KINDERFORSCHER AN DER TUHH

Instructions for

KNIFFELIX online experiment platform with airplane puzzles

www.kniffelix.de

&

Experiment box "Why Do Airplanes Fly: Center of Gravity & Flight Behavior"

TUHH
Technische Universität Hamburg

KINDERFORSCHER
AT THE TUHH

TUHH
Technical University of Hamburf!.

Incorporate www.Kniffelix.de into your classroom

To accompany the experiment kits, we recommend using our hands-on experiment website Kniffelix.de**.** Kniffelix complements the practical work with digital learning opportunities and supports students in deepening and securing their findings. The platform is designed to be child-friendly and strictly follows the Youth Protection Act.

What does Kniffelix offer?

- short **videos** as a topic introduction with in-depth explanations or for repetition
- **Educational games** with which content is practiced or deepened in a playful way
- **Comprehensible explanations** of the evaluation of the experiments
- **Game rules for the safe use of the Internet** (also for download) with community tasks to practice. The KinderForscher-Team personally checks everything before content is manually published by us. (→ more at "Results exchange" below)

Use in the classroom

The materials are suitable:

- for the **independent work** of the students
- for **repetition** or **deepening**
- or for **shared use in the classroom**
  - Videos as an **introduction**
  - Declarations on **safeguarding results**
  - Educational games to **deepen your knowledge**
  - Exchange of results via the **Kniffelix community**

    With the help of the Community Rules (Kniffelix.de/Nutzungsregeln), the students acquire important media skills, such as the responsible handling of other users and their own data on the Internet.
- Processing the entire Kniffelix material as a **digital learning station** for preparation or follow-up

Matching Kniffelix puzzles for the KinderForscher loan experiment kits:

- Pizza puzzle complements the experiment box

"How does a researcher work on the example of "yeast"?

- Airplane puzzle completes the experiment box "Why Do Airplanes Fly: Shear Point & Flight Behavior"

- Helicopter puzzle completes the experiment box "Helicopter: From model to drawing"
- Wing puzzle completes the experiment kit "Why do airplanes fly: wings and lift"
- Earth puzzle completes the experiment box "Soil types and their water absorption"
- Ketchup puzzle complements the experiment box "Ketchup and Non-Newtonian Liquids"
- Other topics with boxes: Mushrooms & Chromatography

Where do you find the topics? What does the "Seitenstark Seal of Approval" mean?

On www.kniffelix.de you will find an overview of the Kniffelix puzzles for beginners on the homepage. (Advanced topics are also available there.)

These are the Kniffelix puzzles for beginners:

Pizza:

Yeast, enzymes, bioprocess engineering

Soil:

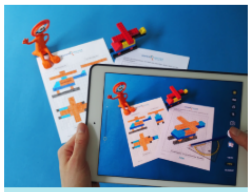
Soil types, water retention

Airplane:

Center of gravity, forces on the airplane

Ketchup:

Flow behavior, non-Newtonian fluids



Helicopter:

2D- and 3D-Drawings, spatial reasoning

Wings:

Air resistance, air currents, lift

- Further free **download materials** and **details on how to use** the platform can be found under the menu item **"For educators"** at the top right of the homepage.
- If you have any questions, need for support or suggestions **please contact us**.

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Teacher's Guide: Is the plane flying?
Center of gravity and flight behavior

Goals of the hour:

- Implement work instructions independently.
- Introduce them to trying things out and thinking further with the help of the experiment worksheet.
- Get to know the importance of the center of gravity in airplanes through a self-built plane, as well as the effects on flight behavior.

1. Introduction: (Prepare pictures for the introduction)

Today, everything will revolve around the topic of "flying". Where can you see airplanes in Hamburg, for example, or work in aviation?

- at the airport, at Airbus, at several institutes of the TUHH and in the DLR School Lab, in the sky

Around 30,000 people work in the aviation sector in Hamburg, and well-trained people are in great demand. The DLR School Lab was founded at the Hamburg University of Technology (TUHH) to get young people interested in this professional field. This is not an institute where research is carried out, but it was developed especially for young people who can carry out experiments on flying, currents in air and water and aircraft construction to get an impression of what aircraft engineers do.

Why are researchers still working on aircraft construction today? For example, what could researchers invent or improve today?

At the TUHH, researchers are investigating, for example:

- How can aircraft be designed even more reliably and safely?
- How can newly formed aircraft be developed with the help of computer programs so that they consume less fuel, for example? This includes a lot of calculations, as well as different parts that must fit together, and much more.
- How can the noise in the aircraft or emanating from it be reduced?

Airplanes are very heavy. Many people can be accommodated in it and transported with it at the same time. So, what keeps the plane in the air? (Collect suggestions) In any case, the wings are very important, and the aircraft also needs a propulsion system, for example a propeller or jet engines.

IF YOU WANT TO EXPLAIN IT EXACTLY: When the aircraft moves forward quickly due to the propeller or the engines, a strong airstream flows around the wings. This creates a lift force that pulls the aircraft upwards.

What kind of flying objects have you ever seen in the sky? Airplane, Glider, Helicopter, Hot Air Balloon, Zeppelin, Parachute

How do they differ? fast/slow forward movement, air is not heated, with/without motor

Holding up pictures for the introduction of the lesson (of a tilted plane on the ground): What can be seen in this picture? What's wrong?
This plane is incorrectly loaded. It got too much weight at the back and tilted backwards as a result. The front wheel is in the air.

It is very important to secure luggage and air freight very well in the hold of an aircraft so that the cargo does not shift during the flight.

Today we want to find out why the center of gravity of an airplane plays a very important role and build an airplane out of foam and a wooden strip – something like this one. (Show an airplane without Play-Doh.) Unfortunately, it doesn't fly properly. Do you see what happens when I throw it? (The plane climbs up at the front, makes a loop and then spins to the ground.) Do you know why that is? (Collecting ideas) Well, the plane only climbs up at the front, as if it were pushed up at the front and pulled down at the back (illustrate on the plane). This is because there are two forces acting on this plane that need to be balanced: the lift force that pushes the plane up and the weight force that pulls it down (picture of hour introduction of airplane holding up in the air). The lift force comes from the air that flows around the wings and pushes the plane up on the wings (press under the wings with your index finger). The weight force comes from the weight of the plane and from everything it is loaded with. It pulls the Flyer down (pull the plane down with your hand).

