Air Spring Load, Rate and Natural Frequency

Load, vertical stiffness and natural frequency of an air spring from gauge pressure, effective area, volume, polytropic exponent and area change.

Method: Polytropic air spring model

Input parameters

Unit system: SI

Parameter	Value	Unit
Gauge pressure	5.0000	bar
Effective area	300.00	cm²
Air volume (including any reservoir)	12.000	L
Polytropic exponent (1.0–1.4)	1.3800	
Change of effective area with compression	20.000	mm
Atmospheric pressure	101.33	kPa

Calculated results

Parameter	Value	Unit
Load supported	15.000	kN
Spring rate	72.237	kN/m
Natural frequency with that load	1.0937	Hz
Rate from volume change alone	62.237	kN/m

Notes for this case

• Load F = p_gA_e. Compressing the spring raises its absolute pressure polytropically, giving k = n(p_g + p_a)A_e²/V, plus p_g·dA_e/dz from the change of effective area (rolling-lobe piston shape). Because both load and rate rise with pressure, the natural frequency stays nearly constant as load changes, which is why air suspension keeps ride quality laden and unladen. Adding a reservoir volume lowers the rate. Dynamic compression is near adiabatic (n ≈ 1.4).

Formula and method

$$F = p_g A_e, \quad k = \frac{n(p_g + p_a)A_e^2}{V} + p_g \frac{dA_e}{dz}, \quad f_n = \frac{1}{2\pi}\sqrt{\frac{kg}{F}}$$

Variables

p_g	Gauge pressure	Pa
A_e	Effective area	m²
V	Air volume (including any reservoir)	m³
n	Polytropic exponent (1.0–1.4)	-
dA_e/dz	Change of effective area with compression	m
p_a	Atmospheric pressure	Pa
F	Load supported	N
k	Spring rate	N/m
f_n	Natural frequency with that load	1/s
k_V	Rate from volume change alone	N/m

Method and standards

Air spring.

Assumptions and limits

- Small displacement; ideal gas; uniform pressure.

References

Polytropic air spring model

Report details

Report reference	FCC-WC5G-0MKH (the same inputs always give the same reference)
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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/vehicle-dynamics/air-spring-rate

Open this case on calc.firecad.com →

Reopens the calculator with the inputs of this report.