Experiment Booklet

Kinderleicht!

Child's Play: lightweight design explained for all ages.

FH JOANNEUM University of Applied Sciences
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Dear Pupils,

we really enjoyed working with you on the "Kinderleicht" project. We've prepared this experiment booklet to remind you, your parents, and your teachers about the contents of the project.

The booklet contains 12 experiments. To help you navigate the booklet better, we have indicated the subject area to which each experiment belongs on the page margins.

We hope that you learned a lot during our workshops and that we were able to spark or further develop your interest in technical and scientific topics.

THANK YOU for participating so enthusiastically!

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How the four topics fit together

In this experiment booklet, we take you on an exciting journey of discovery through four fascinating topics: climate change, lightweight construction, composite materials and magnetism. These topics play an important role in research and technology and have special connections to each other. We are going to explore those connections together.

Climate change is a global phenomenon that affects us all. It shows how important it is to develop sustainable and environmentally friendly technologies. This is where lightweight construction comes into play. Lightweight construction allows vehicles and machines to be built in such a way that they consume less energy and therefore have less impact on the environment. This leads us to composite materials, which are often used in lightweight construction. These materials are not only light and strong but can also be manufactured in such a way that they are more environmentally friendly than traditional materials.

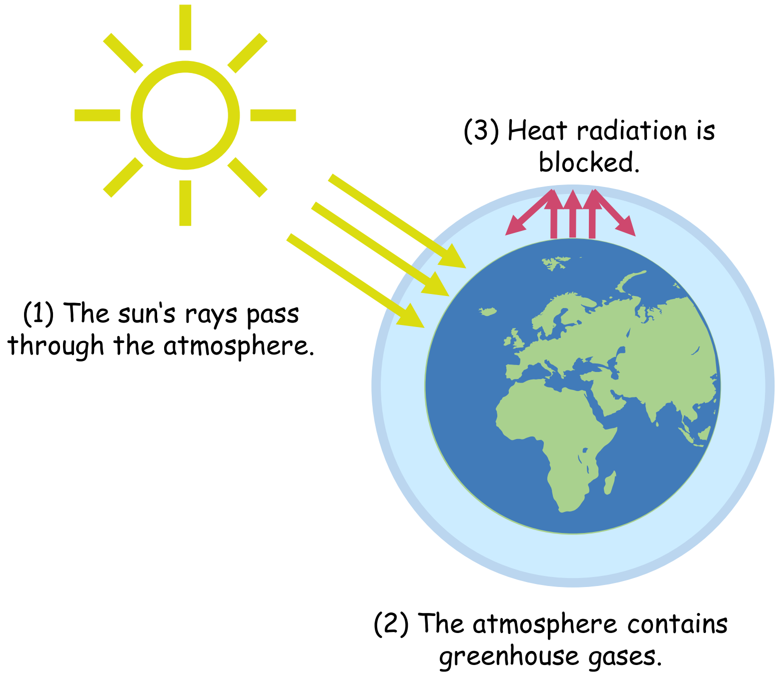
Magnetism doesn't seem to have much in common with our project at first glance, yet it is a key technology used in many modern applications, from maglev trains to electric motors used in environmentally friendly vehicles. These technologies help us to reduce our dependence on fossil fuels, creating a cleaner future for us all.

Together, these four topics show how science and technology can work together to make our world a better and more sustainable place. In each chapter of this booklet, you will find exciting experiments and activities to help you understand and experience the science behind these important topics.

Greenhouse Effect

What is the natural greenhouse effect?

Our atmosphere consists of air. The air consists mainly of nitrogen (78%) and oxygen (21%), but also of other gases such as ozone, methane, water vapour and carbon dioxide. Each of these gases is important for life on our planet. Without oxygen, for example, we humans could not breathe. Methane, water vapour and carbon dioxide are also known as greenhouse gases. They allow the sun's rays to pass through the atmosphere, but at the same time prevent the heat from radiating away from our planet. This leads to a warming of the earth, similar to that of a greenhouse in the garden. The greenhouse gases are responsible for ensuring that our planet is warm enough for plants and living organisms to exist.



