First the Free-Body-Diagram for the wheel. Since the wheel would presumably be lifted, there's no contact point with the ground. There is a reaction force in point A, with a normal and a tangent component. The normal reaction force doesn't contribute to the moment around the center point, M_C, as it's directed towards the center. There is also a resulting reaction force in point C, with an x and y component. Since the wheel will be rotating around point A, I assume this force must be directed normal to line A-C. Hence, F_x and F_y must be related by equation (4).

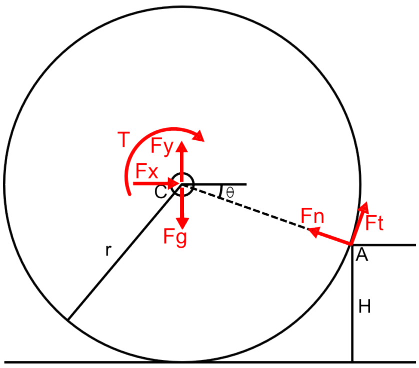

Figure 1: Free Body Diagram Wheel

Equations of Motion:

$$M_C = T - F_t r \tag{1}$$
$$F_x = F_t sin(\theta) - F_n cos(\theta) \tag{2}$$
$$F_y = F_t cos(\theta) + F_n sin(\theta) - F_g \tag{3}$$
$$tan(\theta) = \frac{F_x}{F_y} \tag{4}$$
$$M_A = T + F_y r cos(\theta) + F_x r sin(\theta) \tag{5}$$

Solving: There are now 5 equations and 6 unknown variables (M_C, F_x, F_y, F_n, F_t and M_A). So we set M_C as 0, which then allows us to solve the equations. From equation (1), (3) and (4):

$$F_t = T/r \tag{6}$$

$$F_n = \frac{F_y + F_g - F_t cos(\theta)}{sin(\theta)} \Rightarrow \frac{\frac{F_x}{tan(\theta)} + F_g - F_t cos(\theta)}{sin(\theta)} \tag{7}$$

Inserting (7) into (2):

$$\begin{aligned}
F_x =& F_t sin(\theta) - \frac{cos(\theta)}{sin(\theta)} \left(\frac{F_x}{tan(\theta)} + F_g - F_t cos(\theta) \right) \\
&\Rightarrow F_t sin(\theta) - \frac{cos(\theta)}{sin(\theta)} \frac{F_x}{tan(\theta)} - \frac{cos(\theta)}{sin(\theta)} F_g + \frac{cos(\theta)}{sin(\theta)} F_t cos(\theta) \\
&\Rightarrow \left(F_t \left(sin(\theta) + \frac{cos(\theta)}{sin(\theta)} cos(\theta) \right) - \frac{cos(\theta)}{sin(\theta)} F_g \right) / \left(1 + \frac{cos(\theta)}{sin(\theta) tan(\theta)} \right)
\end{aligned} \tag{8}$$

θ is calculated from $sin(\theta) = \frac{r-H}{r}$ and with F_x, I can calculate F_y and hence M_A. With Excel I can then plot M_A against H, so no need to deduct an explicit formula.

For the C-leg, I'm mostly using the same procedure, although the deductions are more elaborate. There's also another variable d for the horizontal distance between C and A. For the wheel, d was determined by H and the rim of the wheel, but for the leg d can be freely chosen.

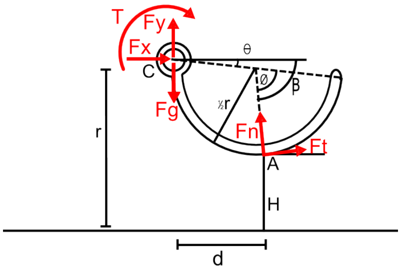

Figure 2: Free Body Diagram Leg

Equations of Motion:

$$\begin{aligned} M_C =& T + F_n cos(\beta)(r-H) - F_n sin(\beta)d \\ & - F_t sin(\beta)(r-H) \\ & - F_t cos(\beta)d \quad (9) \\ F_x =& F_t sin(\beta) - F_n cos(\beta) \quad (10) \\ F_y =& F_t cos(\beta) + F_n sin(\beta) - F_g \quad (11) \\ tan(\alpha) =& \frac{F_x}{F_y} = \frac{r-H}{d} \quad (12) \\ M_A =& T + F_y d + F_x (r-H) \quad (13) \end{aligned}$$

Solving: First simplifying equation (9):

$$\begin{aligned} M_C =& T + F_n(cos(\beta)(r-H) - sin(\beta)d) - F_t(sin(\beta)(r-H) + cos(\beta)d) \\ =& T + F_n C_1 - F_t C_2 \end{aligned}$$

With $C_1 = cos(\beta)(r-H) - sin(\beta)d$ and $C_2 = sin(\beta)(r-H) + cos(\beta)d.$

Enter eq.(12) into eq.(11), combine with eq.(10), then solve to obtain F_n:

$$\begin{aligned} F_t sin(\beta) - F_n cos(\beta) &= (F_t cos(\beta) + F_n sin(\beta) - F_g)\, tan(\beta) \\ \Rightarrow F_n \left(\frac{-cos(\beta)}{tan(\alpha)} - sin(\beta) \right) &= F_t \left(\frac{-sin(\beta)}{tan(\alpha)} + cos(\beta) \right) - F_g \\ \Rightarrow F_n &= \frac{F_t C_3}{C_4} - \frac{F_g}{C_4} \quad (14) \end{aligned}$$

