Experiment 9: Moments of Inertia

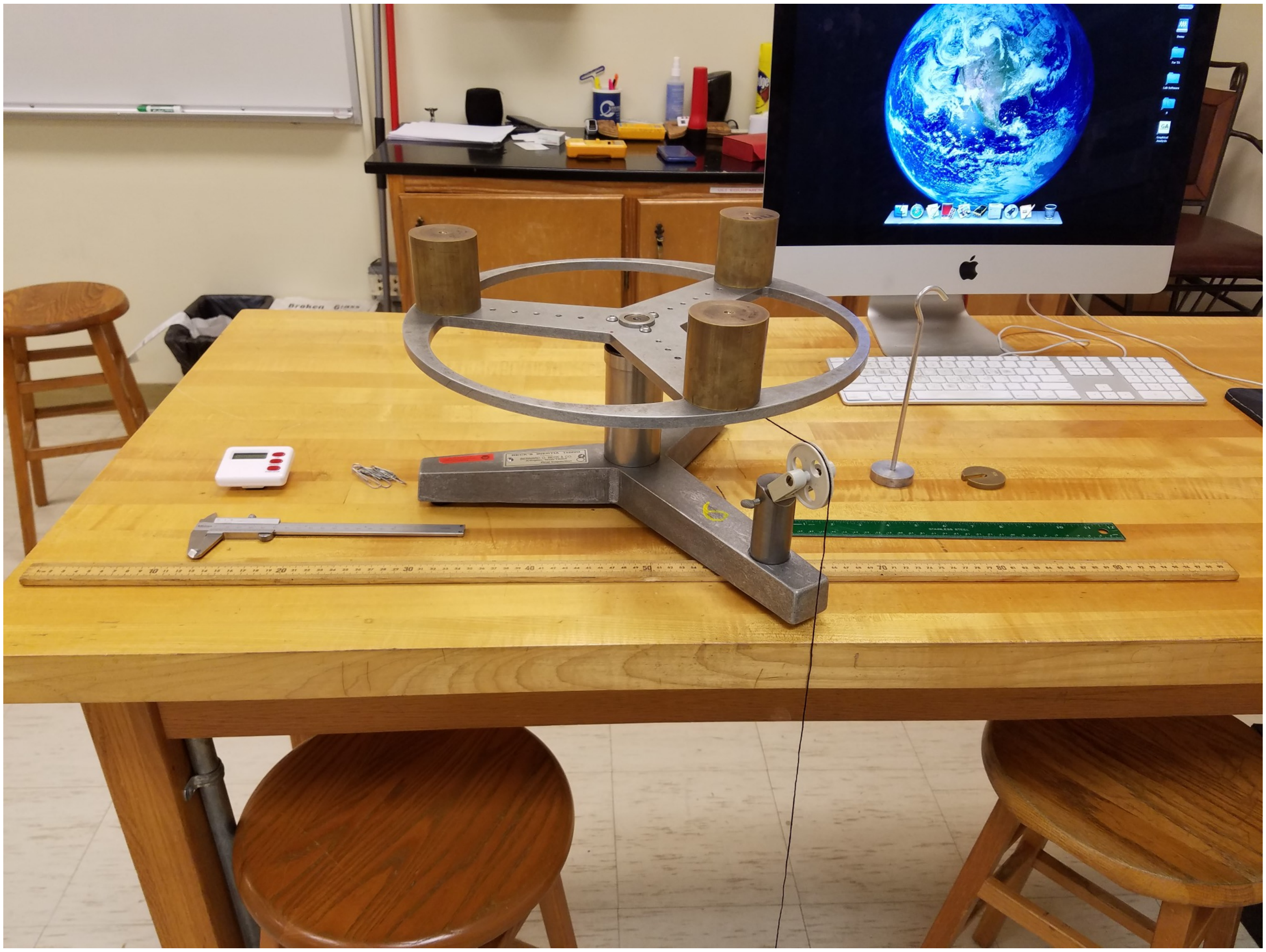

Figure 9.1: Beck's Inertia Thing with masses

EQUIPMENT

Beck's Inertia Thing
Vernier Caliper
30cm Ruler
Paper Clips
Mass Hanger
50g Mass
Meter Stick
Stopwatch

Advance Reading

Text: Torque, Rotational Motion, Moment of Inertia.

Objective

To determine the moment of inertia of a rotating system, alter the system, and accurately predict the new moment of inertia .

Theory

Moment of Inertia (I) can be understood as the rotational analog of *mass*. **Torque** (τ) and **angular acceleration** (α) are the rotational analogs of *force* and *acceleration*, respectively. Thus, in rotational motion, Newton's Second Law:

$$F = ma \tag{9.1}$$

becomes:

$$\tau = I\alpha. \tag{9.2}$$

An object experiencing constant angular acceleration must be under the influence of a constant torque (much like constant linear acceleration implies constant force). By applying a known torque to a rigid body, measuring the angular acceleration, and using the relationship $\tau = I\alpha$, the moment of inertia can be determined.

In this experiment, a torque is applied to the rotational apparatus by a string which is wrapped around the axle of the apparatus. The tension **T** is supplied by a hanging mass and found using Newton's second law.

Figure 9.2: String wrapped around axle.

If we take the downward direction as positive, and apply Newton's second law, we have:

$$\Sigma F = mg - T = ma \tag{9.3}$$

so the tension is

$$T = m(g - a) \tag{9.4}$$

The rotational apparatus has an original moment of inertia I_0 **with no additional masses added.** When additional masses are added, it has a new moment of inertia I_{new}. The added masses effectively behave as *point masses*. The Moment of Inertia for a point mass is $I_p = MR^2$, where M is the mass and R is the radius from the point about which the mass rotates. Thus, the relationship between I_0 and I_{new} is given by

$$I_{new} = I_0 + I_{p1} + I_{p2} + ... = I_0 + M_1R_1^2 + M_2R_2^2 + ... \tag{9.5}$$

where M is an added mass and R is the distance of this mass from the center of the wheel (i.e. from the axis of rotation). So, if multiple masses are added at the same radius, we have

$$I_{new} = I_0 + \Sigma I_p = I_0 + (\Sigma M)R^2 \tag{9.6}$$

In comparing this to Eq. 9.1, we consider that all masses, along with the disk, experience the same *angular acceleration*. If we were looking for the *Force* on a system of connected masses all experiencing the same acceleration, we would simply sum the masses and multiply by *acceleration* (i.e. a stack of boxes being pushed from the bottom). Similarly, when looking for the *Torque* on a system, we must sum the moments of inertia and multiply by *angular acceleration*.