This is also the case with other aircraft. The problem, however, is that in this one not both forces act in the same place. If I press the bar from below in one place and from above in another, it rotates. But if I press in the same place from below and above, it does not rotate.

So the important thing about a force is the point at which it acts.
In the case of weight force, this point is called **the center of gravity**.

What is the focus of an object?
When you hang an object, its center of gravity is always perpendicular to its suspension. You can balance the object in the center of gravity, because it is from this point that the force of gravity acts that pulls the object towards the earth.

WHO WANTS TO EXPLAIN IT EXACTLY: Although every passenger in the plane, every suitcase and so on has its own weight force and is pulled downwards from the earth at the point where it is, you can also combine all these weights into a total weight with a center of gravity.
When objects move in the aircraft, this center of gravity shifts.

By the way, the calculation of the total weight and the position of the center of gravity before take-off is an important part of flight planning. It is the pilot's job to ensure that the weight of the aircraft does not exceed the maximum limit before take-off and that the centre of gravity is in the correct range.

Back to our plane: The lift force is generated on the wings, so it pushes the plane up quite far forward. Where do you think the weight force pulls when the plane climbs up at the front? (Further back.) So you have to shift **the center of gravity**, the point of application of the weight force, forward so that it is also **with the wing**. How can you get more weight to the tip of the plane? You may know a trick from building paper airplanes. (Make paper clips on the tip or fold the tip particularly thickly.) We do this with Play-Doh on our plane.

Every aircraft, whether made of paper or metal, large or small, only flies if the center of gravity of the aircraft is approximately at the wings. (Balance airplane on a pin under the wings. Without the Play-Doh, it's too heavy at the back. Therefore, we have to increase the weight at the front with Play-Doh. Then the plane flies well!)

- Now you build your foam-wood plane. Make sure that the center of gravity is in the middle under the wings. Observe the flight behavior of your aircraft depending on where the center of gravity is and consider why it is so important that aircraft loads do not shift during flight.

2. Experiment:

   Each child builds a foam-wood plane. The children learn about the term center of gravity and learn that it is important in aircraft construction that the center of gravity is on the wing, as this is where the lift pushes the aircraft upwards. Afterwards, they can enjoy the topic of flying through their own flight experiments and be encouraged to continue to deal with the topic.

3. Debriefing:

   - How did you cope with the work instructions?
   - Were you able to build the aircraft in such a way that the center of gravity was in the middle under the wings?
   - How did the plane fly then? The plane flew very well straight ahead and calmly.
   - What happened when the center of gravity was not in the middle under the wings? The plane crashed, flew downhill quickly, flew very restlessly and briefly.
   - What is the center of gravity in a real aircraft?
     In real aircraft, the center of gravity is slightly in front of the wing, because there is still a force at the back of the elevator that pulls the aircraft down at the back (you can think of it as the elevator is like an inverted wing and therefore generates a force downwards, so three forces are balanced).
     (Picture of airplane in the air with the three forces showing)
   - How can it happen that the center of gravity of an aircraft is not in the right place?
     If the aircraft is loaded incorrectly or the load slips, the center of gravity is not in the right place. In addition, the center of gravity changes when the aircraft loses weight, for example because fuel is consumed or when a parachutist jumps off.

If there are only small changes, it doesn't matter, because it can be compensated for by the elevator, for example. On long-haul flights, where a lot of fuel is consumed, the remaining fuel can be pumped from one tank to another in order to achieve a better weight distribution.

What do you think could happen if the center of gravity of a real airplane is not in the right place?
If the center of gravity is in the wrong place, the plane will not be able to take off, or if the center of gravity shifts in the air, the plane may crash.

4. Further information for teachers

In the DLR School Lab, the students are divided into several small groups and work with supervisors at various stations on the topics of air and water currents, sound insulation in aircraft construction and flying. (By the way: The School Lab can also be visited on the subject of ships!) More information about the DLR School Lab at http://www.dlr.de/schoollab/desktopdefault.aspx/tabid-1732/10608_read-23753/

Further teaching materials can also be found on www.skyfuture.de in the "Future Pilots" programme for schools. (Young talent initiative with competition of the German Aerospace Industries Association (BDLI))

Other experiment kits on the topics of aerospace:

- Why do airplanes fly? Wing shape & lift (from autumn 2020 on Kniffelix)
- Helicopter: From model to drawing (Also on Kniffelix →Helicopter puzzles)
- The Juri magazine Experiment: Bionics & Helicopters
- The Juri Magazine Experiment: Rocket Propulsion & Space

Material list for teachers

Why do airplanes fly? Center of gravity & flight behavior

(when using the experiment kit of KINDERFORSCHER AN DER TUHH)

1 CAMERA (in "General Box" if supplied for project)
1 box "Why do airplanes fly? Center of gravity & flight behavior"

1x Teacher's manual with all documents in a blue folder 25x Student worksheet: Is the plane flying?$_{Focus}$"
25x Knowledge Box "Aircraft and their Focus"

Introductory material:

1x3 laminated double-sided diagrams 1x sample aircraft

For the experiment:

For each of the 6 groups:

1x laminated station sheet "Is the aircraft flying?"
1x Scotch tape
1x scissors (in the airplane wings box, if you have those too)

For every child

1x wooden strip
1x foam wing
1x foam horizontal stabilizer 1x foam vertical stabilizer

Centrally deploy:

- Play-Doh
- Thread

Red text=Must be provided by yourself, not included in box

Material list for teachers

Why do airplanes fly? Center of gravity & flight behavior

(Without experiment kit)

Introductory material:

- 5 Aircraft diagrams
- If necessary, 1 example aircraft

For the experiment:

For each of the 6 groups:

- Instructions Foam Wood Flyer Part 1 and Part 2
- Scotch tape
- Scissors
- Ruler if necessary

For every child

- 1 wooden strip approx. 18-20 cm long
- A light, stable material (e.g. cardboard, thin, stable foam) from which the components of the aircraft are cut
- Student worksheet: Is the plane flying?$_{Focus}$"
- Knowledge Box "Aircraft and their Focus"

Centrally deploy:

- Play-Doh
- Thread
- Camera (also possible use: tablets, mobile phones)

What's wrong with this plane?

