ACTIVITY

Model rockets: Rocket calculations

Classroom resources for lower secondary

Nordic esero

NAROM | ANDØYA SPACE CENTER

About this activity

In this activity you are going to build and launch your own model rocket and do physical and mathematical calculations on the rocket.

Content

Introduction

When launching a rocket, it is always based on safety measurements and calculations on both the rocket itself and the rocket engine. When launching model rockets we are doing the same thing.

In these activities you are going to calculate things like velocity, high of apogee, stability e.g.

Before your rocket is finished, use a theoretical mass of 0.1 kg. After finishing you rocket use the rockets real weight and do the calculations again.

Calculation tips:

- Assume acceleration and motor thrust as constant. For instance, the thrust force $F = \bar{F}$, for $t = t_b$
- Try to derive the equations before inserting numbers.
- Actual values for the rocket are calculated in task 6, after you have built your own rocket. Before task 6, set initial start mass to M = 0.1kg
- Remember to use SI-units in your calculation

Equipment

What you need	Where to buy	More information
Model rockets	www.Apogeerockets.com	
Glue		
Knife		
Rocket motor	https://www.raketenmodellbau-klima.de/	Model rockets can also be bought from here
Wadding		Fireproof cloth
Launch pad		
Weight scale		

Safety precautions

Before launch of the model rockets go through this checklist

- Launch lug are on
- Nosecone is loose, not glued stuck
- Right rocket motor is in place
- Is launch area placed approximately 70m from buildings and cars
- Safety distance on operator 5m, while spectators is 10m.
- No people in front or back of the rocket in wind direction.
- Never adjust the angle of the launcher more than 30 degrees from zenith

Check area for dangers such as drones, airplane and wind before countdown.

Activity 1: Build and launch rocket

The model rockets are complete kits with instructions. As tools for the building use sandpaper, knife/scissors, glue and tape to build the rocket-

Pre-flight presentations

Before launch, you may present the rocket for the other groups.

- Present the rocket's name, type and mission
- Present the most important calculations for the trajectory (like v_{max} and H_{max} .

Launch schedule:

To make sure you'll have a smooth and safe launch, it is important to do some preparations.

- Make a schedule so every group is prepared and ready with their rocket when it's their turn.
- Each group should have a "Pad Supervisor" to press the "fire" button (the red button) at the end of countdown.
- Each group is responsible for rocket recovery after launch (for safety reasons, wait till all groups have launched).

Schedule

1. Group A – Avion (Precision)
2. Group B – Avion (Precision)
3. Group A – Avion/Payload (Height)
4. Group B – Avion/Payload (Height)
5. Group A – Courier (Egg)
6. Group B – Courier (Egg)

Tips to all groups

If it's cold, the parachute might not open. To avoid that, keep it warm and wait with packing the parachute to right before launch. This will increase your chances for a successful deployment.

If your group is launching a height-rocket you need to mount the height sensor right before it's your turn.

Activity 2: Rocket calculations

Exercise 1: Force, weight and size of rocket

My rocket is a (find the type of rocket on the kit):

A. Find the rocket motor type from table A.

Answer:

B. Find the average thrust, $\overline{F}$, of the motor from table A

Answer:

C. Find the mass, m_m, of the motor from table A

Answer:

D. Determine the total mass of the rocket, m_t including the motor.

Answer:

E. Determine the rocket frontal areal, A (see figure 1). Remember that your rocket has only 3 fins, not 4 as shown in the figure. Use the unit of centimetre and give your answer in cm^2.

