Propeller Shaft Critical (Whirling) Speed

First critical (whirling) speed of a tubular propeller shaft between universal joints, and the highest road speed before it is reached for an axle ratio and tyre.

Method: First bending natural frequency of a simply supported tube

Input parameters

Unit system: SI

Parameter	Value	Unit
Tube outside diameter	76.200	mm
Tube inside diameter	71.200	mm
Length between joint centres	1.6000	m
Elastic modulus	207.00	GPa
Density	7,850.0	kg/m³
Safety factor on critical speed	1.3000	
Axle (final drive) ratio	3.7300	
Tyre rolling radius	330.00	mm

Calculated results

Parameter	Value	Unit
First critical speed	4,928.9	rpm
Highest allowed shaft speed	3,791.5	rpm
Road speed at the allowed shaft speed (top gear 1:1)	126.46	km/h
Mass per metre	4.5439	kg/m

Notes for this case

• A shaft between joints behaves as a simply supported beam: its first bending natural frequency, ω = (π/L)²√(EI/m′), is the speed at which it whirls. Critical speed rises with diameter (stiffness grows faster than mass) and falls with the square of length, so long vehicles use two-piece shafts or larger, thinner tubes, or carbon fibre. In top gear (1:1) the shaft turns at the axle ratio times the wheel speed.

Formula and method

$$\omega_c = \left(\frac{\pi}{L}\right)^2 \sqrt{\frac{EI}{m'}}, \quad I = \frac{\pi(D^4 - d^4)}{64}, \quad m' = \rho\frac{\pi(D^2 - d^2)}{4}$$

Variables

D	Tube outside diameter	m
d	Tube inside diameter	m
L	Length between joint centres	m
E	Elastic modulus	Pa
ρ	Density	kg/m³
k_s	Safety factor on critical speed	-
i_a	Axle (final drive) ratio	-
r	Tyre rolling radius	m
n_c	First critical speed	rad/s
n_{max}	Highest allowed shaft speed	rad/s
v_{max}	Road speed at the allowed shaft speed (top gear 1:1)	m/s

m'	Mass per metre	kg/m

Method and standards

Propshaft critical speed.

Assumptions and limits

- Simply supported uniform tube; first mode.

References

First bending natural frequency of a simply supported tube

Report details

Report reference	FCC-0JZ7-BPW0 (the same inputs always give the same reference)
Generated	23 November 2026, 18:18 UTC
Calculator	Propeller Shaft Critical (Whirling) Speed
Method last reviewed	17 November 2026
Software release	FireCAD Calc, release of 22 November 2026
Release checks	3 reference cases of this calculator, computed independently, are checked on every release

Results are for engineering estimation. Verify critical designs against the referenced standards and your own data.

This calculator online

https://calc.firecad.com/automotive/transmission/propshaft-critical-speed

Open this case on calc.firecad.com →

Reopens the calculator with the inputs of this report.