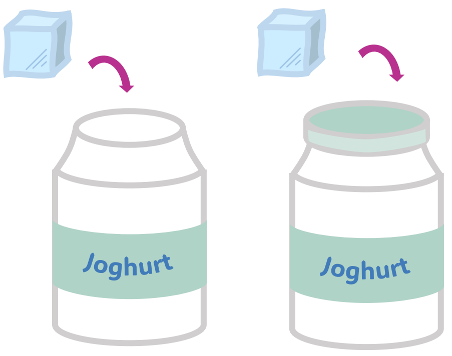
Greenhouse Effect

Experiment 1: Greenhouse Effect in a Jar

You can recreate the greenhouse effect in your classroom with the following experiment. The glass is our atmosphere; the ice cube represents our glaciers. You can use the lid to represent the greenhouse gases.

Materials:

- 2 clean yoghurt or jam jars (0,5 l)
- A lid for one of the jars
- 2 ice cubes of equal size



Instructions:

1. Place an ice cube in each jar.
2. Close one jar with a lid and leave the other jar open.
3. Now place both jars in the sun (preferably on the windowsill). IMPORTANT: Not directly over the heater!
4. Observe how both ice cubes melt.
5. Measure the time it takes for both cubes to melt completely.
6. Document the measured times!

Greenhouse Effect

Experiment 1: Greenhouse Effect in a Jar

Results:

Jar	
with lid	
without lid	

Discuss what you have observed with your teacher.

❓ Which ice cube melted faster?

❓ Can you give a reason for this?

Greenhouse Effect

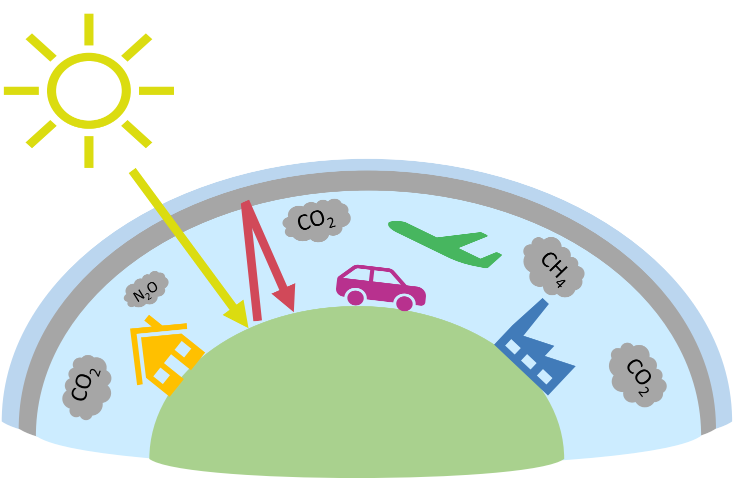
How do humans influence the Earth's temperature?

As you may know, greenhouse gases in the air help keep our planet warm. Without them, the Earth would be too cold for people, animals, and plants to survive.

However, over the past several decades, humans have been adding extra greenhouse gases to the air. This happens when we drive cars, use heating in winter, fly airplanes, and run factories and power plants. Because of this, more heat gets trapped in the Earth's atmosphere, causing the planet to warm up. Scientists have found that recent years have been some of the hottest on record!

This rise in temperature affects people, animals, and plants. We see more extreme heat, droughts, wildfires, storms, and melting glaciers. Some animals and plants struggle to survive because they cannot adapt to these changes.

To help our planet, we can take small steps to reduce greenhouse gas emissions, such as using less electricity, walking or biking instead of driving short distances, and planting trees.



Greenhouse Effect

Experiment 2: How Does Carbon Dioxide Affect Temperature?

In this experiment, we will create carbon dioxide gas and see if it changes the temperature of water inside a covered space. The glass bowl will represent Earth's atmosphere.

Materials:

- 2 large glass bowls (e.g., salad bowls)
- 2 glasses filled with water
- 1 small container (e.g., an egg cup)
- Vinegar
- Baking powder
- A thermometer

Instructions:

1. Measure the temperature of the water in both glasses and write it down.
2. Place one glass of water under an upside-down glass bowl.
3. In the small container, mix vinegar and baking powder to create carbon dioxide gas.
4. Place the container with the bubbling mixture inside the upside-down bowl, making sure it does not spill into the water.
5. Leave both glasses of water for about 15 minutes.
6. Measure the temperature in both glasses again and compare the results.