Source: Sebastian Krebs (License: CC BY)

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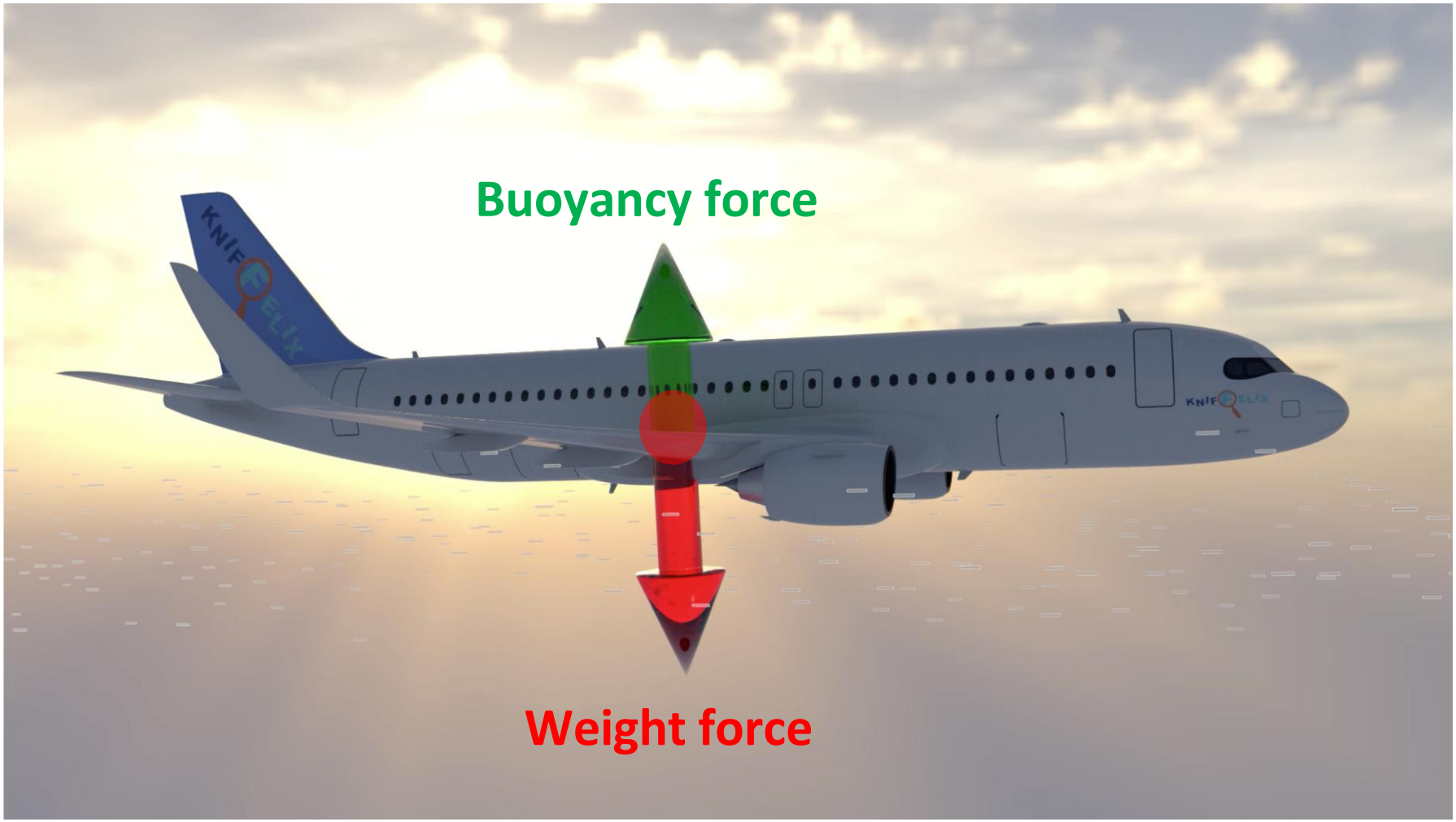
Where is the center of gravity of an aircraft?

Source: Sebastian Krebs (License: CC BY)

The center of gravity of an aircraft

(slightly simplified for lesson introduction)



