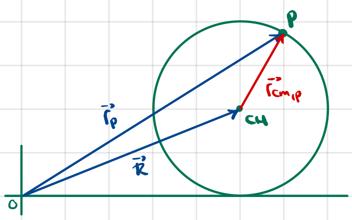
The wheel



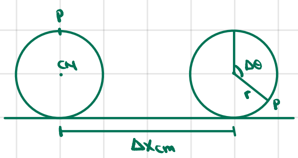
The wheel rotates with angular speed $|\omega(t)| = |\theta'(t)|$. Points on the rim have tangential speed $R|\omega(t)|$, relative to the CM.

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



$S = r\Delta\theta = \Delta x_{cm} = v_{cm}\Delta t$

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

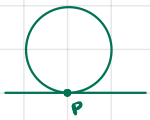
$\lim v_{cm,avg} = \lim r\frac{\Delta\theta}{\Delta t}$

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

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 and 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