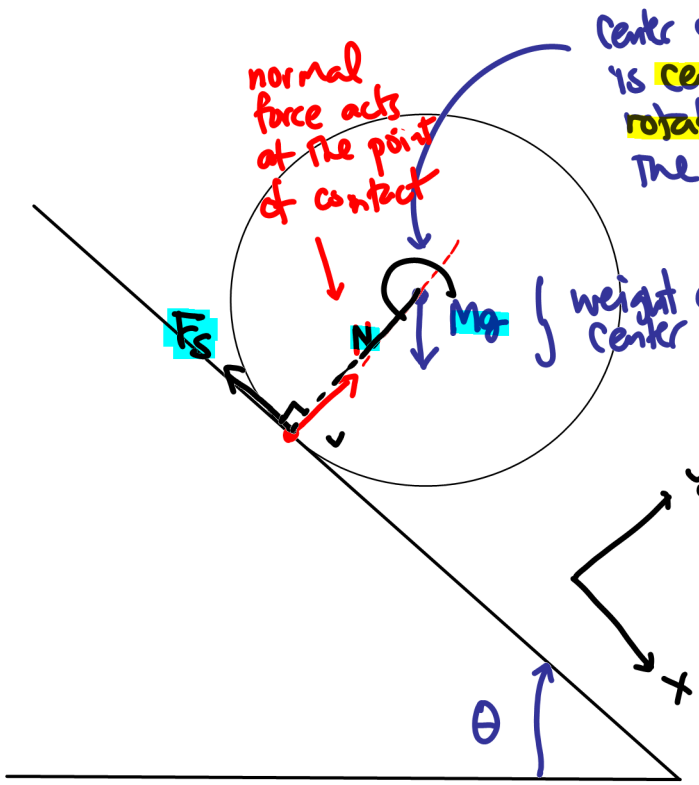


RIGID CYLINDER ROLLING DOWN A RIGID RAMP WITHOUT SLIPPING

no relative motion between the cylinder and the ramp at the point of contact

Neither Mg nor N generates a torque at center of rotation.
↳ for the problem to be no-slip, there must be a static friction force

- no motion in y-direction → $\Sigma F_y = 0 \rightarrow N = Mg\cos\theta$ (unlikely to be related to N. (not max))
- there is motion in x-direction → $\Sigma F_x = Mg\sin\theta - F_s = ma$
  (translational motion in x-direction)
- (+) rotational motion

$$I = r \cdot F_s = I\alpha$$

$r \cdot F_s$: torque generated by the static friction
$I\alpha$: rotational motion
the only force that generates torque

no slipping: $\alpha = \frac{a}{r}$

(1) $Mg\sin\theta - F_s = ma$

(2) $r \cdot F_s = I\alpha$

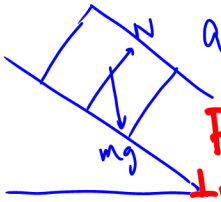
for a cylinder $I = \frac{1}{2}Mr^2$

$\therefore F_s = \left(\frac{1}{2}Mr^2\right)\left(\frac{a}{r}\right)$

$F_s = \frac{1}{2}Ma$ ← substitute back into (1)

$Mg\sin\theta - \frac{1}{2}Ma = Ma$

$g\sin\theta = \frac{3}{2}a \rightarrow a = \frac{2}{3}g\sin\theta$



$F_s \le \mu_s N = \mu_s Mg\cos\theta$

$\frac{1}{2}Ma \le \mu_s Mg\cos\theta$

as long as $F_s \le \mu_s N$

The cylinder rolls slower than when it slides down without friction