Tube Span Natural Frequency (Euler–Bernoulli Beam)

First natural frequency of a tube span from its length, end fixity, diameters, Young's modulus and mass per metre including contents and hydrodynamic added mass.

Method: Euler–Bernoulli beam f = (λ²/2πL²)√(EI/m) with λ = π; 3.9266; …

Input parameters

Unit system: SI

Parameter	Value	Unit
Span between supports	1.5000	m
End conditions	Pinned–pinned (λ = π)	
Tube outside diameter	50.800	mm
Tube inside diameter	44.200	mm
Young's modulus at temperature	190.00	GPa
Tube material density	7,850.0	kg/m³
Contents and added mass per metre Fluid inside the tube (ρ_in π d_i²/4) plus the hydrodynamic added mass of the fluid outside, about C_m ρ_out π d_o²/4 with C_m near 1 for an isolated tube (more in a close bundle).	1.5000	kg/m

Calculated results

Parameter	Value	Unit
Second moment of area	13.956	cm⁴
Total mass per metre	5.3657	kg/m
First natural frequency	49.077	Hz

Notes for this case

- Real supports (baffles, ties) are between pinned and clamped; compare f_n with vortex shedding and acoustic frequencies with a margin.

Formula and method

$$f_n = \frac{\lambda^2}{2\pi L^2}\sqrt{\frac{EI}{m}}, \quad I = \frac{\pi(d_o^4 - d_i^4)}{64}, \quad m = \rho_t \frac{\pi(d_o^2 - d_i^2)}{4} + m_a$$

$$\lambda = \pi \ \text{(pinned–pinned)}, \quad 3.9266 \ \text{(clamped–pinned)}, \quad 4.7300 \ \text{(clamped–clamped)}$$

Variables

L	Span between supports	m
ends	End conditions	-
λ	first-mode eigenvalue for the end conditions	-
d_o	Tube outside diameter	m
d_i	Tube inside diameter	m
E	Young's modulus at temperature	Pa
ρ_t	Tube material density	kg/m³
m_a	Contents and added mass per metre	kg/m
I	Second moment of area	m⁴
m	Total mass per metre	kg/m
f_n	First natural frequency	1/s

Method and standards

Euler–Bernoulli beam theory for the first bending mode of a uniform span, with the eigenvalues for the chosen end conditions as tabulated by Blevins; the mass per metre is the tube metal plus the contents and added mass you enter.

Assumptions and limits

- Uniform beam, small deflection.
- The added mass is your input: contents $\rho_{in}\,\pi\,d_i^2/4$ plus about $C_m\,\rho_{out}\,\pi\,d_o^2/4$ for the fluid outside (C_m near 1 for an isolated tube, higher in a close bundle); for gas outside it is negligible.

References

- Euler–Bernoulli beam $f = (\lambda^2/2\pi L^2)\sqrt{(EI/m)}$ with $\lambda = \pi$
- 3.9266
- 4.7300 (Blevins, Formulas for Natural Frequency and Mode Shape)

Report details

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Release checks	2 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/boilers-power-plant/boiler-pressure-parts/tube-natural-frequency

Open this case on calc.firecad.com →

Reopens the calculator with the inputs of this report.