$$circle\ area = \pi r^2$$

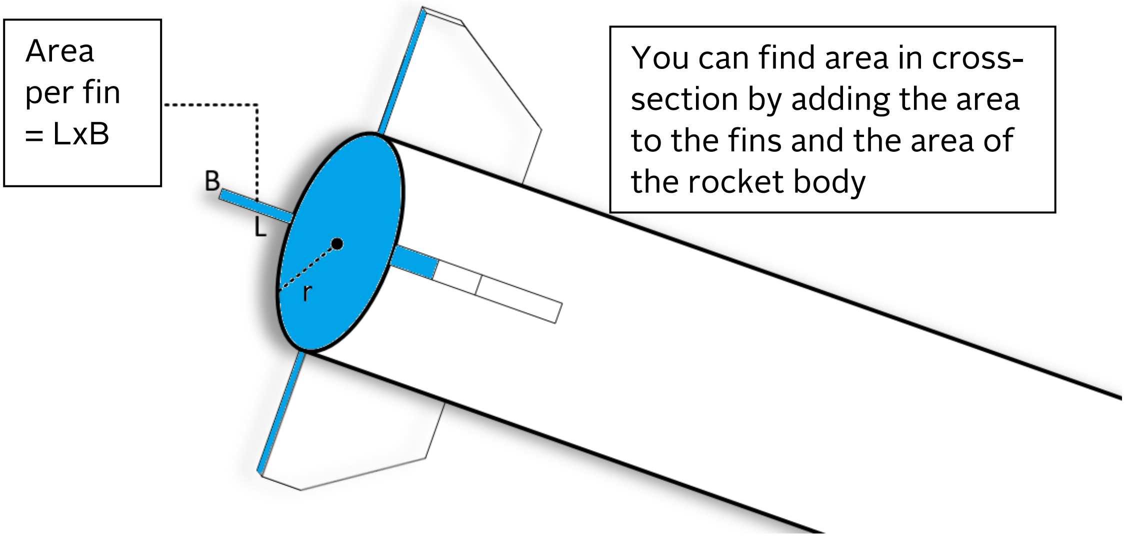


Figure 1: How to determine the frontal area

Answer:

F. Use table A to find the engine burnout time, t_b

Answer:

Exercise 2: Rocket Trajectory

A. When the rocket is at the launcher and the engine is fired, the rocket is accelerated upwards. This acceleration, a_m, can be found by using the second law of Newton:

$$F = m_t \cdot a_m \qquad (1)$$

$$a_m = \frac{F}{m_t} \qquad (2)$$

Use equation (2), the thrust and mass, m_t, ot calculate the acceleration of the rocket.

Answer:

B. In reality the acceleration of the rocket is less than what you found in task A. This is because gravity and other external forces are slowing down the rocket while the engine is burning. The value, $g \approx 10\ m/s^2$, tells us how much the rocket is slowed down by gravity. Use the new acceleration, a, by using equation (3):

$$a = a_m - g \qquad (3)$$

Answer:

C. When you know the acceleration, a, you can use this to calculate the velocity of the rocket (after the burnout of the engine).

$$v = a \cdot t_b \qquad (4)$$

Here, t_b, is «burnout time" (the time it takes before the engine has stopped burning.
Use equation (4) to calculate the rocket's velocity after burnout.

Answer:

D. To find the height of the rocket when it has stopped burning, you use the velocity, v, and the burnout time, t_b, in equation (5).

$$h_b = \frac{v \cdot t_b}{2} \qquad (5)$$

Calculate the height of the rocket after burnout.

Answer:

E. The rocket will continue to rise a few seconds after the engine burnout. But eventually it will fall back to ground because of gravity. The maximal height of the rocket is called apogee, h_a.

