

## PHYSICS 105 FIRST MIDTERM EXAM

October 25, 2007

This exam consists of **four** problems. When we begin, check to see that this copy of the exam has all four. Use the same exam booklet for all problems, continuing to another booklet if necessary. **Print** your name on **each** booklet as you start it. On the cover of your first booklet, **COPY** and **SIGN** the following pledge:

*I pledge my honor that I have not violated the Honor Code during this examination.*

At the end of the exam, indicate clearly on the cover of your first exam booklet how many booklets you used.

Some useful test-taking hints:

- You may not be able to complete every problem. Keep moving – do what you know first.
- Make it clear what your answer is by circling it.
- Use symbols rather than numbers wherever possible and check units.
- Whenever possible, check whether an answer or intermediate result makes sense before moving on.
- If you get stuck on an early part of a problem, check the later parts — some may be independent and doable.
- If you get stuck on an early part of a problem, and a later part depends on it, **clearly** define a symbol for the unknown answer and use it in later parts. However, keep in mind that we often give multiple parts to guide you through a problem.
  
- **To get full credit you need to show your work!**

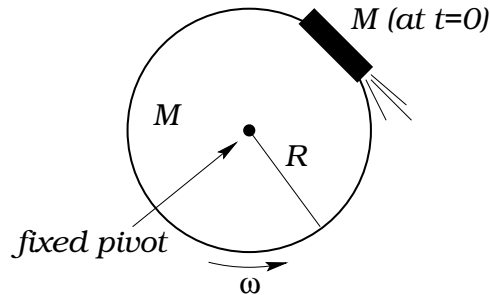
**The exam will last 1.5 hours: 7:30-9:00 PM**

**Good luck!**

**Problem 1.** [10 points] A string is wrapped around a cylinder of radius  $R$  and mass  $m$ . You then hold onto the string with your fingers and drop the cylinder so that the string neatly unwinds and so that the axis of symmetry of the cylinder remains horizontal. While the string is unwinding from the cylinder, what is the tension your fingers feel? Please give your answer in terms of  $m$  and  $g$ .

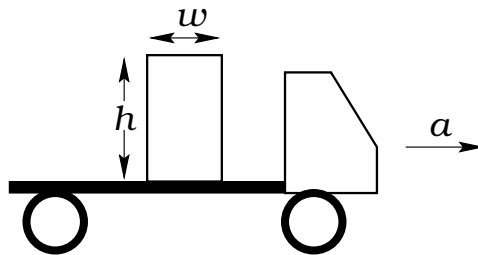
**Problem 2.** [20 points] A fireworks pinwheel is made from a uniform disk of mass  $M$  and radius  $R$  ( $I_{cm} = \frac{1}{2}MR^2$ ), nailed (with a frictionless nail) through its center to a post. The disk is horizontal – you can ignore gravity. A rocket engine, also of mass  $M$  but of negligible size, is attached to the edge of the disk, pointing tangentially. The mass of the casing of the rocket is negligible, so the initial mass of rocket fuel is  $M$ . When the rocket is burning, it ejects fuel with exhaust velocity  $u$  **with respect to the rocket**.

- [10 points] Derive a (differential) equation for the angular acceleration  $d\omega/dt$  in terms of the rate of fuel burned,  $dm/dt$ , and the other parameters of the problem.
- [10 points] If the pinwheel starts from rest, what is its final angular velocity  $\omega_f$ ?



**Problem 3.** [10 points] A rectangular crate of height  $h$  and width  $w$  sits on the back of a flatbed truck, as shown. If the coefficient of static friction between the truck bed and crate is large enough to keep the crate from slipping, how fast can the truck accelerate before the crate topples over? (Hint: draw a free-body diagram for the case when the crate is **just about** to topple.)

(As with some other problems we have worked on, this problem can be attempted using “fictitious forces.” Since we haven’t developed these methods in 105, you may use them here only if you **derive** the method first.)



**Problem 4.** [20 points]

A ball of mass  $M$  is dropped from rest at a height  $h$  above the ground. The ball hits the ground and bounces back up to a height  $kh$  where  $0 < k \leq 1$ . You may assume that  $h$  is much larger than the radius of the ball.

- a) [5 points] What is the impulse,  $J_y$ , on the ball from the collision with the ground?

For part b, the same ball is dropped again from the same height only this time it is given an initial angular velocity. Thus, when it hits the ground, it bounces off to the right (positive  $x$  direction) a distance  $d$  as shown below. The impulse in the  $y$  direction,  $J_y$ , is unchanged. In the collision with the ground, the ball briefly experiences a horizontal frictional force with kinetic coefficient  $\mu$ . Assume that  $h$  and  $d$  are much larger than the radius of the ball.

- b) [15 points] What is  $\mu$  in terms of  $h$ ,  $k$ , and  $d$  and any other parameters you may need? Note that the angular velocity of the ball after the collision is unknown.