Experiment 2: How Does Carbon Dioxide Affect Temperature?

Results:

Water glass	Temperature [°C]
with additional carbon dioxide	
without additional carbon dioxide	

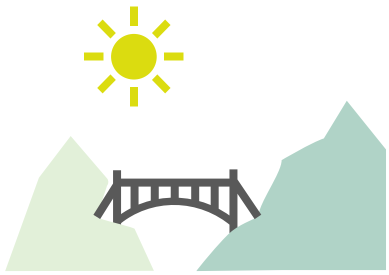
Discuss what you have observed with your teacher.

- Which water has heated up more?
- By how many degrees Celsius has the temperature in both glasses of water risen?
- Why are the temperatures different?

Lightweight Construction

Nature as a model for bridge building

Bridges can be found everywhere in the landscape. They can be made of wood, metal, concrete or a combination of several materials.



Some bridges only need to support a few people walking across, while others, like massive highway bridges, needs to hold the weight of many cars and trucks. A bridge has to be strong, but it also shouldn't be too heavy.

When designing bridges, people have taken inspiration from nature. For example, some bridges have hollow spaces or chambers inside, similar to bamboo, which can grow very tall while staying strong and flexible. Other bridges have a fan-like shape, just like the leaves of a palm tree, to help them handle heavy loads.

Bamboo trunk with chambers

Palm leaf with folded leaves

Experiment 3: Different Bridge Models

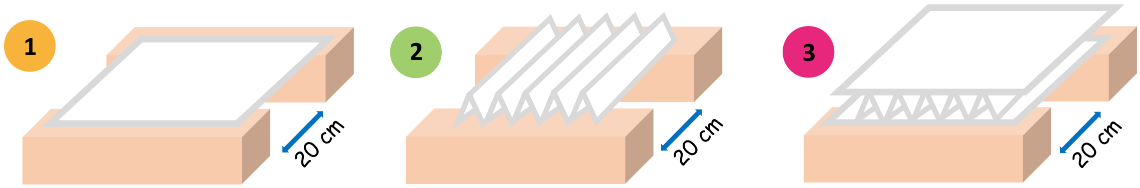
This experiment shows that the construction of a bridge is very important for its stability. At the same time, however, it is important to build a bridge that is as light as possible.

Materials:

- Paper (preferably DIN A4)
- 2 wooden blocks of the same size (or 2 stacks of books)
- Small weights (e.g. sugar cubes)
- A long ruler

Instructions:

1. Place the 2 wooden blocks (or stacks of books) 20 cm apart. If you have neither wooden blocks nor books, you can also move 2 school desks 20cm apart.
2. Build these 3 different bridge models from the paper.



3. Place the weights on the paper bridge and note how much weight the bridge can carry.

Experiment 3: Different Bridge Models

Results:

Bridge model	Weight
Bridge 1	
Bridge 2	
Bridge 3	

Discuss what you have observed with your teacher.

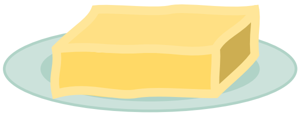
- Which bridge is most stable?
- Which bridge is lightest?

Experiment 4: The Most Stable Bridge

Based on Experiment 3, you now have an idea of what a stable paper bridge could look like. Now it's time to work in teams and see which team can build the longest bridge! The bridges should each carry a weight of 0.25 kg (e.g. a pack of butter).

Materials:

- Paper (preferably DIN A4)
- Weight of 0.25 kg (e.g. 1 pack of butter, pack of nuts, etc.)



Instructions:

- Go together in teams of 3.
- Build a bridge that can support a weight of 0.25 kg between two tables. The tables should be as far apart as possible. The team with the longest bridge wins!
- Rules:
    - You can use as many sheets of paper as you like.
    - The paper must NOT be cut, glued or jammed in anywhere.
    - No support may be placed under the bridge.

Experiment 4: The Most Stable Bridge

Results:

Describe the results of your bridge building here!