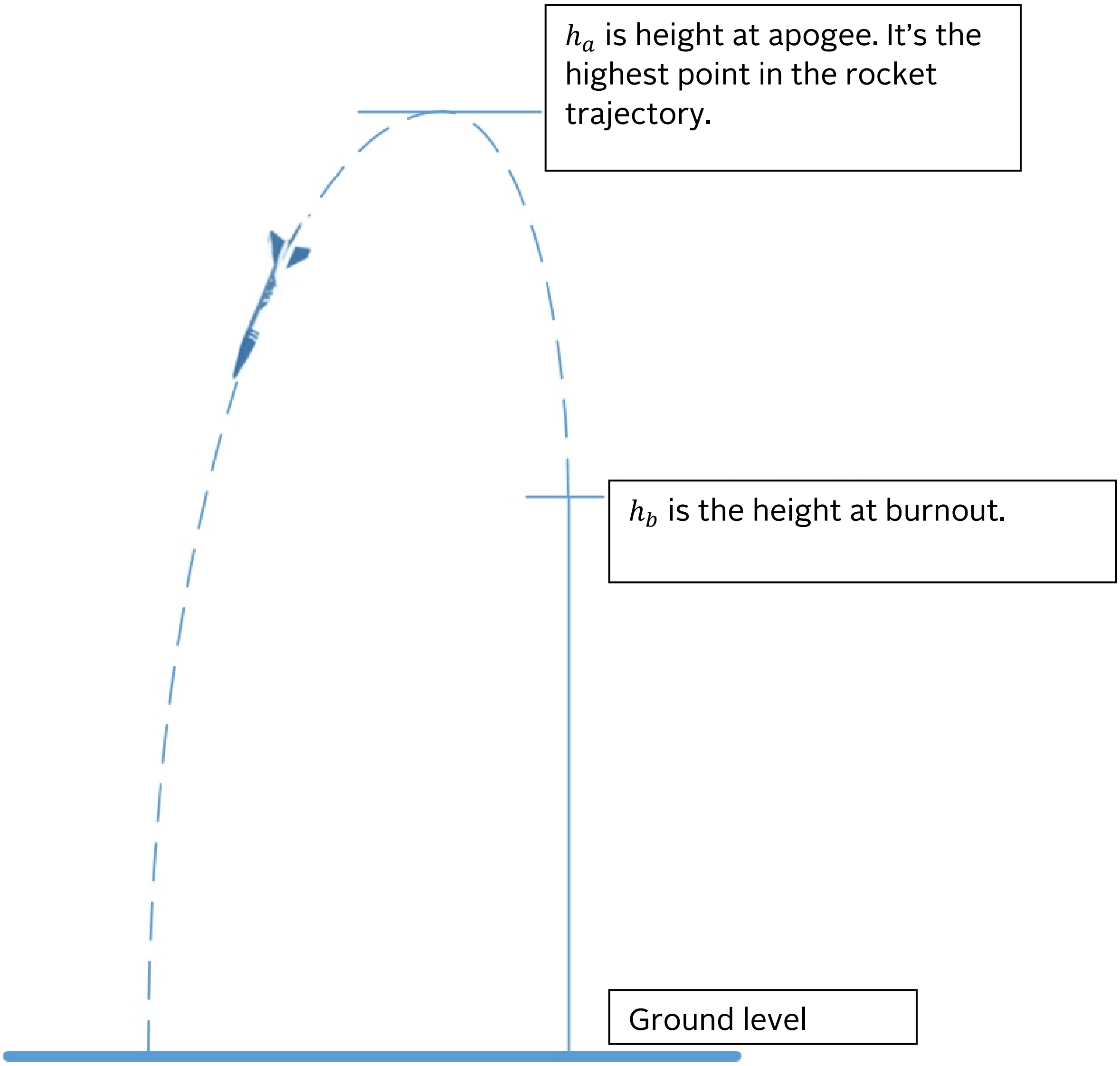


Figure 2: Height at burnout and apogee

To calculate the rocket's apogee, we need to know the force of gravity working on the rocket. Here on earth (at sea level) the value of g is $g = 9{,}81\ m/s^2$, but to make the calculation easier we will use $\boldsymbol{g \approx 10\ m/s^2}$. in this activity. Use equation (6) to calculate **apogee**:

$$h_a = \frac{v^2}{2 \cdot g} + h_b \qquad (6)$$

Answer:

**In reality the rocket will not reach the calculated apogee. That is because we have ignored air resistance in our calculations.*

F. It is important to know how air resistance influence our rocket. In this exercise you will use the frontal area, *A, that you calculated in exercise 1E. Air resistance is dependent on both the frontal area of the rocket and its velocity.* The equation for air resistance is: $L = {}^{1}/_{2}\, \rho v^2 c_d A$ (where ρ is air density and c_D is air resistance coefficient). A simplified version of this one is equation (7).

