# Centrifugal Force and Friction

***Roger F. Larson,*** Yokota High School, PSC 78, Box 4321, APO AP 96326; larsonrj@yta.attmil.ne.jp

Many physics teachers utilize turntables and coins to measure and compare centrifugal force with frictional forces. However, if you have access to a Rotary Motion Probe (RMP) you may want to try the following investigation in your physics lab.

Direct your students to predict and then measure the speed at which a washer will fly off a rod undergoing rotational acceleration. The theoretical speed at which the washers fly off the rod is predicted by equating the force of static friction $F_f$ to the centrifugal force $F_c$.

$$F_F = F_C$$

$$\mu\, mg = mv^2/r$$

$$v = (r\mu g)^{0.5} \qquad (1)$$

Thus, to predict the critical speed $v$, measure the coefficient of static friction $\mu$, the radius $r$, then apply Eq. (1) above.

To begin, zero the RMP using gravity to ensure a vertical orientation (see Fig. 1). Next rotate the rod so that it is horizontal, slip a washer on the rod, and tilt the rod slowly until the washer begins to slide (see Fig. 2). The RMP can read angles with a resolution of 0.25 degrees. Using the $\mu = \tan\theta$ relationship, calculate the coefficient of static friction between washer and rod.

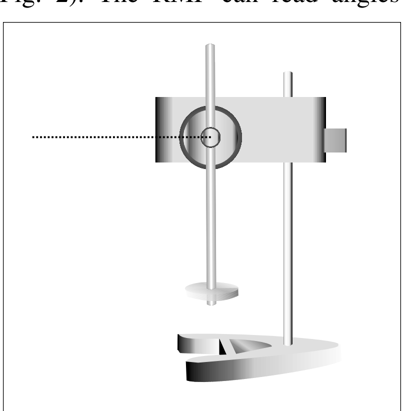

Fig. 1.

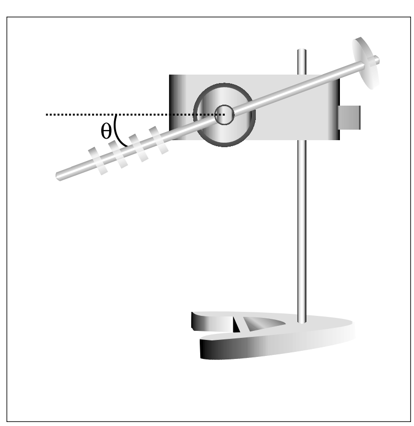


Fig. 2.

Now mount the RMP on a table so that its rod will spin horizontally (see Fig. 3). Place a metal washer near each end of the rod using the predetermined radial distance. Wrap a thread several times around the RMP pulley and attach a large paper clip to the other end as shown. As the paper clip falls, the rod accelerates and a few seconds later the washers slide off the rod. The centrifugal force has exceeded the force of static friction.

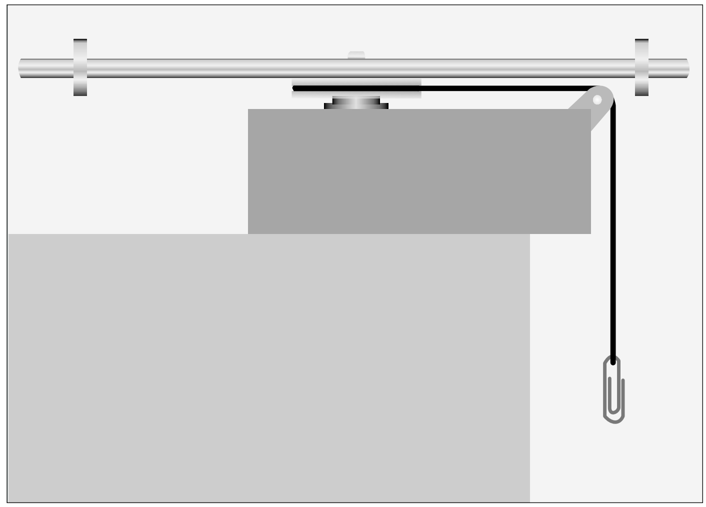

Fig. 3.

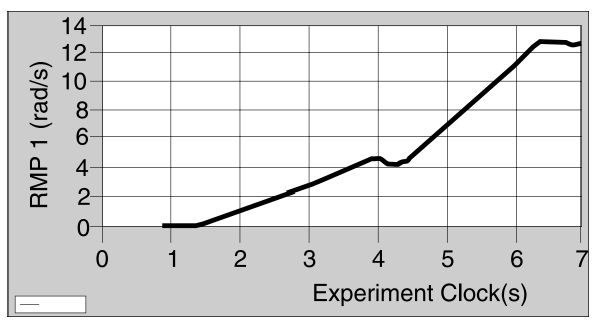


Fig. 4.

The resulting graph of angular velocity versus time is shown in Fig. 4. My physics students have been impressed with the amount of information inherent in their real-time

| | |
|---|---|
| **Slide angle ($\theta$)** | 12.3° |
| **$\mu = \tan\theta$** | 0.22 |
| **Radius** | 0.13 m |
| **Theoretical speed** | 0.52 m/s |
| **Measured speed ($\omega$)** | 4.2 radians/s |
| **Measured speed** | |
| **($v = \omega r$)** | 0.54 m/s |
| **Difference in speeds** | 4% |

**Table I. Sample data.**

graph. The point of inflection that occurred at 4 s indicates that the centrifugal force exceeded the force of friction and is thus an indicator of the measured critical speed (4.2 radians/s). The brief period of negative slope following that point is a result of an increase in rotational inertia as the washers begin to slide outward along the rod. An increase in acceleration of the rod is also apparent from the larger slope of the velocity-time graph after the washers fly off the rod. At 6.3 s the paper clip hit the floor.

Considering the uncertainties of determining static friction, I was pleased to obtain a difference of only 4% between the theoretical and measured critical speed for the washer when it overcomes static friction (see Table I). This investigation is just one of 40 probe-based physics activities soon to be published in a lab guide by Team Labs Corporaton.

## Reference

1. Rotary Motion Probe and accessory kit are available from Team Labs Corporation, 6859 North Foothills Highway, Building D200, Boulder, CO 80302; cost: $237.