

**"Constants"**

$g = 32.2[\text{ft/s}^2]$  "Acceleration of gravity"

"From: <http://hpwizard.com/tire-friction-coefficient.html>"

$\mu = .75$  "Coefficient of static friction"

$\mu_R = .05$  "Coefficient of rolling friction"

**"Scenario Inputs"**

$P = 1[\text{lbf}]$  "Dragging Force"

$m = 2.5 * \text{convert}(\text{lbf}, \text{slug})$  "Mass of vehicle"

$r = 1.54[\text{in}] * \text{convert}(\text{in}, \text{ft})$  "Radius of wheel/track"

$a = v/\text{deltat}$  "Constant Acceleration Rate"

$v = 0.3[\text{ft/s}]$  "velocity"

$\text{deltat} = .75[\text{s}]$  "Constant Acceleration Time"

$\eta_G = 0.48$  "Efficiency of gear train"

$\eta_M = .40$  "Efficiency of Motor"

$F = F_{\text{Track}}$  "Maximum force scenario"

**"Motor Specs"**

$\text{EMF} = 9[\text{V}]$  "Motor voltage"

$\omega_M = T_M * S \backslash T$  "Motor speed"

$T_s = 5.67 * \text{convert}(\text{N}\cdot\text{mm}, \text{in}\cdot\text{lbf})$  "Stall Torque"

$\omega_{\text{max}} = 6130[\text{rev/min}]$  "Maximum speed of motor"

$S \backslash T = \omega_{\text{max}} / T_s$  "Tvs.S slope"

**"Newton's laws applied to chassis"**

$\text{SIGMA}_{F_x} = 0$  "Sum of forces in X"

$\text{SIGMA}_{F_x} = F - P - m * a - m * g * \sin(\text{THETA})$

$\text{SIGMA}_{F_y} = 0$  "Sum of forces in Y"

$\text{SIGMA}_{F_y} = N - m * g * \cos(\text{THETA})$

**"Newton's laws applied to wheel"**

$\text{SIGMA}_{M_a} = 0$  "Sum of moments about axle"

$\text{SIGMA}_{M_a} = (F/2 * r + \mu_R * N/2 * r) * \text{convert}(\text{ft}\cdot\text{lbf}, \text{in}\cdot\text{lbf}) - T$

**"Rotational Dynamics"**

$\omega_W = v/r * \text{convert}(1/\text{s}, \text{rev/min})$  "Speed of wheel"

$\omega_W * T = \omega_M * T_M * \eta_G$  "Gear Train Relation"

$R_G = \omega_M / \omega_W$  "Gear Ratio"

$W_{\text{dot\_wheel}} = v/r * T * \text{convert}(\text{in}\cdot\text{lbf}/\text{s}, \text{W})$  "Power at axle"

$W_{\text{dot\_M}} = W_{\text{dot\_wheel}} / \eta_G$  "Power output of motor"

$E_{\text{dot\_M}} = W_{\text{dot\_M}} / \eta_M$  "Power input to motor"

$E_{\text{dot\_M}} = I_M * \text{EMF}$  "Electrical Power"

**"Tractive Force Analysis"****"Grousers Function: Gerhart et al"**

$F_{\text{Track}} = b * I * c * (1 + 2 * h/b) + N * \tan(\phi) * (1 + 0.64 * (h/b * (\arctan(b/h) * \text{convert}(\text{deg}, \text{rad}))))$

$b = 13.4 * \text{convert}(\text{mm}, \text{in})$  "Track width"

$l = 85 * \text{convert}(\text{mm}, \text{in})$  "Track Length"

$h = .75 * \text{convert}(\text{mm}, \text{in})$  "Grouser Height"

$c = 0 * \text{convert}(\text{kPa}, \text{psi})$  "Coefficient of Cohesion (loose dirt)"

$\phi = 45[\text{deg}]$  "Soil Angle of Repose"

$F_f = \mu * N$  "Simple Friction Model"

## SOLUTION

## Unit Settings: SI C kPa kJ mass deg

$a = 0.4$ [ft/s <sup>2</sup> ]	$b = 0.5276$ [in]
$c = 0$ [psi]	$\delta t = 0.75$ [s]
EMF = 9 [V]	$\eta_G = 0.48$
$\eta_M = 0.4$	$\dot{E}_M = 2.533$ [W]
$F = 2.284$ [lbf]	$F_r = 1.624$ [lbf]
$F_{Track} = 2.284$ [lbf]	$g = 32.2$ [ft/s <sup>2</sup> ]
$h = 0.02953$ [in]	$I_M = 0.2815$ [A]
$l = 3.346$ [in]	$m = 0.0777$ [slug]
$\mu = 0.75$	$\mu_R = 0.05$
$N = 2.166$ [lbf]	$\omega_M = 3235$ [rev/min] {338.7 [rad/s]}
$\omega_{max} = 6130$ [rev/min]	$\omega_W = 22.32$ [rev/min] {2.338 [rad/s]}
$P = 1$ [lbf]	$\phi = 45$ [deg]
$r = 0.1283$ [ft]	<b><math>R_G = 144.9</math></b>
$\Sigma F_x = 0$ [lbf]	$\Sigma F_y = 0$ [lbf]
$\Sigma M_a = 0$ [in-lbf]	$S\backslash T = 122151$ [rev/min-in-lbf]
$T = 1.842$ [in-lbf] {208.1 [N-mm]}	$\Theta = 30.04$ [deg]
<b><math>T_M = 0.02648</math></b> [in-lbf] {2.992 [N-mm]}	$T_s = 0.05018$ [in-lbf] {5.67 [N-mm]}
$v = 0.3$ [ft/s] {9.144 [cm/s]}	<b><math>\dot{W}_M = 1.013</math></b> [W] {0.001359 [hp]}
$\dot{W}_{wheel} = 0.4864$ [W]	

No unit problems were detected.

## KEY VARIABLES

$T = 1.842$ [in-lbf] {208.1 [N-mm]}	<i>Torque on axle</i>
$\omega_W = 22.32$ [rev/min] {2.338 [rad/s]}	<i>Speed of wheel</i>
<b><math>T_M = 0.02648</math></b> [in-lbf] {2.992 [N-mm]}	<i>Torque of motor</i>
$\omega_M = 3235$ [rev/min] {338.7 [rad/s]}	<i>Speed of motor</i>
<b><math>R_G = 144.9</math></b>	<i>Gear ratio required</i>
$v = 0.3$ [ft/s] {9.144 [cm/s]}	<i>Resultant Velocity</i>
<b><math>\dot{W}_M = 1.013</math></b> [W] {0.001359 [hp]}	<i>Required power output of motor</i>
$\dot{E}_M = 2.533$ [W]	<i>Electrical power required by motor</i>
$\Theta = 30.04$ [deg]	<i>Maximum angle of ascent</i>

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*This model includes rolling friction, continuous track friction on soil, gear train efficiency, and motor efficiency, but ignores moment of inertia effects of the wheel and track system.*