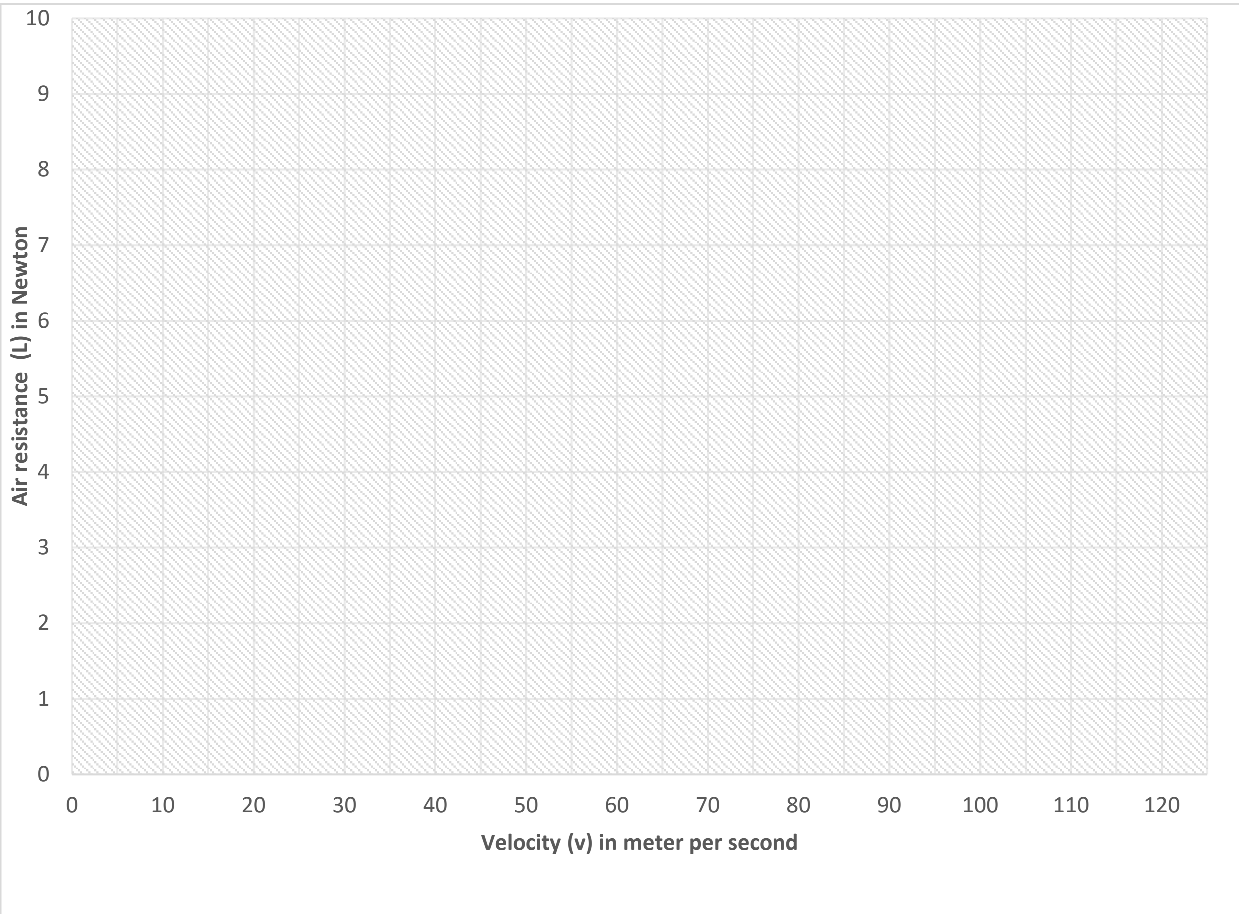
$$L = \frac{A \cdot v^2}{40000} \qquad (7)$$

Use equation (7) to calculate the air resistance at different velocities.

x	Velocity, v (in m/s)	0	10	25	50	75	100	125
y	Air resistance, L							

Calculate the air resistance for the rocket at the rocket burnout, use the velocity from exercise 2C.

G. Plot the values from the table in the diagram below. Velocity at x-axis and air resistance at y-axis. Draw the graph.



H. In the graph, mark where you have engine burnout. Hint: Use your answer from exercise F to find the coordinates.

I. Calculate the force of gravity on your rocket, $F = m \cdot g$, and compare it with the air resistance. Which of the two forces are strongest? And how many times stronger?

