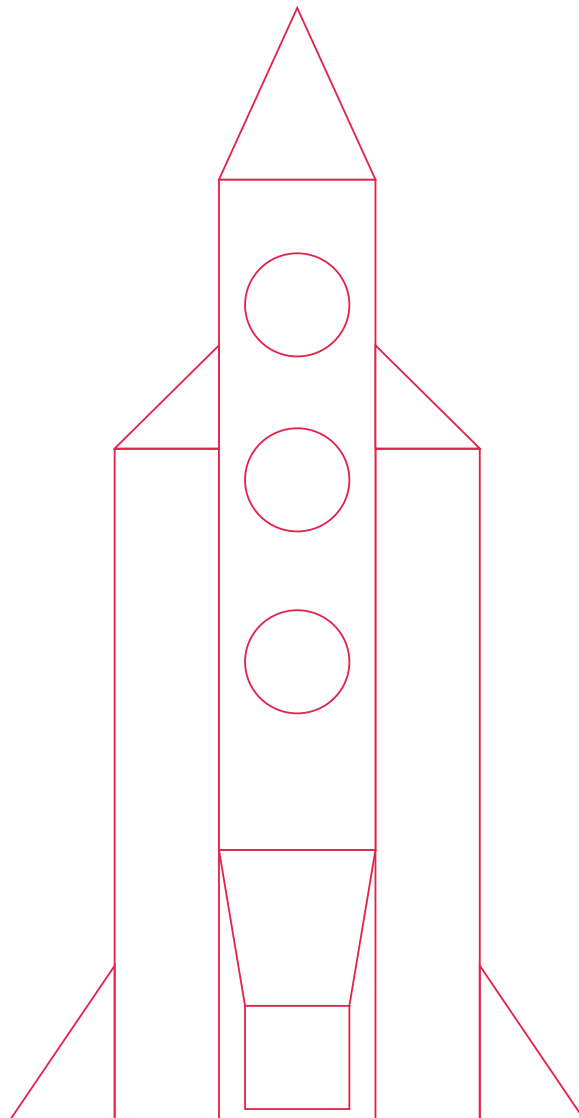
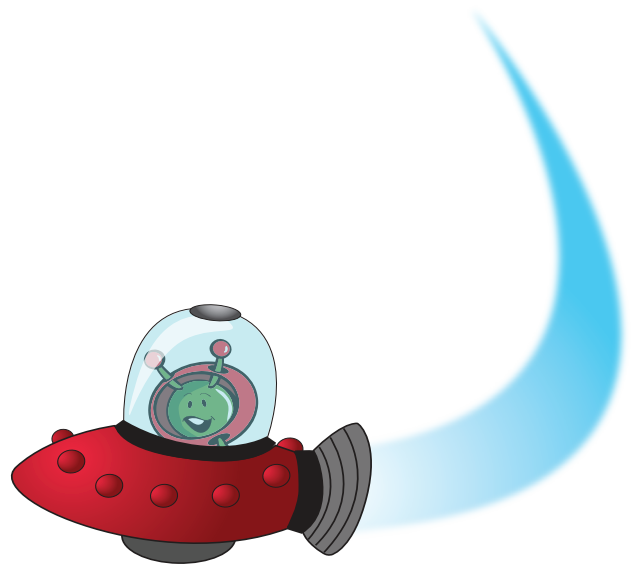


teach with space

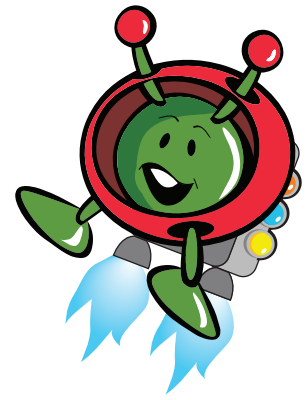
→ UP, UP, UP!

Build and launch your own rocket





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→ UP, UP, UP!

Build and launch your own rockets

FAST FACTS

Age range: 8-12 years old

Type: group practical activities

Complexity: easy

Teacher preparation time: 30 minutes

Lesson time required: 25-60 minutes per activity

Cost per class: low-medium

Location: indoors and outdoors (to launch the rockets)

Include use of: 3D printed launch elbow using files link: <http://esamultimedia.esa.int/docs/edu/1PBL.zip>

Outline

In this set of four group activities pupils build three different rockets. The first is a simple paper rocket powered by blowing into a straw, the second is a more complex paper rocket powered by squeezing a water bottle, and the third is a chemical rocket. Pupils will launch their rockets to investigate which variables affect the distance travelled and their trajectory. They will eventually gain a good understanding of rockets are, and how they work.