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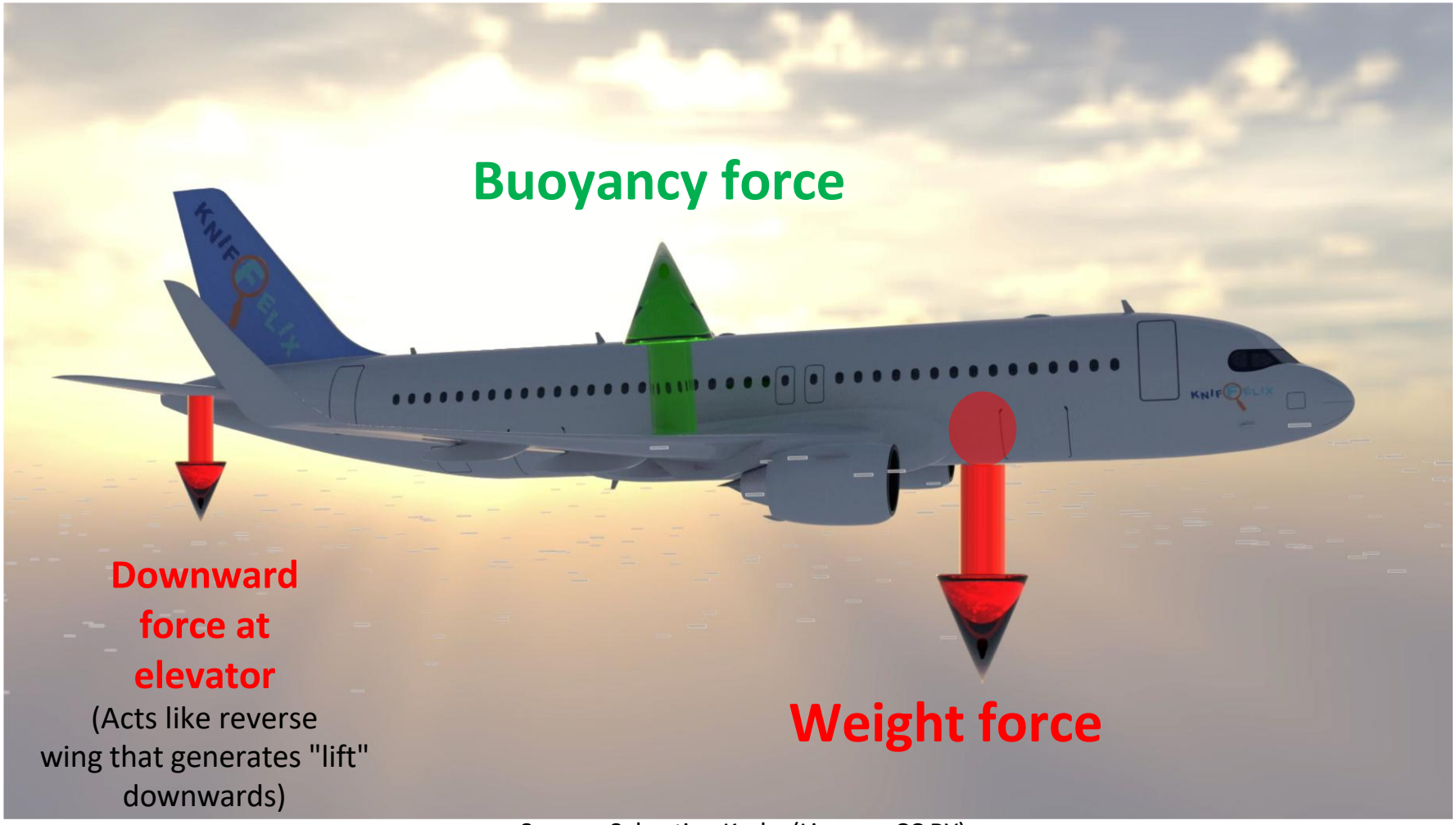
The center of gravity of an aircraft

(more precisely, for the end of the lesson)



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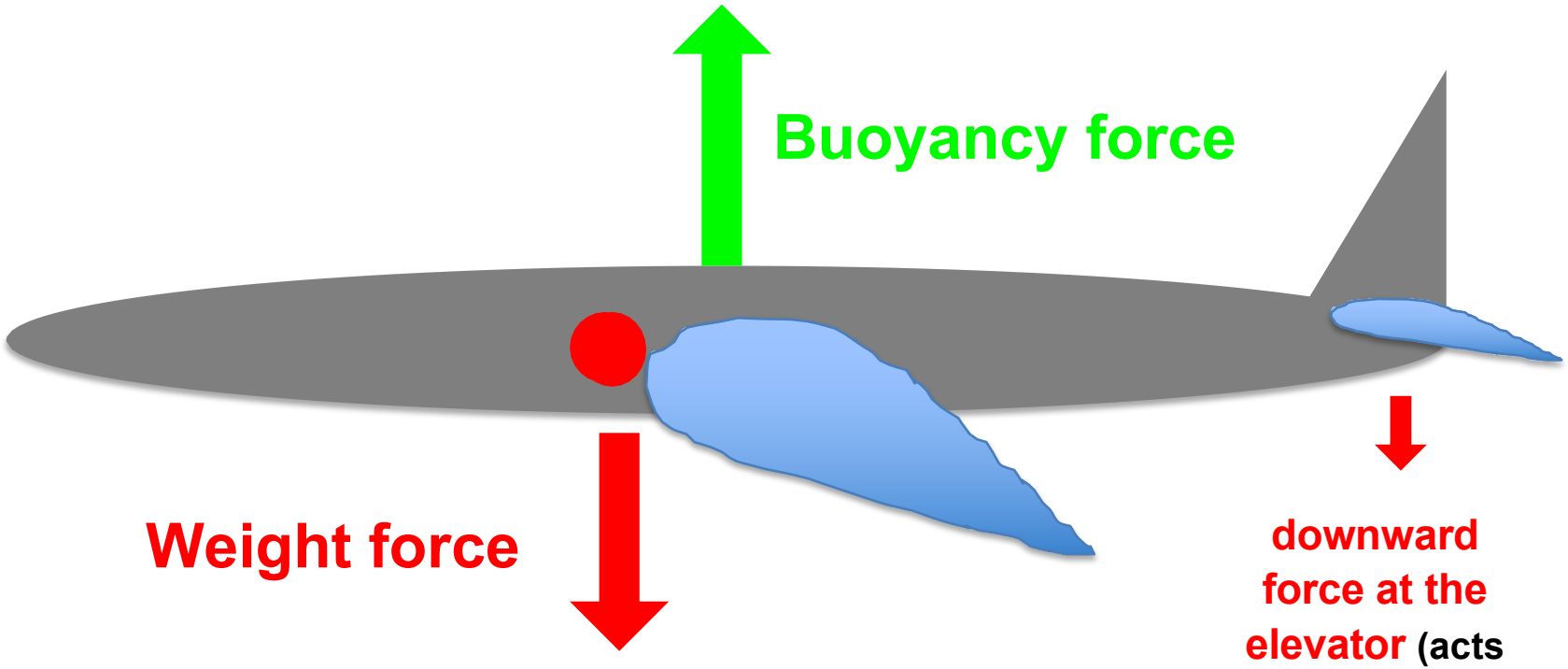
The center of gravity of an aircraft



Instructions Foam Wood Flyer Part 1

You will need the following materials:

- A wooden strip approx. 18-20 cm long
- A light, stable material (e.g. cardboard, thin sturdy foam) from which you can cut the components of your plane
- Scotch tape
- A pair of scissors
- (For a later attempt you will need Play-Doh and a thread)

Cutting:

Cut the following components from cardboard or thin, sturdy foam:

- 1 vertical stabilizer
- 1 horizontal stabilizer
- 1 wing

On the next page we will show you our shapes with sample dimensions. You can draw these shapes on your material with the measurements suggested here.

