

The *only external forces acting on the vehicle* in the XY plane are the four friction forces (one at the bottom of each wheel) of the floor pushing on the wheel in reaction to the driving torque being applied to the wheel. This friction force F at each wheel has a magnitude and direction, and can be decomposed into an F_x and an F_y component at each wheel as shown on the diagram.

Because of symmetry, all the F_x components are equal to each other in magnitude. All the F_y components are also equal to each other in magnitude, also due to symmetry.

Because the vehicle is in static equilibrium, the net torque on the vehicle in the XY plane must be zero. Thus, F_x must equal F_y (because the wheels are at the corners of a square).

The magnitude of the friction force F at each wheel is given by $F = \sqrt{F_x^2 + F_y^2}$. Since F_x is equal in magnitude to F_y , this simplifies to $F = \sqrt{2 \cdot F_y^2} = F_y \cdot \sqrt{2}$.

The maximum static friction at each wheel is given by $F_{\max} = \mu \cdot N$, where N is the normal force at each wheel. Therefore, solving $F = F_{\max} \Rightarrow F_y \cdot \sqrt{2} = \mu \cdot N$ for F_y gives the maximum magnitude of F_y which can be supported by static friction: maximum $F_y = \mu \cdot N / \sqrt{2}$.

Each wheel is also in static equilibrium, so the net torque on each wheel, in the plane of the wheel, must be zero. The only external torques acting on the wheel (in the plane of the wheel) are the driving torque τ being applied to the wheel, and the torque $F_y \cdot r$ produced by the F_y component of friction at that wheel. Thus, **F_y must equal τ/r** . Replacing F_y with τ/r , we get: **$\tau = r \cdot \mu \cdot N / \sqrt{2}$** as the maximum torque that can be applied to each wheel before the wheels start to slip and the vehicle starts to rotate.