Pupils will learn

- What a rocket is and why it goes up
- About rocket stability and the importance of the fins and the nose
- That the distance travelled by a rocket depends on the initial launch energy or power, and the initial launch angle
- That objects need energy to move

Pupils will improve

- Their ability to explore and test ideas
- Their skills in taking measurements, interpreting results, and making conclusions
- Their ability to recognise and control variables when necessary
- Their project development skills



→ BACKGROUND

Why do we need rockets?

Note: This information is also in pupil activities document

On Earth, there is a force that continuously pulls us down towards the ground. We are so used to this force that we do not even notice it anymore. But when we jump, we always fall down again because of this force. This force is called **gravity***

If an astronaut wanted to escape Earth's gravity, he would have to jump very, very high and very, very fast, otherwise he would fall back down to Earth (as he does in Figure 1, jumps 1 and 2).

But, if the astronaut could jump with the right direction and speed, he would be able to counteract the Earth's strong gravity. With this specific direction and speed, instead of falling directly to the ground, he would fall towards Earth, but miss the planet; as a result he would fall around the Earth and enter **orbit*** (Figure 1, jump 3). The astronauts on the International Space Station and satellites observing the Earth are also in orbit.



↑ The force of gravity pulls us down to the ground continuously. To escape it, astronauts would need to jump with a very high speed and specific direction.

No astronaut can jump fast enough to escape Earth's gravitational pull! That is why scientists have invented rockets.

Why do rockets go up?

Note: This information is also in pupil activities document

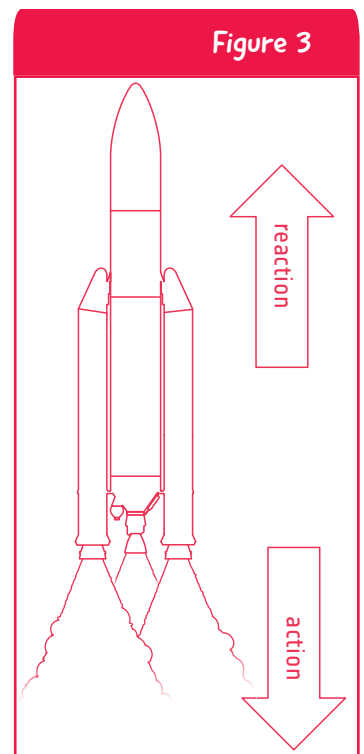
To launch a rocket, thousands of kilograms of fuel must be burned continuously in just a few minutes. The burning of fuel produces hot gases that are forced out of the back of the rocket giving it the acceleration and speed that it needs to launch (Figure 2).



↑ Rocket launch sequence. This is a Soyuz rocket launching from French Guiana in 2015.

As the hot gases are pushed out downwards, there is a **reaction force*** that pushes the rocket upwards - in the opposite direction. This reaction force is called **thrust***.

Newton's third law* explains how rockets produce thrust – given two objects, when one object applies a force on the second object, the second object simultaneously reacts with an equal and opposite force on the first object. Another way of saying this is: for every action, there is an equal and opposite reaction (Figure 3). This is exactly what happens when the air is let out of a balloon. The air goes one way and the balloon moves in the opposite direction. In a rocket, the combustion gases are pushed through the engines' nozzle, producing an action, which generates a reaction force, which pushes the rocket up into the sky and towards space.



↑ Newton's 3rd Law, or Law of Action-Reaction, explains why a rocket goes upward.

→ SUMMARY OF ACTIVITIES

The four proposed activities have been developed using an inquiry-based science learning approach. Pupils will plan and conduct simple investigations, record their predictions and observations, and analyse the results. At the end they will design their own research project.

These activities can be performed in the classroom, but a larger space such as the school hall, the gym or an outdoor space is ideal. Choose an area to be the 'launch area', from which pupils will launch their rockets.

Even though pupils will work in groups of 2-4 people to build and launch the rockets, distribute the pupil activity sheets to every pupil, on which they will write their observations and conclusions regarding the different experiments.

Activity 1 introduces pupils to the topic of rockets, and allows pupils to discover what rockets are used for. Pupils will carry out research into one specific type of ESA rocket. Activity 1 should take about 25 minutes to complete.

Activity 2 guides pupils to make simple paper rockets. Pupils test rockets with and without noses, to understand why rockets are closed with a nose at one end. This can be linked to Newton's third law of motion. Activity 2 should take about 30 minutes to complete.