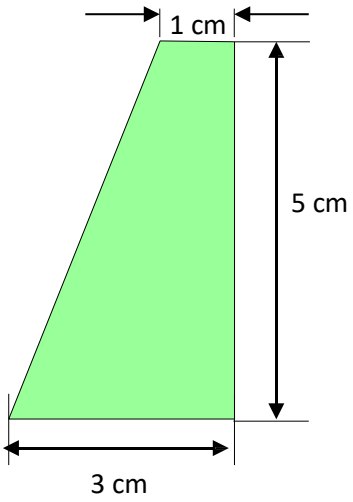
If you want to make it easier, you can use our molds as a template. When printing, it can happen that the dimensions change slightly and do not match those indicated. But that's not a bad thing.

Of course, you can also come up with your own measurements.

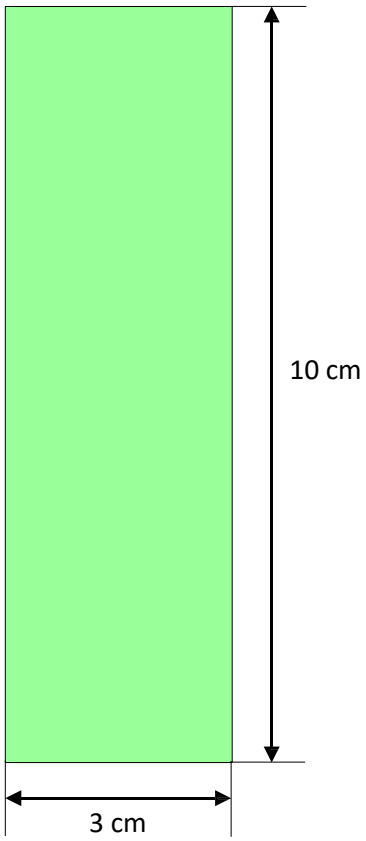
- Continued on page 2 -

Shapes and Sample Dimensions:

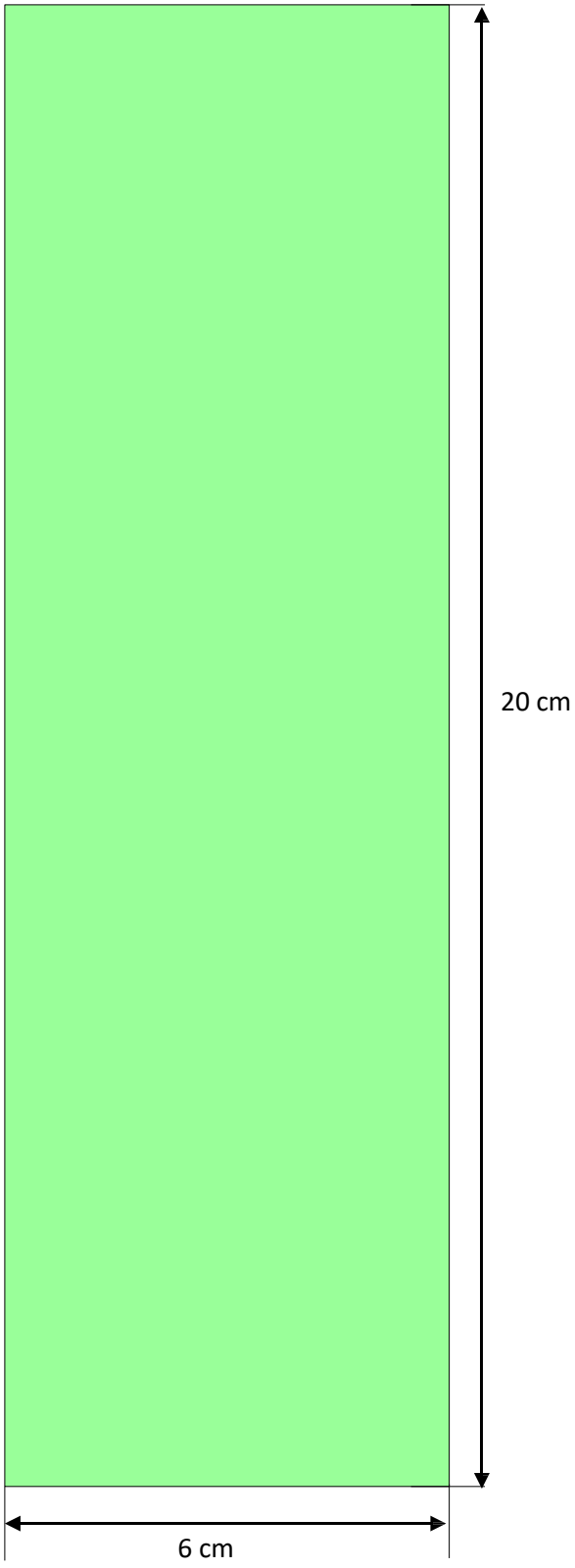
Horizontal stabilizer



Vertical stabilizer



Wing

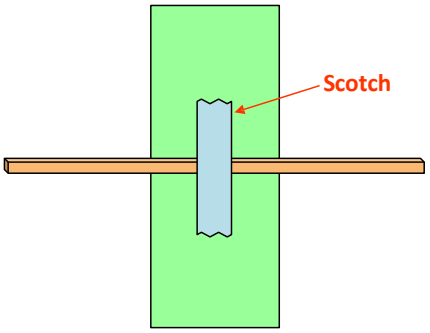


- Continued on page 3 -

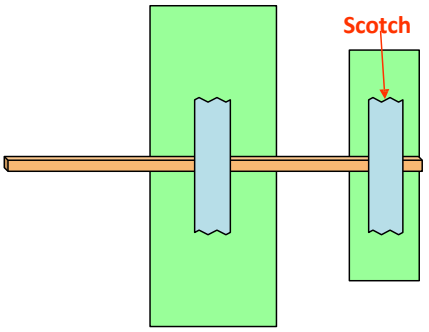
Instructions:

