Rocket Burnout Speed and Apogee with Drag

Burnout speed and height, apogee and time to apogee of a vertical rocket with constant thrust and quadratic drag, by numerical integration, against no drag.

Method: Vertical rocket flight with thrust; drag and gravity

Input parameters

Unit system: SI

Parameter	Value	Unit
Lift-off mass	0.60000	kg
Propellant mass	0.060000	kg
Average thrust	60.000	N
Burn time	2.0000	s
Drag coefficient	0.45000	
Body diameter	54.000	mm
Air density (constant)	1.1700	kg/m³

Calculated results

Parameter	Value	Unit
Burnout speed	168.97	m/s
Burnout height	176.16	m
Apogee height	824.19	m
Time to apogee	12.172	s
Thrust-minus-drag acceleration just before burnout, in g	8.0797	
Apogee without drag	2,049.5	m
Thrust-to-weight at lift-off	10.197	

Notes for this case

• Vertical flight, constant thrust and mass flow, quadratic drag ½ρC_D A v|v| with constant density, integrated by fourth-order Runge–Kutta. Weathercocking, wind and Mach effects are ignored.

Formula and method

$$m\frac{dv}{dt} = F - \frac{1}{2}\rho C_D A v|v| - mg, \quad \frac{dm}{dt} = -\frac{m_p}{t_b} \ (t < t_b)$$

Variables

m_0	Lift-off mass	kg
m_p	Propellant mass	kg
F	Average thrust	N
t_b	Burn time	s
C_D	Drag coefficient	-
d	Body diameter	m
ρ	Air density (constant)	kg/m³
v_b	Burnout speed	m/s
h_b	Burnout height	m
h_{apo}	Apogee height	m

t_{apo}	Time to apogee	s
a_b/g	Thrust-minus-drag acceleration just before burnout, in g	-
$h_{apo,vac}$	Apogee without drag	m
$F/(m_0 g)$	Thrust-to-weight at lift-off	-

Method and standards

Point-mass vertical trajectory.

Assumptions and limits

- Vertical flight, constant density, constant C_D.

References

Vertical rocket flight with thrust, drag and gravity

Report details

Report reference	FCC-P47F-BA8M (the same inputs always give the same reference)
Generated	23 November 2026, 17:50 UTC
Calculator	Rocket Burnout Speed and Apogee with Drag
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/model-rocket-altitude

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Reopens the calculator with the inputs of this report.