Activity 3 involves building a launch system using a water bottle, to launch a larger paper rocket. It requires use of the 3D printed launch elbow. If you have not been given one of these at an ESA teacher workshop, you can download the .stl file from the webpage of this resource and 3D print it yourself using a 3D printer at a makerspace, or using a 3D printing web service. Activity 3 should take about 1 hour to complete.

Activity 4 requires students to create their own experiment to investigate rocket fuel. The rocket gets energy from the reaction between an Alka-Seltzer tablet and water. Activity 4 should take about 40 minutes to complete.

Health and safety

The proposed activities should be carried out with the supervision of an adult. Pupils should be warned to:

- o Wear safety goggles to prevent eye injury during launch.
- o Launch the rockets in an open area, which is clearly identified in advance.
- o Not launch the rockets in the direction of other people.
- o Stand behind the launch point.
- o Not lean over the rocket if it fails to launch; it can always launch at an unexpected moment.

→ ACTIVITY 1: GET ME OFF THIS PLANET!

In this activity, pupils investigate rockets, including analysing their main characteristics, and investigating why they have different sizes. Pupils develop an understanding of what rockets are, and what they are used for.

Equipment

- 1 pair of scissors
- Glue
- Sticker paper (to print the rocket stickers in appendix 1- optional)

Note: Pupils will need internet access to answer question 3 of this activity.

Exercise

1. In appendix 1, there are three different sticker strips. Divide the class into 3 groups. Each pupil in Group 1 should receive the first sticker strip, each pupil in Group 2 should receive the second sticker strip, and each pupil in Group 3 should receive the third sticker strip. Ask pupils to answer question 1 from the pupil activity sheet.
2. Ask pupils to compare and contrast the rockets and then to answer question 2. To help them, explain that rockets carry **payloads*** in the top section of their main bodies. Some rockets are used to place satellites into orbit, while others have been used to take people and probes towards the Moon and deeper into space. The main contributors to the overall size of a rocket are the payload size and the desired destination (to get into deep space, more fuel and therefore extra tanks are necessary).
3. Divide each group of pupils into three smaller groups. Each smaller group should research one of the three rockets from their sticker strip (to be decided by you). Explain to your class which rocket they should investigate, and how they could carry out this investigation. Pupils can look for information on the internet and should complete question 3 from the activity sheet. Ask a representative from each group to present the main characteristics of their rocket.



→ ACTIVITY 2: AIR FOR THE ROCKET (I)

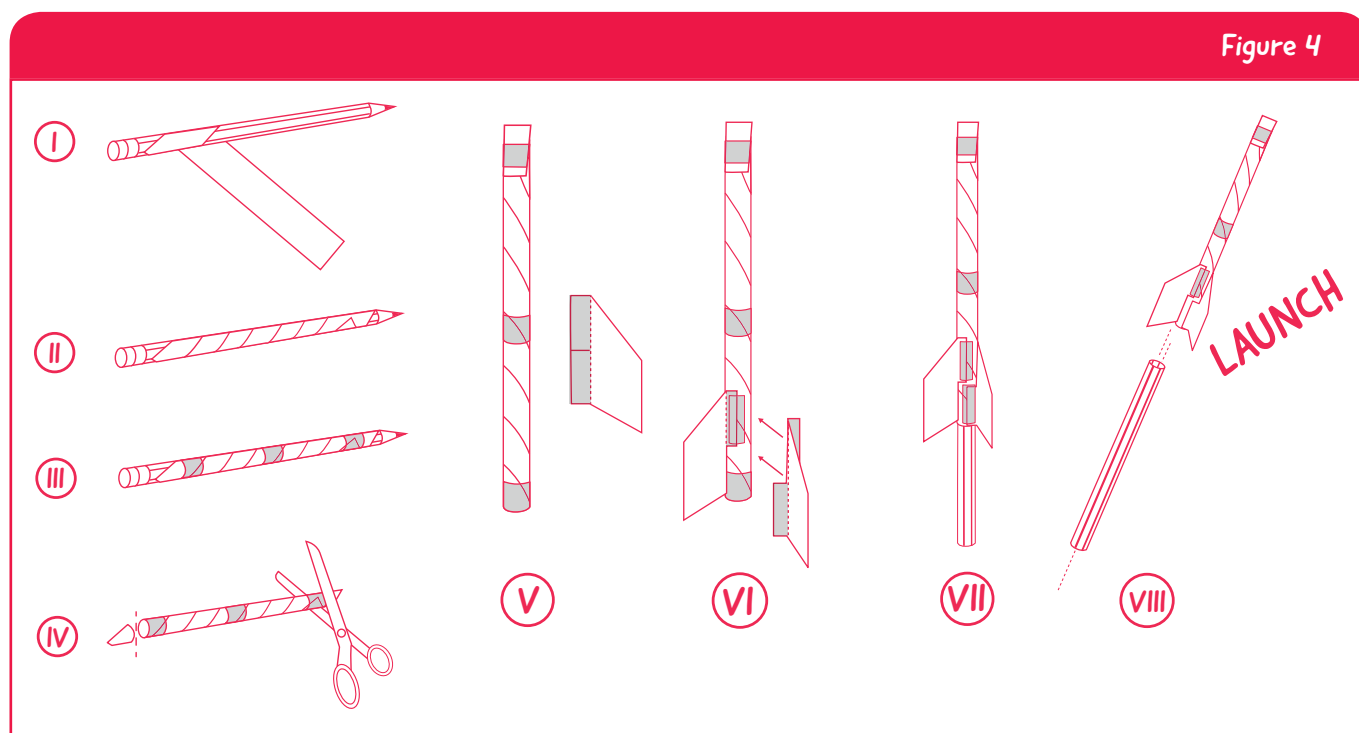
In this activity, pupils begin to explore paper rockets. They build a paper rocket and observe its performance in the air in two different development stages. Firstly the rocket is launched with an open end. Secondly it is launched with a folded end, which represents a nose. Pupils use a drinking straw to launch the rockets. They should eventually understand that rockets work using Newton's third law of motion.

