$$F(b-R) + Ma_x R = -\frac{I}{R} a_x$$

$$a_x \left(MR + \frac{I}{R}\right) = F(R-b)$$

$$a_x = \frac{R-b}{MR+\frac{I}{R}} F$$

$$\boxed{a_x = \left(1-\frac{b}{R}\right)\left(\frac{F}{M+\frac{I}{R^2}}\right)}$$

> 0 , $I > 0$ reduces a_x

B : $I'\alpha = -F(R-b) = -I' \frac{a_x}{R}$

$$I' = I + MR^2$$

$$F(R-b) = \left(I+MR^2\right) \frac{a_x}{R}$$

$$a_x = \frac{R(R-b)}{I+MR^2} F$$

$$\boxed{a_x = \left(1-\frac{b}{R}\right)\left(\frac{F}{M+\frac{I}{R^2}}\right)}$$

Energy in Translational Motion

Translational: $\frac{1}{2} M v_{cm}^2$

Rotational $\frac{1}{2} I_{cm} \omega^2$

No slipping: $\omega R = v_{cm}$

$$\frac{1}{2} M v_{cm}^2 + \frac{1}{2} I_{cm} \left(\frac{v_{cm}}{R}\right)^2$$

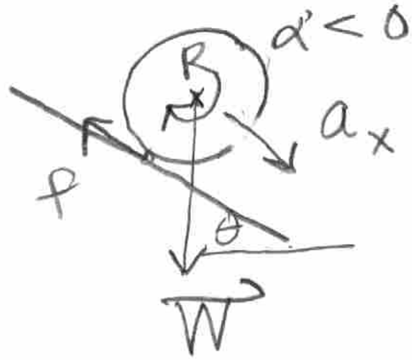
$$= \frac{1}{2}\left(M + \frac{I_{cm}}{R^2}\right) v_{cm}^2$$

$$Mgh = \frac{1}{2}\left(M + \frac{I_{cm}}{R^2}\right) v_{cm}^2$$

$$v_{cm} = \left[\frac{2gh}{1 + \frac{I_{cm}}{MR^2}}\right]^{1/2}$$

Demonstration

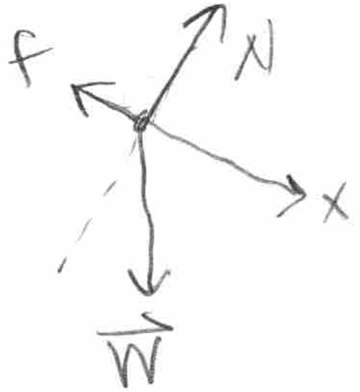
Does not address friction necessary to achieve rolling...



$a_x = -\alpha R$

x component of $\vec{W}$

$= Mg \sin\theta$



x: $Mg\sin\theta - f = Ma_x$

y: $N - Mg\cos\theta = 0$

$N = Mg\cos\theta$

$f < \mu_s N = \mu_s Mg\cos\theta$

Now solve for f

Use c.m. as rotation point.

$$I_{cm}\alpha = -fR = -I_{cm}\frac{a_x}{R}$$

$$\text{or } a_x = +\frac{fR^2}{I_{cm}}$$

$$Mg\sin\theta - f = \frac{MR^2}{I_{cm}} f$$

$$f = \frac{\cancel{Mg}\sin\theta}{1 + \frac{MR^2}{I_{cm}}} < \mu_s \cancel{Mg}\cos\theta$$

$$\tan\theta < \mu_s\left(1 + \frac{MR^2}{I_{cm}}\right)$$

rotation enables "steeper" incline, but remember, it rolls.

ball... $I_{cm} = \frac{2}{5}MR^2$

$$\tan\theta < \mu_s\left(1 + \frac{MR^2}{\frac{2}{5}MR^2}\right)$$

$$\boxed{\tan\theta < \frac{7}{2}\mu_s}$$