Rocket Nozzle Exit Mach, Thrust Coefficient and Specific Impulse

Exit Mach number and pressure, thrust coefficient, c*, thrust and specific impulse of an ideal rocket nozzle from chamber conditions and area ratio.

Method: Ideal rocket nozzle relations

Input parameters

Unit system: SI

Parameter	Value	Unit
Chamber pressure	7.0000	MPa
Chamber temperature	3,400.0	K
Ratio of specific heats of the exhaust	1.2200	
Exhaust molar mass	22.500	kg/kmol
Nozzle area ratio A_e/A_t	16.000	
Throat area	200.00	cm²
Ambient pressure	101.33	kPa

Calculated results

Parameter	Value	Unit
Exit Mach number	3.6799	
Exit pressure	44.505	kPa
Thrust coefficient	1.5507	
Characteristic velocity	1,718.1	m/s
Thrust	217.10	kN
Specific impulse	271.69	s
Propellant mass flow	81.483	kg/s

Notes for this case

- Ideal frozen-composition nozzle: isentropic, one-dimensional, perfect gas. Real nozzles reach about 92–98 % of the ideal C_F.

Formula and method

$$\varepsilon = \frac{1}{M_e}\left[\frac{2}{\gamma+1}\left(1+\frac{\gamma-1}{2}M_e^2\right)\right]^{\frac{\gamma+1}{2(\gamma-1)}}, \quad c^* = \frac{\sqrt{\gamma R T_c}}{\gamma\sqrt{\left(\frac{2}{\gamma+1}\right)^{\frac{\gamma+1}{\gamma-1}}}}$$

$$C_F = \sqrt{\frac{2\gamma^2}{\gamma-1}\left(\frac{2}{\gamma+1}\right)^{\frac{\gamma+1}{\gamma-1}}\left[1-\left(\frac{p_e}{p_c}\right)^{\frac{\gamma-1}{\gamma}}\right]} + \frac{p_e - p_a}{p_c}\varepsilon, \quad F = C_F p_c A_t$$

Variables

p_c	Chamber pressure	Pa
T_c	Chamber temperature	K
γ	Ratio of specific heats of the exhaust	-
$\mathcal{M}$	Exhaust molar mass	kg/kmol

ε	Nozzle area ratio A_e/A_t	-
A_t	Throat area	m²
p_a	Ambient pressure	Pa
M_e	Exit Mach number	-
p_e	Exit pressure	Pa
C_F	Thrust coefficient	-
c^*	Characteristic velocity	m/s
F	Thrust	N
I_{sp}	Specific impulse	s
$\dot{m}$	Propellant mass flow	kg/s

Method and standards

Ideal rocket thermodynamics.

Assumptions and limits

- Ideal nozzle, frozen flow, perfect gas, axial exit.

References

Ideal rocket nozzle relations

Report details

Report reference	FCC-FYWC-NSF5 (the same inputs always give the same reference)
Generated	23 November 2026, 17:50 UTC
Calculator	Rocket Nozzle Exit Mach, Thrust Coefficient and Specific Impulse
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/mechanical/aerospace/rocket-nozzle-thrust-coefficient

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Reopens the calculator with the inputs of this report.