Equipment

- 1 A4 sheet of paper
- 1 straw (wide diameter if possible)
- 1 pencil (of the same diameter as the straw, or slightly bigger)
- 1 pair of scissors
- Sticky tape
- Template for the fins (appendix 2)

Exercise

1. Give each group the equipment they need to build and launch a rocket. The pupils should initially follow instructions I to IV ONLY of the figure below (Figure 4), also presented in the pupil activity sheet, to build the body of their rocket.



↑ Building a paper rocket to be launched with a straw.



2. Before launching the rockets, ask pupils to discuss in groups how they think their rocket will behave in the air. What trajectory do they expect the rocket to follow? Is it going to fly far? Pupils should write their predictions in Table A2 in the activity sheet.
3. Then, one member of each group should go the 'launch area' to launch their rocket. All pupils should be able to see the launch. Pupils should write what they observe in Table A2.
4. Pupils will now improve their rocket. For that, they will add fins and a pointy top to be the nose. Pupils should follow instructions V to VII of Figure 4 (Figure A5). Note that it is only the addition of the nose that is important; in this activity, the addition of the fins is only for fun.
5. Pupils should write their predictions and observations for the second launch in Table A2.
6. Ask pupils to answer questions 2 and 3 from their activity sheet. Discuss their answers as a class. In addition to question 3, encourage discussion by asking pupils if they have ever seen pictures or videos of a real rocket launch. Ask them to describe the moment of the launch (they should recognise the sound and the light produced by the burning of the fuel and the exhaust gases coming out of the rocket).

Answers to discussion questions 2 and 3

2. Compare your observations from Launch 1 and Launch 2. Describe and explain any differences between the two launches.

The rocket without a folded end does not fly at all, and the rocket with a nose flies with a parabolic trajectory. Blowing into the launch straw creates a higher pressure behind the rocket. However, this only happens for the rocket with the nose. It is the folded end that prevents the air immediately escaping from the paper rocket and thus the air inside it is pressurised. This produces an action force. In real rockets, the action force is produced by hot gases being forced out of the back of the rocket. The rocket actually launches because of the equal and opposite **reaction force** (Newton's third law).

3. Based on your observations, explain what you think is necessary to give a rocket in order to launch it into space. How is launching a real rocket different to launching a paper rocket?

To launch a rocket into space it is necessary to give it some energy. Real rockets get their energy from burning fuels that emit gases behind them, which send them forwards. Paper rockets get their energy from the moving air.



→ ACTIVITY 3: AIR FOR THE ROCKET (II)

In this activity, pupils build a paper rocket and use a plastic water bottle to launch it. They investigate how changing the launch angle affects the trajectory of the rocket and answer the key question: which launch angle results in the rocket travelling the furthest horizontally? As a follow up activity, pupils can investigate how the launch pressure affects the trajectory of a rocket. Pupils will come to understand how rocket motion is affected by changing variables.