1. Place the wing on the table.
   Determine the center of the wing.

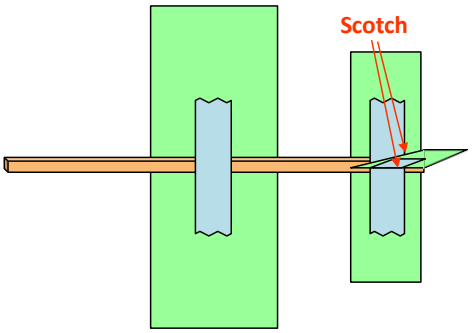
   Place a wooden strip on this centerline so that it is almost as much in the front as it is in the back
   protrudes over the wing and glue it to the wing with a long piece of scotch tape.



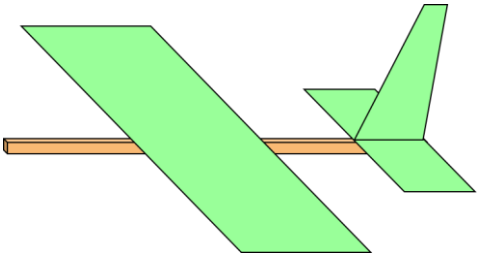
2. Now glue the horizontal stabilizer with scotch tape behind the wing to the wooden strip.



3. Now glue the vertical stabilizer on both sides with scotch tape.



4. Try your plane! Does it fly?

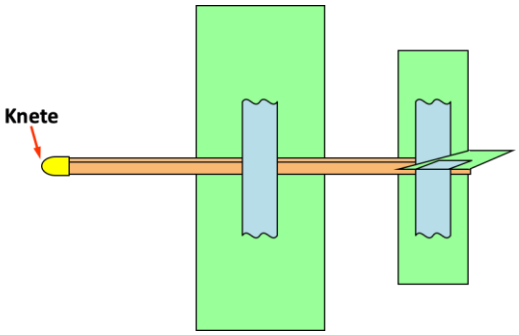


Instructions Foam Wood Flyer Part 2

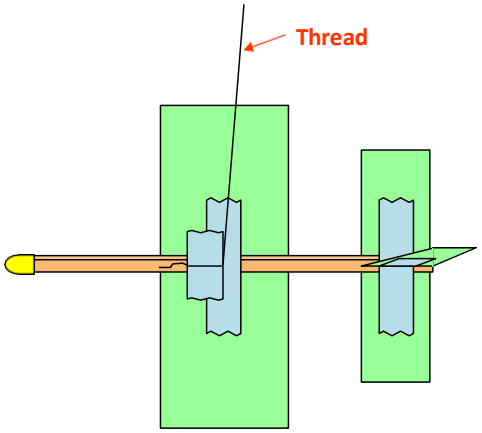
You need the plane from the 1st part and:

- Play-Doh
- A thread
- Scotch tape

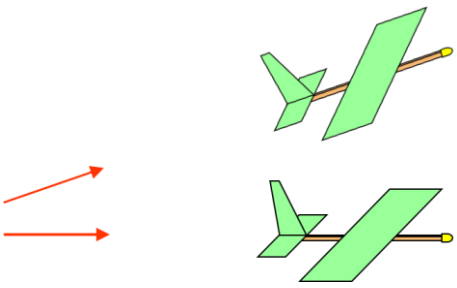
1. Since the model didn't fly well yet, you have to move the center of gravity forward by making it heavier at the front with Play-Doh. You can but of course also use a material other than modelling Play-Doh.



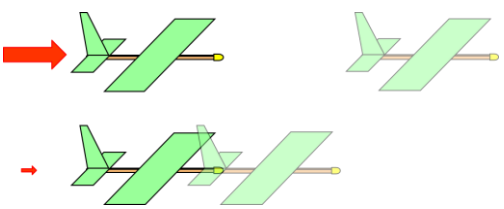
2. **2. How much dough is good??**
   In order for the aircraft to fly well, it must be horizontal in the air when it is suspended by a thread above the wing.
   Therefore, glue a thread with scotch tape in the middle of the wing to the wooden strip and let the plane hang down by the thread.
   If it hangs with the tip down, remove some Play-Doh.
   If the tip is pointing upwards, you'll need more Play-Doh.



3. **Flight tests:**
   Now your plane is ready to go. Let him fly. How does it fly on:
   If you throw it slightly up or if you throw it straight forward?

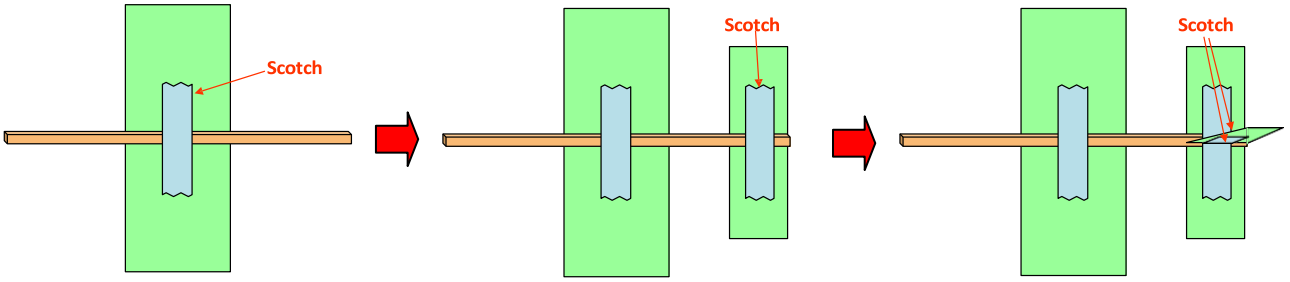


   How does it fly better:
   with a lot of momentum or
   if you throw it just very lightly?

