05. Applying Newton's Second Law to Rolling Motion

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The child at the top is pretending to be a steamroller by pushing a 24 kg, 0.60 m radius cylindrical object around his backyard. The boy pushes horizontally with a force of 70 N. The coefficient of friction between the cyclinder and the ground is (0.5, 0.4).

Let's draw a free-body diagram and write Newton's second law in the x-, y-, and q-directions.

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x-direction y-direction q-direction

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Note that the description does not specify whether the cylinder *rolls* or *skids* when the child pushes it. We will have to make an assumption, continue with the calculation, and then check our assumption for validity. Let's assume that the bottom of the cyclinder *does not slip* in its contact with the ground, which means the cylinder rolls without slipping around the backyard.

If the cyclinder bottom does not slip in its contact with the ground, the horizontal acceleration (and velocity) of the cyclinder bottom must equal zero. Since the acceleration of the cylinder bottom is the sum of the acceleration due to translation of the CM and the acceleration due to rotation about the CM, for the bottom to have zero horizontal acceleration means that the acceleration due to rotation,

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must be equal in magnitude, and opposite in direction, to the translational acceleration of the CM. Thus,

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Combining this with our y- and q-equations yields:

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This pair of equation has the solution

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Now we must check the validity of our assumption. If the cylinder rolls without slipping, the frictional force is static. Thus,

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Since our calculated value for $F_{friction}$ is less than 118 N, the cyclinder does remain in static contact with the ground during its motion, our assumption is validated, and our numerical results are correct.