Equipment

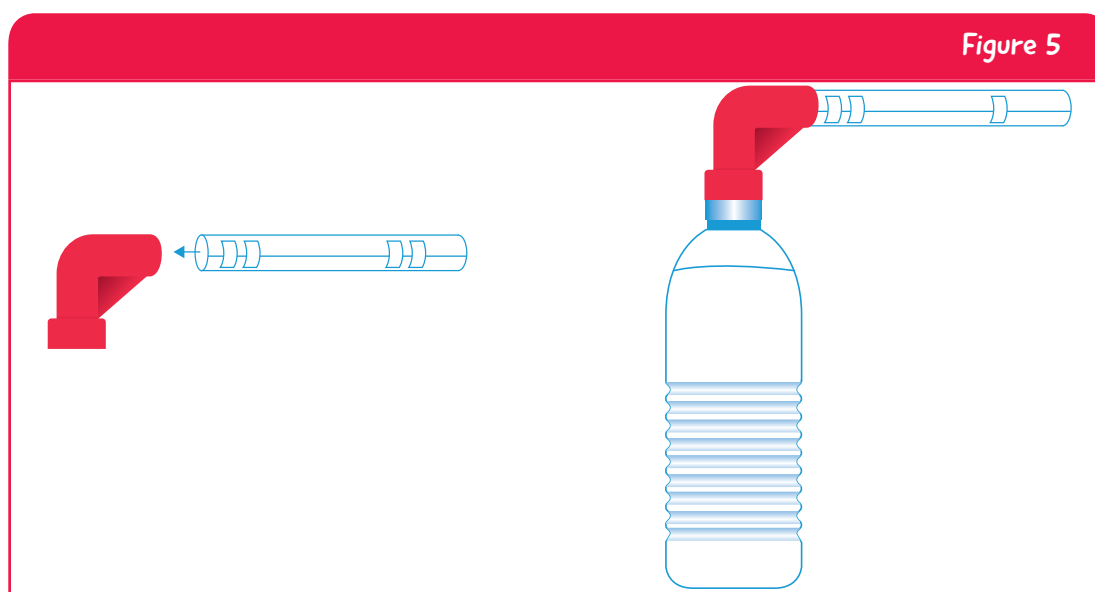
Per group:

- 2 A4 sheets of paper
- Nose and fins template (Appendix 3)
- 1 500 ml plastic water bottle (Ensure this fits onto a 3D printed launch elbow)
- 1 3D printed launch elbow
- 1 protractor
- 1 pair of scissors
- Sticky tape
- Long measuring tape

Exercise

1. Give each group the equipment described in the equipment list. Pupils start by assembling the rocket launch platform (Figures 5 and A5) and then they build the paper rocket. Make sure that the rocket platforms are taped very securely. For detailed instructions, see pupil activity sheet

Pupils can cut the fins and nose from the template in appendix 3.



↑ Rocket launch platform

2. Before launching the rockets, explain to teams that they will investigate how changing the launch angle affects the horizontal distance travelled by the rocket. Ask them to predict the relationship between these two parameters.

3. Assign tasks to team members. One pupil is the launcher, a second pupil confirms the launch angle and gives the launch command and a third pupil measures the launch distance and returns the rocket to the launch site ready for its next flight.

Note: To help measure long distances, pupils can place markers (e.g. cones) at 1 m intervals, up to 20 m from the launch point. They can then count the cones to measure how many metres their rockets travel.

4. For each launch angle (75° , 60° , 45° , 30°) pupils launch the rocket twice and calculate the average distance travelled by their rockets. Encourage pupils to repeat the launch exactly in the same conditions (same launch angle and same pressing force on the water bottle).

5. Pupils should write the distance travelled in Table A3. Older pupils can then draw a graph of distance travelled versus angle of launch (see Figure 6 on page 12 for results).

6. Ask pupils to answer questions 2 and 3 from the discussion in their activity sheet. Discuss their answers.

7. As an extension, ask pupils what they think will happen to the trajectory of the rocket if they press the water bottle with more strength. They should write their hypotheses in the activity sheet.

8. Pupils will test their hypotheses. Ask how they will make it a fair test. Stress to them the importance of making sure that only one aspect of the test (one variable) is changed. For this activity, the variable that changes is the strength applied to the bottle (launch pressure).

9. Pupils compare their results with the results from the previous activity. For that they should choose a value for the launch angle from Table A3.

