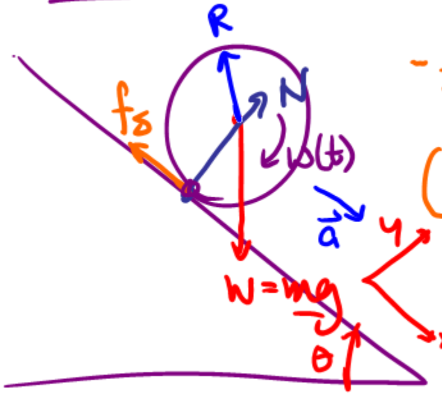
NO SLIPPING, RAMP BALL



- f_s allows the ball to rotate
(without friction, the ball slides rather than rotate)

- Neither N nor W generate a torque about the CM
- τ_{net} comes from f_s alone.

$f_s \leq \mu N$

$$\sum F_y = 0 \rightarrow N = mg\cos\theta$$

evaluated at CM.

$$\boxed{\sum F_x = mg\sin\theta - f_s = ma}$$

Translational Problem

evaluated at CM

$a = \alpha R$

$$\tau = I\alpha$$

$$\boxed{f_s \cdot \cancel{R} = \left(\frac{2}{5}m\cancel{R^2}\right)\left(\frac{a}{\cancel{R}}\right)}$$

Rotation Problem

only applies because there is no slippage

$$f_s = \frac{2}{5}ma$$

as long as $f_s \leq \mu N$

$$\cancel{m}g\sin\theta - \underbrace{\frac{2}{5}\cancel{m}a = \cancel{m}a}$$

$$g\sin\theta = \frac{7}{5}a \rightarrow \boxed{a = \frac{5}{7}g\sin\theta}$$

Constant

$$\alpha = \frac{a}{R}$$

$$\boxed{X = X_0 + V_0 t + \frac{1}{2}at^2}$$

$$\boxed{\omega = \omega_0 + \alpha t}$$

$$\mu \cancel{m}\cancel{g}\cos\theta = \frac{2}{\cancel{5}}\cancel{m}\frac{\cancel{5}}{7}\cancel{g}\sin\theta$$

$$\mu\cos\theta = \frac{2}{7}\sin\theta$$

$$\boxed{\mu \geq \frac{2}{7}\tan\theta}$$

no slipping.

Compare to a block sliding down a frictionless ramp

→ When there is rotation, acceleration is less