J. Look at graph from exercise G. How many times stronger is the air resistance if we double the velocity? What happens to air resistance when the velocity is three times faster?

K. Write down your most important results in the table.

Rocket type:	
Maximal velocity (when you have engine burnout)	
Height at burnout	
Rocket apogee according to my calculations	
Maximal air resistance (when you have maximal velocity).	

Table A

Rocket	**Engine type**	**Average Thrust (F)**	**Engine mass (m_m)**	**Burn time (t_b)**
Avion A	A6-4	4.17 N	0.016 kg	0.6 s
Avion B	B4-4	4.54 N	0.021 kg	1.1 s
Payloader One B	B4-4	4.54 N	0.021 kg	1.1 s
Payloader One C	C6-3	6.25 N	0.025 kg	1.6 s
Egg courier	D9-5	9.52 N	0.028 kg	2.1 s

Appendix 1: Engine Chart

Raketenmotorfibel
Rocket Motor Primer

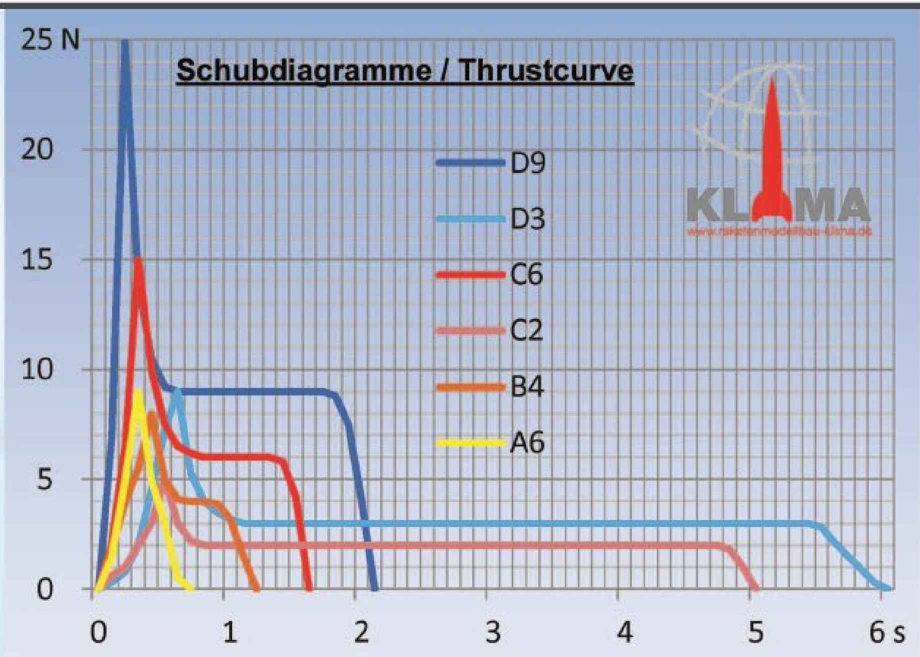
- Standard 18 mm Motoren
- Viele neue Motortypen
- Volle Leistung durch Kompositetreibstoff
- Saubere Ausstoßladung
- Präzise Einzelfertigung
- Einzigartiger Sound

Made in Germany

Standard 18 mm motor size -
Lots of New Motor Types -
New Composite Propellant for high performance flights -
Clean Ejection Charges -
Precision Manufactured Quality -
Unique Sound -

CE

Schubdiagramme / Thrustcurve



Elektroanzünder / Igniters

Best.-Nr. / Item No.: 7001

Sechs Stück Elektroanzünder zum Zünden der Treibsätze mit Zündgeräten (6 oder 9 Volt). Sichere Befestigung mit beiliegenden Stöpseln in den Treibsätzen.

Six electrical igniters for igniting rocket motors with electrical Launch Controllers (either 6 or 9 Volts). The igniters are secured in to the motor nozzles with the included plugs.

Aluhülse / Aluminum Sleeve

Best.-Nr. / Item No.: 8060

Sichere und einfache Befestigungsmöglichkeit der 18 mm Raketenmotoren. Gerne verwendet für Raketengleiter, Raketenautos und auch für Raketenmodelle. Eine Seite ist verschlossen, kann aber je nach Verwendungszweck aufgebohrt werden.