10. Ask pupils to answer questions 2 and 3 for the follow-up activity. Discuss their answers.



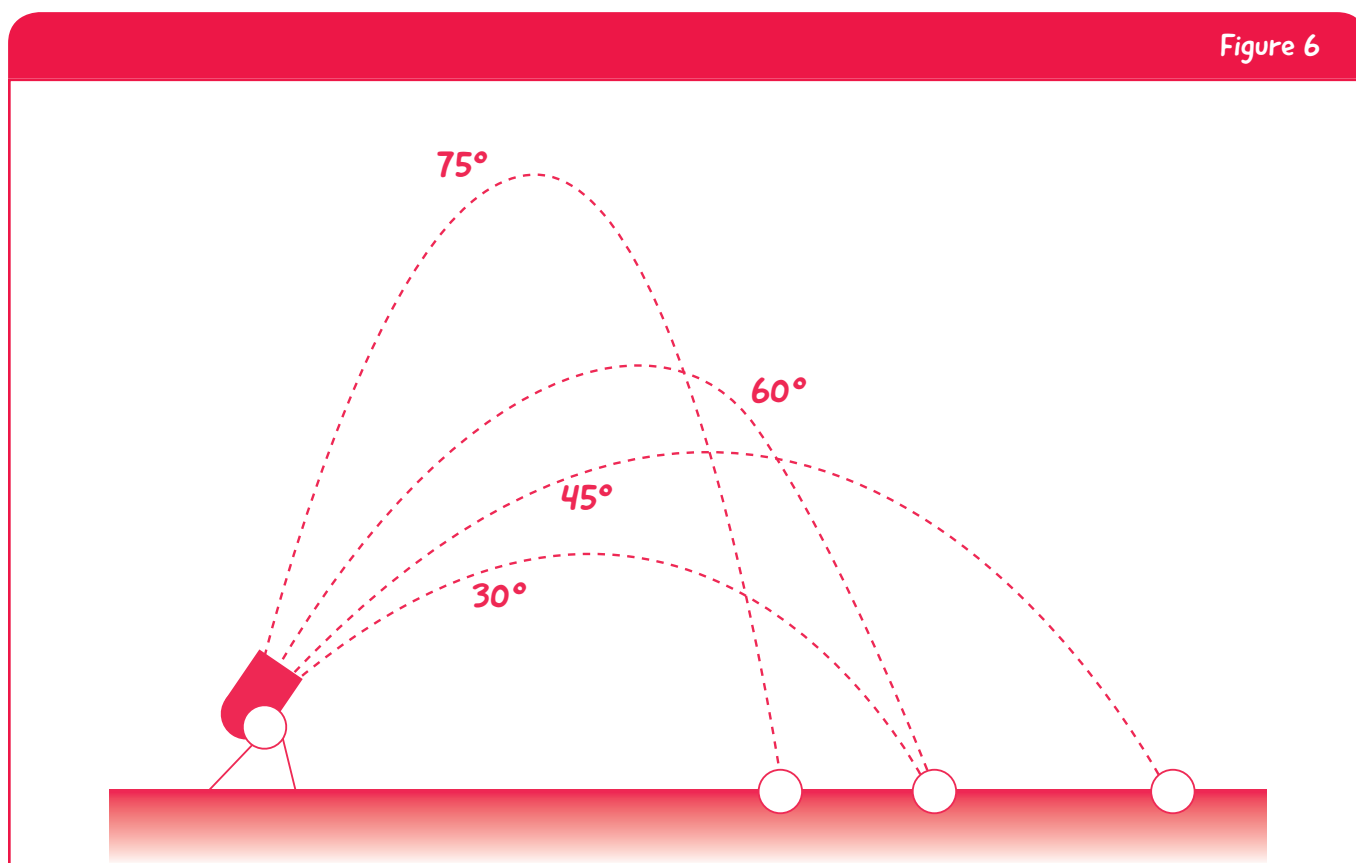
Answers to discussion questions

2. From your results explain how the launch angle affects the rocket's trajectory.

Pupils will observe that launching at an angle of 45° makes the rocket travel furthest. They should also observe that rockets launched at angles of 30° and 60° travel the same distance (Figure A7).

When launching a rocket straight up at an angle of 90° (neglecting air currents), the rocket will fall back to its launch site when its upward motion stops. Gravity causes the paper rocket to decelerate as it climbs upward and then causes it to accelerate as it falls back towards the ground.

If the rocket is launched at an angle of less than 90° , its path follows an arc determined by the launch angle and it will land at some distance from the launch site. The distance that it lands from the launch site depends on the launch angle and the initial velocity. In this activity, the initial velocity is controlled by the amount of pressure applied to the bottle.