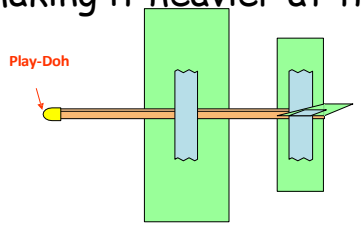


Worksheet: Is the plane flying?Focus

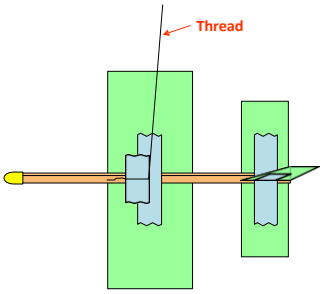
Build and try out a foam-wood plane

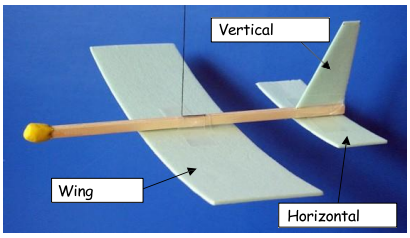


Try your plane! Does it fly? Probably not so good, because the lift pushes it up under the wings, but the weight force pulls the aircraft down, especially at the rear. That's why you have to move the center of gravity forward by making it heavier at the front with Play-Doh.



How much Play-Doh is good? In order for the aircraft to fly well, it must be horizontal in the air when it is suspended by a thread above the wings. Therefore, glue a thread to the wooden strip with scotch tape in the middle of the wing and hold it to it. If it hangs with the nose down, you have to remove some dough again, if the nose points up, you need more dough.





Flight tests:

Now your plane is ready to go. Let him fly.

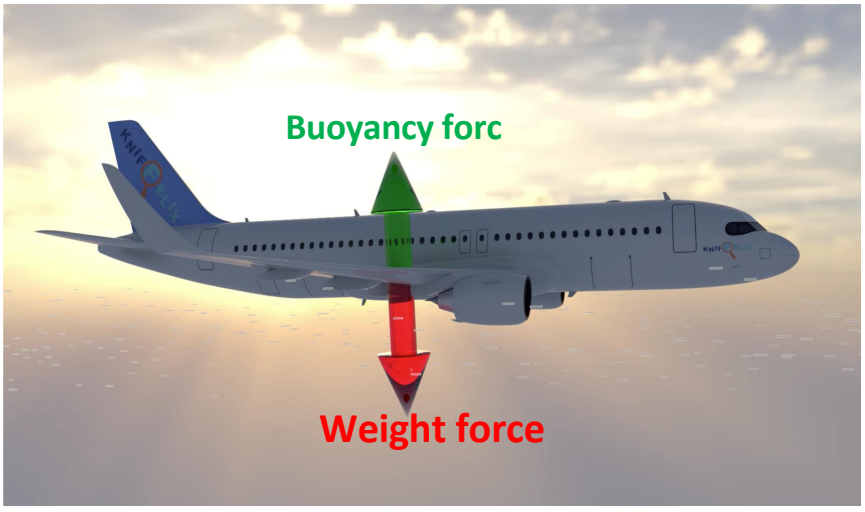
- How does it fly further: when you throw it straight forward or when you throw it slightly upwards?
- How does it fly better: with a lot of momentum or if you just throw it very lightly?

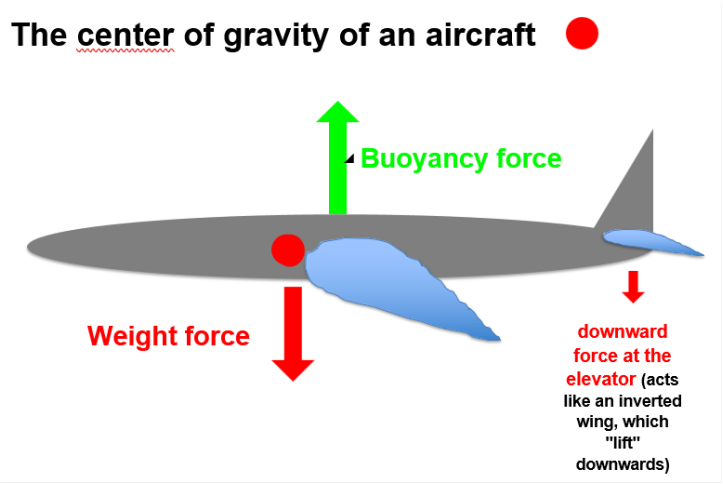
KNOWLEDGE BOX: Aircraft and their center of gravity

Quelle: Sebastian Krebs (Lizenz: CC BY)

What can be seen in this picture? What's wrong? This plane is incorrectly loaded. It got too much weight at the back and tilted backwards as a result. Its center of gravity is too far back. The front wheel is in the air.

Also for an aircraft to be able to fly, the position of the center of gravity of an aircraft is very important! Why? And, where does the center of gravity of an aircraft have to be? When flying, two forces in particular act on a Aircraft that need to be balanced in one point: the lift force that pulls the plane up and the weight force that pulls it down (see picture on the right).

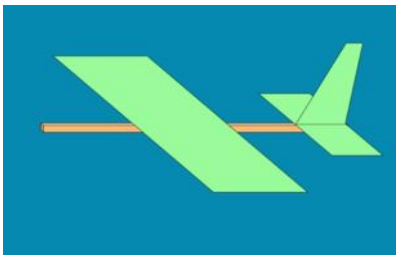




The lift force comes from the air that flows around the wings and pulls the plane up on the wings. (The Auf- bzw. Downward force of the elevator must also be considered.) The weight force comes from the weight of the and through everything with which it is loaded. She pulls the plane down. The important thing about a force is the point at which it acts. In the case of weight force, this point is called the center of gravity. For a horizontal flight, the lift force must act near the center of gravity. Therefore, the center of gravity of an aircraft should be approximately in the middle of the wings or slightly in front of it.

