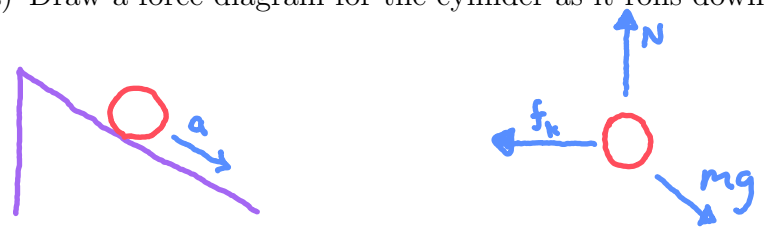
Problem 1

A solid cylinder is released from rest at the top of a ramp, and it rolls without slipping down the ramp. The coefficient of friction between the cylinder and the ramp is μ_s, and the ramp's angle of incline is θ above the horizontal.

(a) Draw a force diagram for the cylinder as it rolls down the ramp.



(b) Derive an expression for the linear acceleration a of the cylinder as it rolls without slipping down the ramp.

$$\Sigma F_x = mg\sin\theta - f_s = ma$$

$$\Sigma\tau = I\alpha \qquad f_s R = I\alpha \rightarrow f_s = \frac{I\alpha}{R} = \frac{Ia}{R^2}$$

$$\frac{f_s}{a} = \frac{I}{R^2} \qquad I = \tfrac{1}{2}MR^2$$

$$a = \frac{f_s R^2}{I} = \frac{f_s R^2}{\frac{1}{2}MR^2} = \frac{2f_s}{M}$$

(c) Perform a unit check on your answer above.

$$m/s^2 = \frac{m^2}{N/s} = \frac{m^2}{\frac{kg}{\frac{m}{s^2}}} = \frac{m}{\frac{kg}{s}}$$

(d) Suppose that we replace the solid cylinder with a hollow, thin-walled cylinder. How would this affect the linear acceleration you found in (b)? No calculations necessary. Discuss this **qualitatively** within your group.

(e) By what factor will the object's linear acceleration change when we replace the solid cylinder with a hollow, thin-walled cylinder?