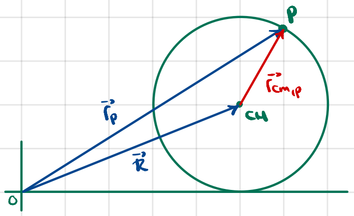
The wheel



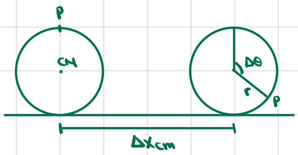
The wheel rotates with angular speed $|\omega(t)| = |\theta'(t)|$. Points on the rim have tangential speed $R|\omega(t)|$, relative to the CM.

From the ground frame the velocity vector has two components: $\vec{V}_{cm}$, and $\vec{V}_{cm,p}$.

$\vec{V}_{cm}$ is just a horizontal vector when the wheel is rolling on a flat surface as above.

$\vec{V}_{cm,p} = -r\omega(t)^2\hat{\theta}$. This vector is different at each point on the wheel.

Not slipping or skidding means the displacement of the CM ΔX_{cm} equals the arc length displacement of a point on the rim



$$s = r\Delta\theta = \Delta X_{cm} = V_{cm}\Delta t$$

$$\Rightarrow V_{cm,avg} = r\frac{\Delta\theta}{\Delta t}$$

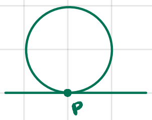
$$\lim V_{cm,avg} = \lim r\frac{\Delta\theta}{\Delta t}$$

$$\Rightarrow V_{cm} = r\omega(t)$$

The CM component of velocity from ground frame needs to have magnitude equal to the tangential speed of a point on the rim.

If $V_{cm} \neq r\omega$ then the wheel is either slipping ($V_{cm} < r\omega$) or skidding ($V_{cm} > r\omega$).

The no-slipping condition $V_{cm} = r\omega$ has implications for the contact point of the wheel wrt the ground.



$$\vec{V}_{g,p} = \vec{V}_{cm} + \vec{V}_{cm,p}$$

$$|\vec{V}_{cm}| = r\omega$$

$$|V_{cm,p}| = r\omega$$

$$\vec{V}_{g,p} = r\omega\hat{i} - r\omega\hat{i} = \vec{0}$$

Point of contact is at rest relative to the ground.

Friction