What happens if the center of gravity is not right?

In an aircraft where the center of gravity is not on the wings (where the lift force acts), the two forces do not act in the same place. I pull the bar of my handcrafted plane down in one place and in another



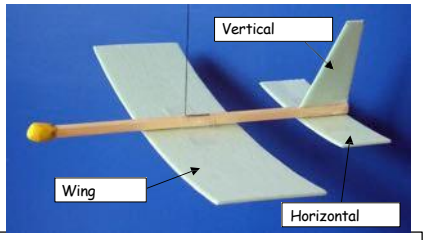
upwards, so it turns. The plane therefore turns and crashes. But if I pull in the same place from below and above, the bar does not rotate. The two forces of my plane are balanced, and it can glide for a long time.

Therefore, if you throw a plane whose center of gravity is not at the wings, but too far back, the plane climbs up at the front, makes a loop and then spins to the ground. It is first pulled up at the front and down at the back, because the buoyancy force acts at the front and the weight force at the rear. By the fact that it rises up in front, it is no longer well surrounded by the air,

the buoyancy force decreases and it falls to the ground.

How can you find out the location of the center of gravity?
When an object is suspended, its centre of gravity is always perpendicular to its suspension. You can balance the object in the center of gravity, because it is from this point that the force of gravity acts that pulls the object towards the earth.

How can you change the center of gravity of your plane?
Without Play-Doh, the center of gravity of your plane is too far back. So you have to shift the center of gravity, the point of application of the weight force, forward so that it is also with the wings. How can you add more weight to the tip of the Fliegers? You may know a trick from building paper airplanes (make paper clips on the tip or fold the tip particularly thick). We do this with Play-Doh on our plane, because:

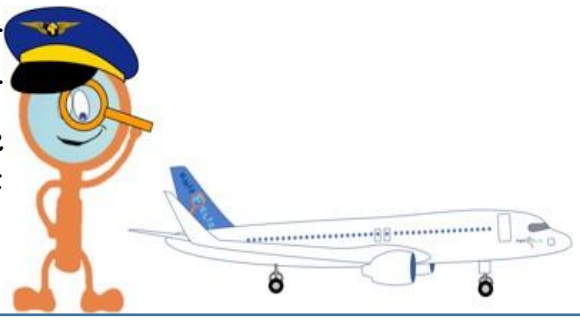


Every aircraft, whether made of paper or metal, large or small, only flies if the center of gravity of the aircraft is approximately at the wings.

What influence do the weight forces of the many passengers and suitcases in an airplane have?
Every passenger on the plane, every suitcase and so on has its own weight force and is drawn down from the earth at the point where it is. But you can also combine all these weights into a total weight with a center of gravity. The problem is when too many objects in the aircraft move in one direction and this center of gravity shifts too much.

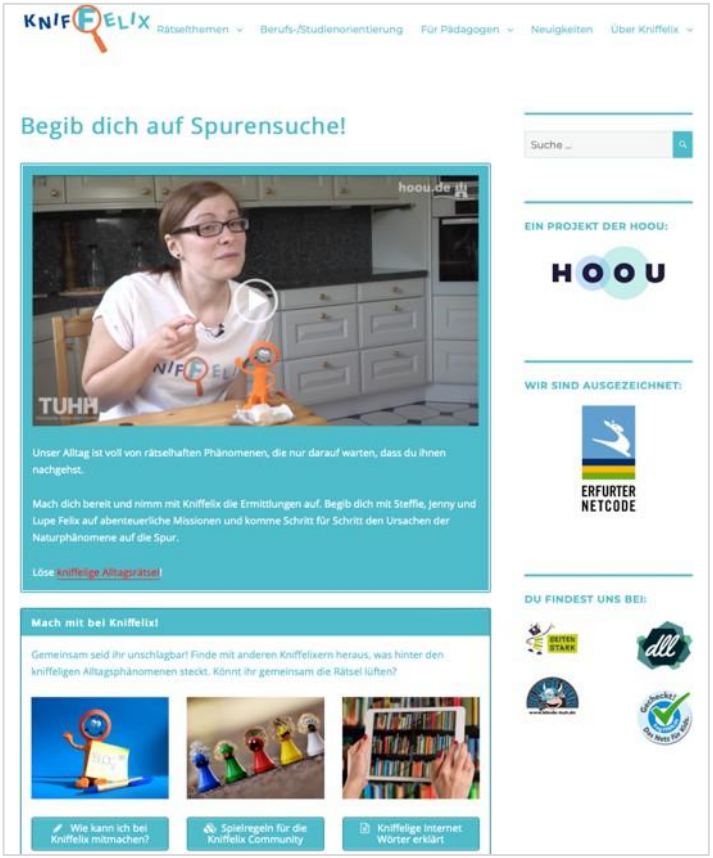
The importance of the center of gravity in flight planning:
The calculation of the total weight and the position of the center of gravity before take-off are important components of flight planning.

It's The pilot's job is to ensure that the weight of the aircraft does not exceed the maximum limit before take-off and that the centre of gravity is in the correct range.



The Kniffelix Experimentation Platform (www.kniffelix.de)

The airplane puzzle is a topic on the interactive experiment website Kniffelix. Here, everyone from 8 to 99+ years old can experiment online for free and safely, playfully deepen your knowledge and, if you want, share your own experimental experiences. In doing so,everyone learns how to deal responsibly with other users and their own data on the Internet. It is important to understand the rules of the game by Kniffelix. The Kniffelix site is strictly based on the Youth Protection Act. Nothing appears online without employees of the Hamburg University of Technology (TUHH) having checked and activated it beforehand.



Examples of the puzzle topics:

Airplanes, wings, helicopters, pizza (yeast), ketchup (non-Newtonian liquids)