a = \frac{m_1 g - \mu_k m_2 g}{m_1 + m_2 + \frac{1}{2}M} = \frac{(3.50\text{kg})(9.80\text{ m/s}^2) - (0.45)(5.75\text{kg})(9.80\text{ m/s}^2)}{3.50\text{kg} + 5.75\text{kg} + \frac{1}{2}(2.0\text{kg})}$$

$\boxed{a = 0.872\text{ m/s}^2}$

$T_1 = m_1(g - a) = (3.50\text{kg})(9.80\text{ m/s}^2 - 0.872\text{ m/s}^2) = \boxed{31.2\text{ N}}$

$T_2 = m_2(a + \mu_k g) = (5.75\text{kg})[0.872\text{ m/s}^2 + (0.45)(9.80\text{ m/s}^2)] = \boxed{30.4\text{ N}}$