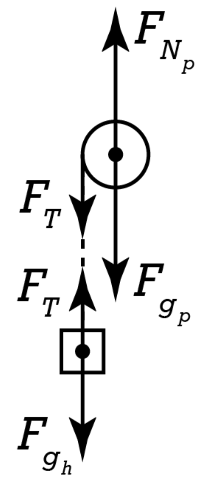
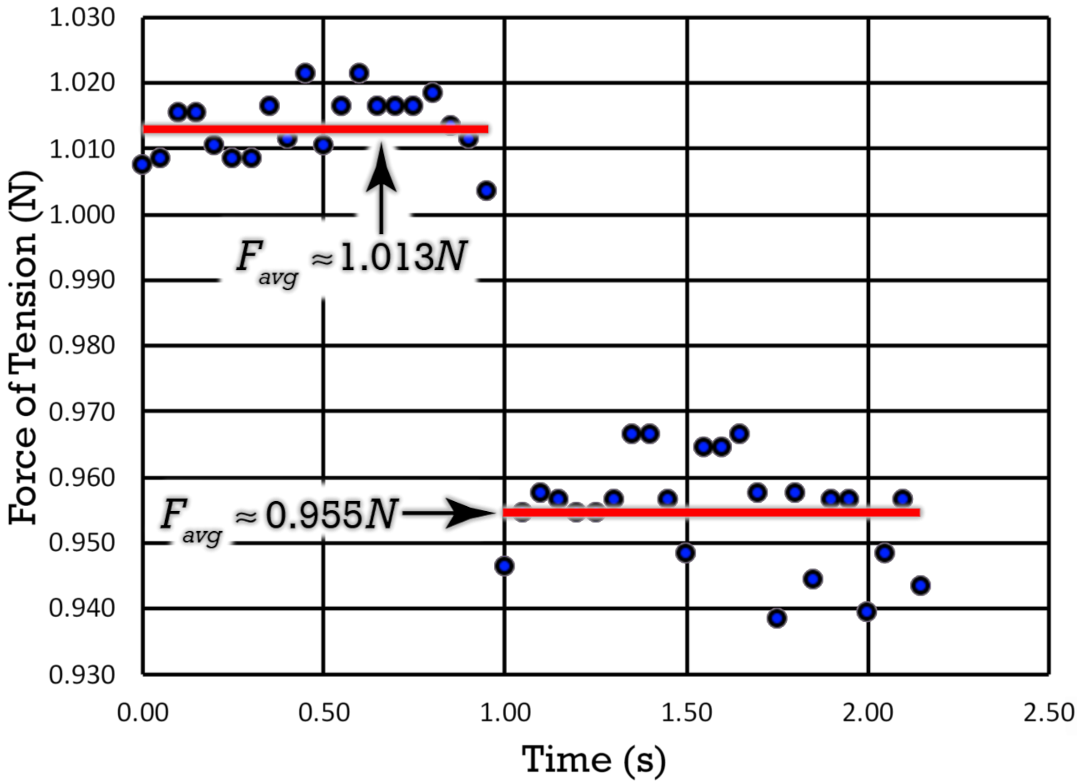
Flipping Physics Lecture Notes:

How the Force of Tension on a Pulley Changes with Angular Acceleration

Previously we determined the rotational inertia of the Rotational Inertia Demonstrator from Arbor Scientific. In order to do so, we measured the force of tension acting on the mass hanging which has the same magnitude as the force of tension acting on the pulley. Let's take a look at how the force of tension changes depending on the angular acceleration of the pulley. We need to start, of course, with free body diagrams. Remember we defined counterclockwise, or out of the board, as the positive torque direction.



Here is the graph for the measured force of tension as a function of time for the first trial:



The hanging mass is released just before 1.00 seconds. The acceleration of the system before that is zero because the system is at rest. Therefore:

$$\sum F_{y\,mass} = F_g - F_T = ma_y = m(0) = 0 \Rightarrow F_T = F_g = mg = (0.103)(9.81) = 1.01043 \approx 1.01N$$

After the hanging mass is released, the force of tension changes because the acceleration of the system is no longer zero:

$$\sum F_{y\,mass} = F_g - F_T = ma_y \Rightarrow F_T = F_g - ma_y = mg - ma_y = m(g - a_y)$$

Be careful of direction here. Remember, we defined counterclockwise or out of the board as positive, therefore, the direction the hanging mass is moving is the positive direction. This is why the force of gravity and acceleration of the hanging mass are both positive when we sum the forces. The way we determine the linear acceleration of the hanging mass is by using the tangential acceleration equation.

$$a_y = a_t = r\alpha = R\alpha$$

$$\Rightarrow F_T = m(g - R\alpha) = (0.103)(9.81 - (0.0202)(29.910)) = 0.948199 \approx 0.948N$$

This predicted value compares quite well to our average force of tension measurement of 0.955 N.