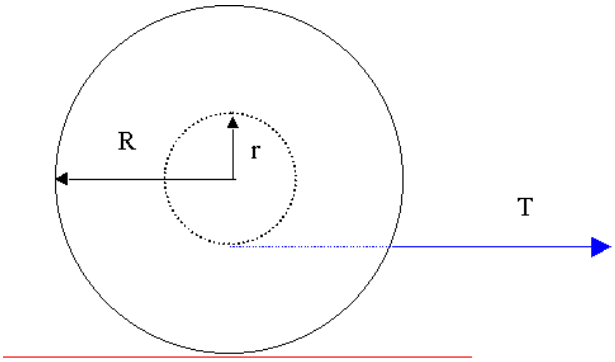
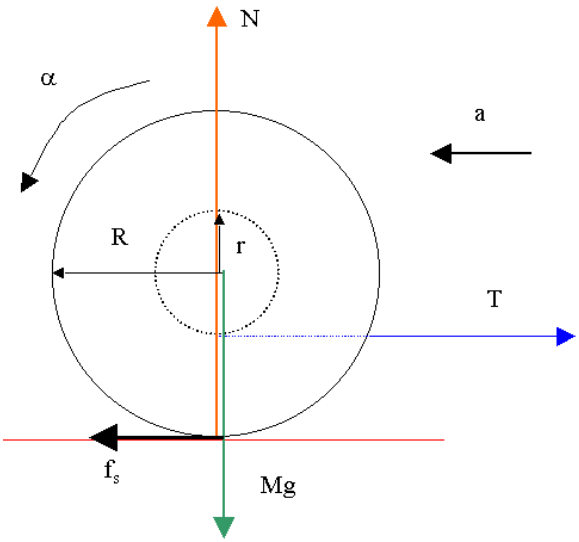
**Answer on Question #52822-Physics-Other**

A yo-yo of Mass M, moment of inertia I, and inner and outer radii r and R, is gently pulled by a string with tension T as shown in the diagram below. Find the linear acceleration.




**Solution**

We know there is a normal and weight acting on the yo-yo but these do not create torques as they operate on or through the Centre of Mass. There is non-maximum static friction acting but we must determine its direction. First if there were no T, there would be no friction. T is twisting the yo-yo counterclockwise pushing the yo-yo into the surface. The surface reacts by pushing back. The free-body diagram looks like




Here I have guessed that the yo-yo will roll backwards. Notice that my choice of a and α are consistent.

I apply Newton's Second Law

$$\Sigma F_x = ma_x;\ \Sigma F_y = ma_y;\ \Sigma \tau_{cm} = I_{cm}a_{cm}$$

$$T - f_s = -Ma;\ N - Mg = 0;\ rT - Rf_s = I\alpha$$

We also know a = Rα .

The torque equation becomes can be solved for $f_s$

$$f_s = \left(\frac{r}{R}\right)T - \left(\frac{I}{R^2}\right)a\ .\ (1)$$

We substitute this into the x-component equation

$$T - \left[\left(\frac{r}{R}\right)T - \left(\frac{I}{R^2}\right)a\right] = -Ma. (2)$$

We bring the term involving a from the left to the right and solve for a in terms of T,

$$\frac{T(R-r)}{R} = -\left(M + \frac{I}{R^2}\right)a. (3)$$

or

$$a = -\frac{(R-r)R}{MR^2 + I}T.$$

The fact that $a$ is negative tells me that my guess about the direction of $a$ and $\alpha$ are wrong. The acceleration is forward and counterclockwise.