↑ Launch angle vs. distance travelled for rockets with the same initial launch velocity. Adapted from ESA video: ATV Jules Verne - The science of leaving the Earth.

3. Identify two possible sources of uncertainty when using this method to launch rockets.

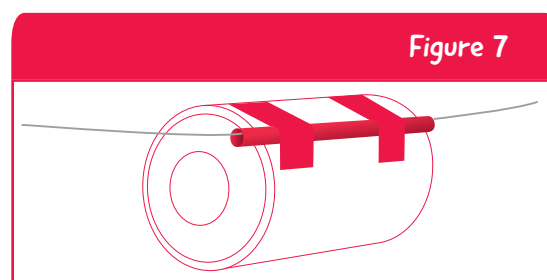
Pupils may find slight differences in the results even when teams are very careful to be consistent. This will happen due to the fact that with this method the initial pressure applied to the bottle is not being measured and it is difficult to control. Also, when pressing hard on the bottle to launch the rocket, it is possible that the launch angle changes slightly. To improve the accuracy of the results, it is important to repeat the trials and take averages.

→ ACTIVITY 4: FUEL FOR THE ROCKET

In this activity, pupils make an effervescent canister rocket in order to investigate the relationship between the amount of fuel that a rocket uses, and the distance that it travels. Through designing their own experiment to carry out their investigation, pupils develop their understanding of how rockets work.

Equipment

- 1 35mm white film canister (the white ones work better than black ones)
- Effervescent tablets (e.g. Alka-Seltzer®)
- Water
- Long measuring tape
- Sticky tape
- 1 pair of scissors
- 2 chairs
- 5 metres of fishing line
- 1 drinking straw
- 1 plastic cup



↑ Experimental set-up

Exercise

1. Give each group an area in which they can work and provide the groups with the equipment they will need to carry out their investigation. Make sure that there is enough space between the “work areas” to allow groups to move safely around. Provide only one effervescent tablet to each team (it’s possible to obtain good results with only one quarter of the tablet!)
2. Ensure that pupils are aware that for a valid experiment, they should only test one variable at a time.
3. It might be necessary to demonstrate to some teams what happens when water is mixed with an effervescent tablet. Encourage pupils to try doing this in their plastic cup and to discuss their observations. Depending on the age of the pupils, you might also like to show them Figure 7, to give them clues about how to set up the experiment.
4. After a successful launch for each team, ask a representative from each group to explain their experiment and to present their results.

→ APPENDIX 1: ESA ROCKETS



Vega



Soyuz



Ariane 5 ECA



Ariane 1



Ariane 3



Ariane 62



Ariane 2

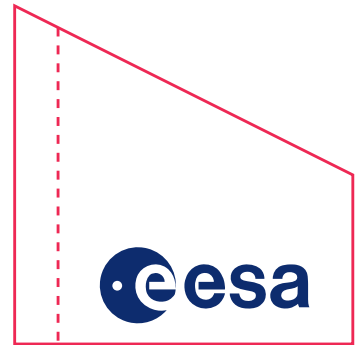
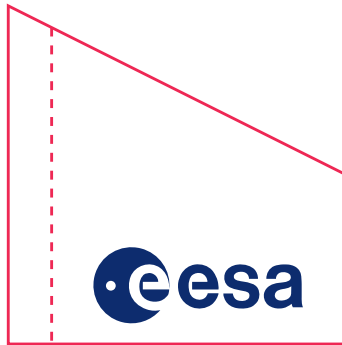
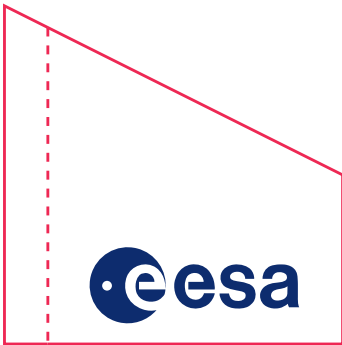


