

EV Vehicle Dynamics Cheat Sheet

Longitudinal force balance, resistive forces and gradeability

ENGINEERING
CHEAT SHEET

Key equations

Quantity	Equation	Notes
Vehicle motion equation	$F_t = F_d + F_r + F_g + m_v a$	Newton's second law. Add rotating inertia for the full acceleration term
Aerodynamic drag	$F_d = \frac{1}{2} \rho_a C_D A_f v^2$	Grows with speed squared: dominates at highway speed
Rolling resistance	$F_r = \mu(v, p, \dots) \cdot m_v g \cos \alpha$	Roughly linear in speed: dominates in city driving
Grade force	$F_g = m_v g \sin \alpha$	Small angles: $F_g \approx m_v g \alpha$
Inertial force	$F_i = (m_v + \Sigma m_{rot}) a$	Rotating masses can be added to vehicle mass
Coastdown road load	$F = F_0 + F_1 v + F_2 v^2$	Measured by coasting from about 115 km/h down to 15 km/h
Gradeability	grade % = $100 \tan \alpha$	Solve $F_{t,max} = F_d + F_r + F_g(\alpha)$ for α
Wheel torque and speed	$T = F_t r_w; \omega = v / r_w$	r_w = tire radius. Traction power $P = F_t v$

Key takeaways

- Energy models focus on **longitudinal dynamics**. Lateral dynamics matter for stability but barely change energy use.
- Aggressive driving raises net forces and energy use substantially.
- Heavier EVs pay three times: more rolling resistance, more inertia, and disproportionate grip demand in corners (**tire load sensitivity**).
- Downhill driving is a chance to recover energy with regenerative braking.
- Three quantifiers for passenger cars: top speed, maximum gradeability, and 0-100 km/h (or 0-60 mph) time.
- Worked example: 4,000 N traction, 400 N drag + rolling, 1,500 kg vehicle gives $\sin^{-1}(3,600 / 14,700) \approx 14^\circ$, **about a 25% grade**.