A safe and simple method for mounting 18 mm rocket motors. Often used for rocket gliders, rocket cars and also for flying model rockets. One side is closed, but can be easily drilled open, depending on the designated use.

Raketenmodellbau Klima GmbH
An der Laugna 1, D-86494 Emersacker,
Tel.: +49 (0) 8293/1734
www.raketenmodellbau-klima.de

Best.-Nr. Item No.	Typ Type	Gesamtimpuls Total Impulse	Schub avg. Thrust	Schubdauer Burning Period	Verzögerung Delay	Gesamtgewicht Total Weight	Pulvergewicht Powder Weight	Max. Startgewicht Max. Lift-Off Wgt.	Verwendung Usage
0164	A6-4	2,5 Ns	6 N	ca. 0,6 s	ca. 4 s	14,5 g	3,5 g	70 g	green, red
0240	B4-0	5,0 Ns	4 N	ca. 1,3 s	0 s	15,8 g	5,0 g	90 g	blue
0244	B4-4	5,0 Ns	4 N	ca. 1,3 s	ca. 4 s	16,8 g	5,8 g	90 g	green, red
0320	C2-0	10,0 Ns	2 N	ca. 5,0 s	0 s	22,3 g	11,5 g	150 g	yellow, purple
0329	C2-P	10,0 Ns	2 N	ca. 5,0 s	verschlossen / plugged	22,5 g	11,0 g	150 g	yellow, purple
0360	C6-0	10,0 Ns	6 N	ca. 1,6 s	0 s	18,7 g	8,9 g	160 g	blue
0363	C6-3	10,0 Ns	6 N	ca. 1,6 s	ca. 3 s	20,5 g	9,5 g	160 g	green, red
0365	C6-5	10,0 Ns	6 N	ca. 1,6 s	ca. 5 s	21,2 g	10,2 g	150 g	green, red
0367	C6-7	10,0 Ns	6 N	ca. 1,6 s	ca. 7 s	22,0 g	11,0 g	140 g	green, red
0369	C6-P	10,0 Ns	6 N	ca. 1,6 s	verschlossen / plugged	19,9 g	8,4 g	160 g	orange, black
0430	D3-0	19,0 Ns	3 N	ca. 6,0 s	0 s	28,0 g	17,2 g	200 g	yellow, purple
0439	D3-P	19,0 Ns	3 N	ca. 6,0 s	verschlossen / plugged	27,7 g	16,7 g	200 g	yellow, purple
0490	D9-0	20,0 Ns	9 N	ca. 2,1 s	0 s	26,3 g	15,5 g	300 g	blue
0493	D9-3	20,0 Ns	9 N	ca. 2,1 s	ca. 3 s	27,1 g	16,1 g	300 g	green, red
0495	D9-5	20,0 Ns	9 N	ca. 2,1 s	ca. 5 s	27,6 g	16,6 g	250 g	green, red
0497	D9-7	20,0 Ns	9 N	ca. 2,1 s	ca. 7 s	28,2 g	17,2 g	200 g	green, red
0499	D9-P	20,0 Ns	9 N	ca. 2,1 s	verschlossen / plugged	26,5 g	15,0 g	300 g	orange, black

Verwendung / Usage

- green: Einstufige Raketen / Single Stage
- red: Letzter in Mehrstufenraketen / Final Stage in multi-stage rocket
- blue: Mehrstufen Treibsatz / Booster Stage
- yellow: Raketengleiter / Boost Glider
- purple: Raketenauto / Rocket Car
- orange: Raketen mit elektronischer Bergungssystemauslösung / Rockets with electronic recovery systems
- black: Bündelung / Cluster

Die Motoren werden in Packungen zu 6 Stück mit beiliegenenden Zündschnüren geliefert. Alternativ sind Elektroanzünder erhältlich. Die Motorlänge beträgt 70 mm und der Durchmesser ist 17,8 mm.
Each motor type comes in a pack of six, including safety fuses for igniting. Electric igniters are separately available. Motor dimensions are 17,8 mm in diameter and 70 mm in length.

Source

- Content developed by NAROM for Nordic-ESERO