Ariane 4

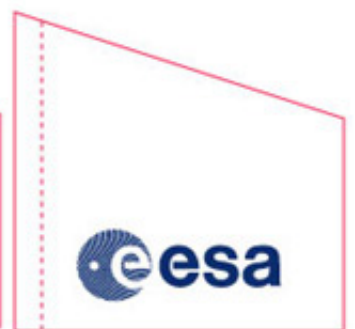
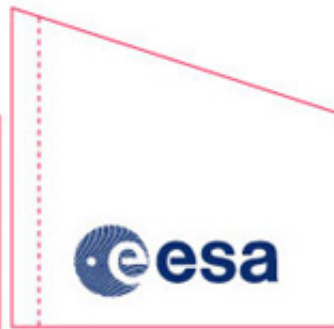
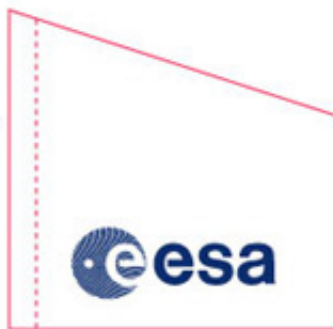
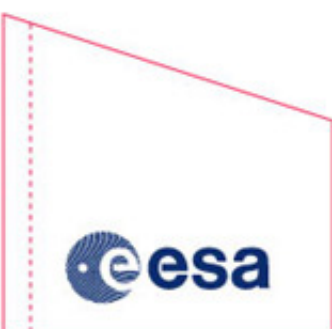
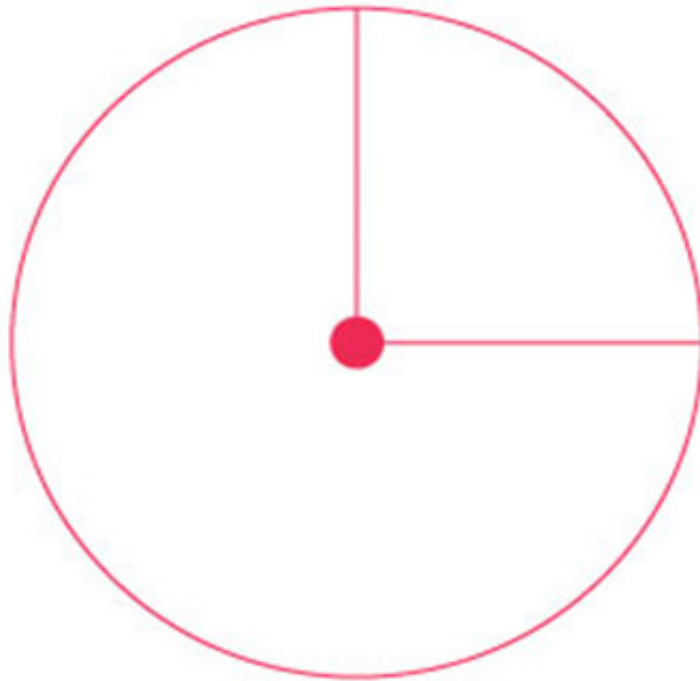


Ariane 64

→ APPENDIX 2: FINS FOR ACTIVITY 2



→ APPENDIX 3: FINS AND NOSE FOR ACTIVITY 3



→ GLOSSARY

Gravity: The force of attraction felt between two objects, in this case the Earth and us.

Orbit: The motion of an object in a circular or elliptical path around another object.

Payload: The load carried by a vehicle, which will be delivered to a specific destination. In the case of a rocket this is often a satellite, or even humans.

Reaction force: Forces always come in pairs. A reaction force is the force that acts in the opposite direction to an initial action force.

Thrust: The propulsive force from an airplane or rocket engine.

Trajectory: The path followed by an object moving under the action of given forces.

→ LINKS

ESA resources

ESA classroom resources:

www.esa.int/Education/Classroom_resources

ESA kids homepage:

www.esa.int/esaKIDSen

Paxi Fun Book:

<http://esamultimedia.esa.int/multimedia/publications/PaxiFunBook>

Extra information about rockets

Activity 1: ESA launchers:

www.esa.int/Our_Activities/Launchers/Launch_vehicles/Europe_s_launchers

Activity 1: ESA kids – European Rockets:

www.esa.int/esaKIDSen/SEMYWIXJD1E_Liftoff_o.html

Activity 2: Newton's three laws of motion:

www.esa.int/Education/Mission_1_Newton_in_Space

Activity 2: ExoMars 2016 liftoff :

<https://youtu.be/wbSyvBICfGc>

Activity 3: ATV Jules Verne - The science of leaving the Earth:

www.esa.int/spaceinvideos/Videos/2014/07/ATV_Jules_Verne_-_The_science_of_leaving_the_Earth

Activity 4: How does a rocket work:

www.esa.int/esaKIDSen/SEMVVIXJD1E_Technology_o.html

3D printed launch elbow files

<http://esamultimedia.esa.int/docs/edu/1PBL.zip>

teach with space – up, up, up | PR23a
www.esa.int/education

Activity concept developed by ESERO Portugal and ESERO NETHERLANDS

The ESA Education Office welcomes feedback and comments
teachers@esa.int

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