Where $C_3 = \frac{-sin(\beta)}{tan(\alpha)} + cos(\beta)$ and $C_4 = \frac{-cos(\beta)}{tan(\alpha)} - sin(\beta).$

Now enter eq.(14) into eq.(9) and again setting M_C to be 0, solving for F_t:

$$\begin{aligned} M_C =& T + \left(\frac{F_t C_3}{C_4} - \frac{F_g}{C_4} \right) C_1 - F_t C_2 \\ 0 =& T + F_t \left(\frac{C_3 C_1}{C_4} - C_2 \right) - \frac{C_1 F_g}{C_4} \\ \Rightarrow F_t =& \left(\frac{C_1 F_g}{C_4} - T \right) / \left(\frac{C_3 C_1}{C_4} - C_2 \right) \quad (15) \end{aligned}$$

With F_t, F_n, F_x, F_y and thus M_A can be calculated.

Still need to determine β, which turned out to be more difficult then I imagined. β is the sum of ϕ and θ. ϕ can be found through the length between C and A.

$$
\begin{aligned}
|C-A| = \sqrt{d^2+(r-H)^2} &= \sqrt{\left(\frac{1}{2}r+cos(\phi)\frac{1}{2}r\right)^2+\left(sin(\phi)\frac{1}{2}r\right)^2} \\
\Rightarrow d^2+(r-H)^2 &= \left(\frac{1}{2}r+cos(\phi)\frac{1}{2}r\right)^2+\left(sin(\phi)\frac{1}{2}r\right)^2 \\
\Rightarrow d^2+(r-H)^2 &= \frac{1}{4}r^2\left(sin^2(\phi)+1+2cos(\phi)+cos^2(\phi)\right) \\
\Rightarrow d^2+(r-H)^2 &= \frac{1}{2}r^2+\frac{1}{2}r^2cos(\phi) \\
\Rightarrow cos(\phi) &= \left(d^2+(r-H)^2-\frac{1}{2}r^2\right)/\frac{1}{2}r^2 \qquad (16)
\end{aligned}
$$

And θ can be found with distance r and height $r-H$.

$$
\begin{aligned}
d &= \frac{1}{2}rcos(\theta)+\frac{1}{2}rcos(\beta) \\
&\Rightarrow \frac{1}{2}r\left(2cos(\frac{\theta+\beta}{2})cos(\frac{\theta-\beta}{2})\right) \\
&\Rightarrow rcos(A)cos(B) \qquad (17) \\
r-H &= \frac{1}{2}rsin(\theta)+\frac{1}{2}rsin(\beta) \\
&\Rightarrow \frac{1}{2}r\left(2sin(\frac{\theta+\beta}{2})cos(\frac{\theta-\beta}{2})\right) \\
&\Rightarrow rsin(A)cos(B) \qquad (18)
\end{aligned}
$$

Where $A=\frac{\theta+\beta}{2}$ and $B=\frac{\theta-\beta}{2}$. We can now combine eq.(17) and (18) and deduct θ.

$$
\begin{aligned}
\frac{d}{rcos(A)} &= \frac{r-H}{rsin(A)} \\
\Rightarrow drsin(A) &= (r-H)rcos(A) \\
\Rightarrow tan(A) &= \frac{r-H}{d} \\
\Rightarrow A = \frac{\theta+\theta+\phi}{2} &= tan^{-1}\left(\frac{r-H}{d}\right) \\
\Rightarrow \theta &= tan^{-1}\left(\frac{r-H}{d}\right)-\frac{1}{2}\phi \qquad (19)
\end{aligned}
$$

I'm now able to plot M_A versus height H for both bodies. For the C-leg, d was taken so the obstacle hits the middle point of the curve, $d = cos(\alpha)L$ with $L = r\sqrt{\frac{1}{2}}$ and $sin(\alpha) = \frac{r-H}{L}$. Other variables r=100mm, T=500Nmm and F_g=20N. The plot shows that the C-leg has a higher M_A, which is what I want. A positive M_A means the body is able to overcome the object, so the wheel can climb a maximum of 15mm, whereas the C-leg can climb a maximum of 50mm.

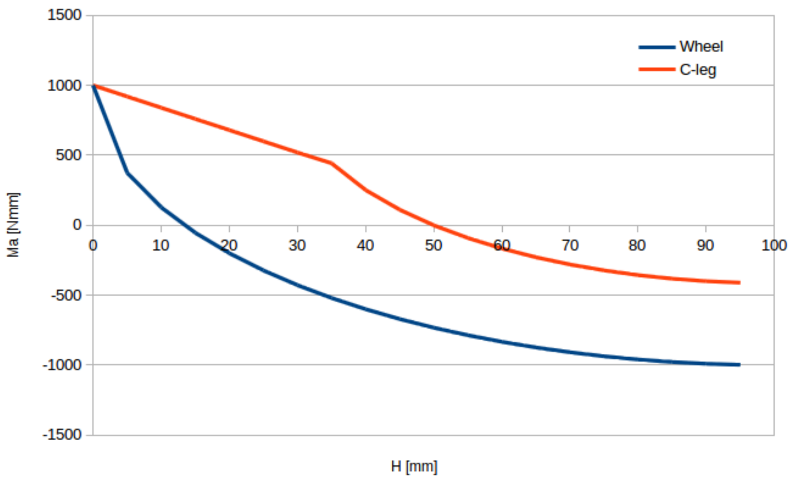

Figure 3: Plotting M_A vs H