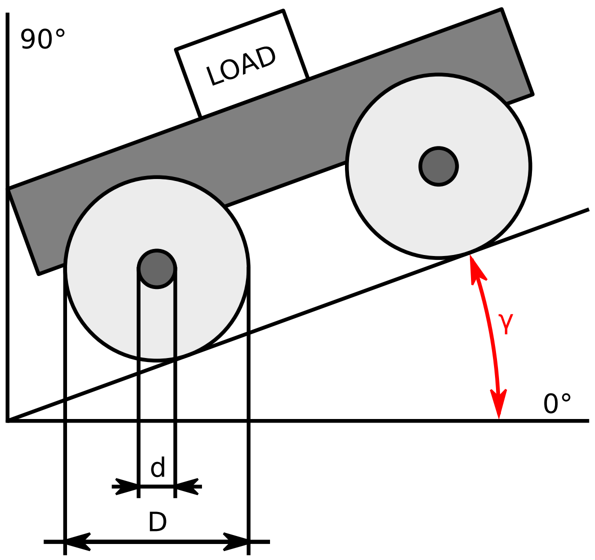
Wheeled Motion



This tool has been created to calculate the transmission of vehicles such as AGVs, AMRs, electric trolleys and forklifts, bridge cranes and gantries, transfer cars for concrete slabs, automated storage and retrieval systems, etc. These vehicles can be powered by one or more motors, including powering each wheel with its own independent motor.

Disclaimer

This tool has been created to assist engineers with the sizing of the different parts of the system. Calculations might not cover all corner cases. and results should always be checked by a qualified engineer. Under no circumstances shall we beheld responsible to any damages to persons or property due to correct or incorrect use of this tool, or to errors in it.

Total Mass

$$m_{load} = m_v + m \quad [kg]$$

Bearing Friction Force

$$F_b = \mu_b \cdot m_{load} \cdot g \cdot \frac{d}{D} \quad [N]$$

Weight Force

$$F_w = m_{load} \cdot g \cdot \cos\left(\frac{\gamma \cdot \pi}{180}\right) \quad [N]$$

Wheel-Surface Rolling Resistance Force

$$F_s = \frac{2 \cdot b_s \cdot m_{load} \cdot \cos\left(\frac{\gamma \cdot \pi}{180}\right) \cdot g}{D} \quad [N]$$

Total Resistive Force

$$F_T = F_w + F_b + F_s \quad [N]$$

Linear Acceleration

$$a = \frac{v}{t_a} \quad [m \cdot s^2]$$

Wheel-Surface Rolling Resistance Factor

⌀ 100 mm PUR on steel	bs ≈ 0.75 mm
⌀ 125 mm PUR on steel	bs ≈ 0.9 mm
⌀ 200 mm PUR on steel	bs ≈ 1.5 mm
⌀ 415 mm PUR on steel	bs ≈ 3.1 mm
Steel on steel	bs ≈ 0.5 mm
Plastic on steel	bs ≈ 2 mm
Plastic on concrete	bs ≈ 5 mm
Hard rubber on steel	bs ≈ 7 mm
Hard rubber on concrete	bs ≈ 10 – 20 mm
Medium-hard rubber on concrete	bs ≈ 15 – 35 mm

Table based on experimental data
Request actual data for your wheels with the manufacturer
For PUR wheels, these factors show considerable variance depending on manufacturer, hardness, geometry and temperature

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Constants

Pi	$\pi \simeq 3.141592654$
Acceleration of Gravity on Earth	$g=9.80665 \ \frac{m}{s^2}$

Inputs

Acceleration time	$t_a \ [seconds]$
System Inclination	$\gamma \ [degrees]$
Drive Wheel Diameter	$D \ [mm]$
Drive Axle Diameter	$d \ [mm]$
System Mass	$m_v \ [kg]$
Load Mass	$m \ [kg]$
Speed	$v \ \left[\frac{m}{s}\right]$
Bearing Friction Coefficient	μ_b
Wheel-Surface Rolling Resistance Factor	$b_s \ [mm]$
Additional Reduction Ratio	i_{ex}
Service Factor	KA
System Efficiency	η_v
Gearbox Efficiency	η_g
Gearbox Moment of Inertia	$J_g \ [kg \cdot cm^2]$
Max. Motor Speed During Cycle	$n_1 \ [rpm]$
Motor Moment of Inertia	$J_M \ [kg \cdot cm^2]$
Number of Motors	no_{tr}

Acceleration Force

$$F_{acc}=a \cdot m_{load} \quad [N]$$

Total Inertia as Seen by the Motor(s)

$$J_m=\frac{91.2 \cdot m_{load} \cdot \left(\frac{v}{n_1}\right)^2}{no_{tr}} \quad [kg \cdot m^2]$$

Load to Motor Inertia Ratio

$$\Lambda=\frac{J_m}{\frac{J_M+J_g}{10000}}$$

Max. Wheel Rotational Speed

$$n_{2\,max}=\frac{v \cdot 1000 \cdot 60}{\pi \cdot D} \quad [rpm]$$

Max. Wheel Rotational Speed

$$\omega_{2max}=\frac{n_{2max} \cdot \pi}{30} \quad \left[\frac{rad}{s}\right]$$

Required Continuous Motor Power

$$P_1=\frac{F_T \cdot v}{1000 \cdot \eta_v \cdot \eta_g \cdot no_{tr}} \quad [kW]$$

Required Acceleration Motor Power

$$P_{1max}=\frac{(F_T+F_{acc}) \cdot v}{1000 \cdot \eta_v \cdot \eta_g \cdot no_{tr}} \quad [kW]$$

Ideal Gearbox Ratio

$$i=\frac{n_1}{n_2 \cdot i_{ex}}$$

Required Acceleration Torque (of each Gearbox)

$$T_{2a}=\frac{P_{1max} \cdot 9550}{n_2 \cdot i_{ex}} \quad [N \cdot m]$$

Required Acceleration Torque Adjusted for Service Factor (of each Gearbox)

$$T_{2aKA} = T_{2a} \cdot KA \quad [N \cdot m]$$

Required Motor Torque

$$T_m = \frac{T_{2a}}{i} \quad [N \cdot m]$$

Required Output Torque (of each Gearbox)

$$T_2 = \frac{P_1 \cdot 9550}{n_2 \cdot i_{ex}} \quad [N \cdot m]$$

Required Output Torque Adjusted for Service Factor (of each Gearbox)

$$T_{2KA} = T_2 \cdot KA \quad [N \cdot m]$$