How many sheets of A4 paper did we use? ----------

How long is our bridge (in cm)? ----------

Draw a picture of your bridge here:

Experiment 5: The Leonardo Bridge

Around 500 years ago, the well-known inventor Leonardo da Vinci wanted to build a bridge that worked without connecting elements such as nails or screws. He wanted the bridge to be as light as possible so that it could be taken on hikes and used to quickly cross a river, for example. In this experiment, we are going to build a bridge, just like Leonardo da Vinci's!

Materials:

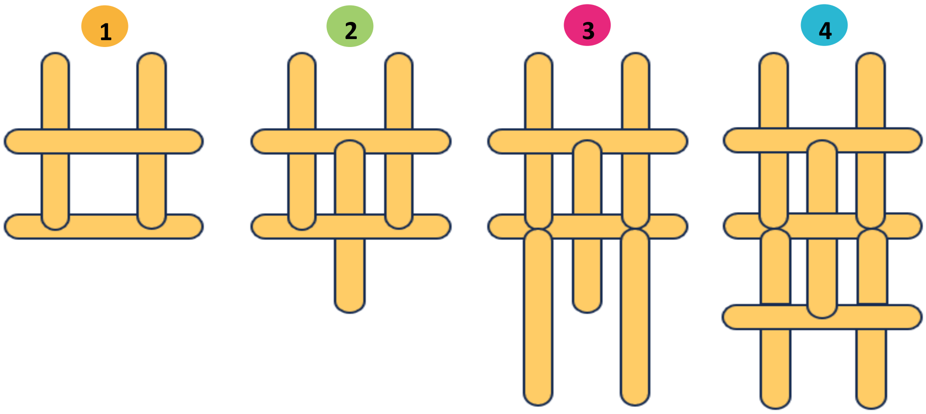
- At least 8 wooden lollipop sticks, a measuring tape and a weighing scales

Instructions:

1. Place four wooden sticks together as shown in Step 1 of the sketch below. Pay close attention to the arrangement!

2. Add a fifth stick, as shown in Step 2.

3. If you want to build a longer bridge, add three more sticks (see Steps 3 and 4 below).



Experiment 5: The Leonardo Bridge

Further instructions:

1. In groups, build three bridges. Try to make each one longer than the first.
2. Measure the length of each bridge and enter the length in the table below. Then weigh the bridge and enter the weight in the table.
3. Finally, try loading each bridge by placing small weights on it. Record the maximum load each bridge can support.

Results:

Bridge model	Width | Weight | Load
Bridge 1	
Bridge 2	
Bridge 3	

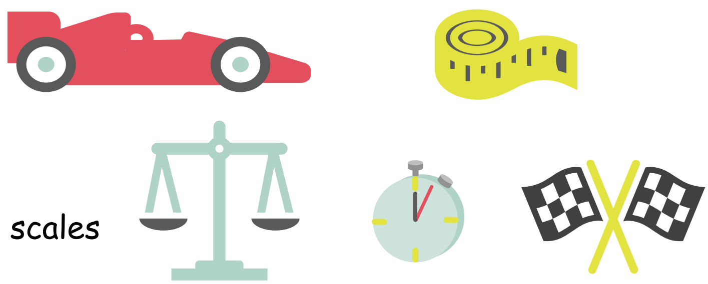
Discuss what you have observed with your teacher.

❓ Why is this bridge stable even though neither glue nor screws were used to build it?

Experiment 6: Newton's 2nd Law

Over 300 years ago, a very famous scientist named Sir Isaac Newton discovered something amazing about the motion of objects. He formulated Newton's second law, which states that the acceleration of an object depends on the force acting on it and its mass. In the following experiment, you will follow in Isaac Newton's footsteps and find out how acceleration, mass and force are related!

Materials:



- A toy car
- A clear, flat surface
- A tape measure and a weighing scales
- A stopwatch
- Several small weights that fit on the toy car
- A partner

Instructions:

1. Place the car on the flat surface and mark its position with adhesive tape or draw a line with your pencil. This is your starting line.

2. Define a time together, which you must then measure with the stopwatch (approx. 3 seconds).

3. Now place the vehicle on the starting line and push it carefully, remembering the force you used to do so. Get your partner to stop the time you have previously set and mark the position of the car after that time.

Experiment 6: Newton's 2nd Law

Results:

How far did the car travel?

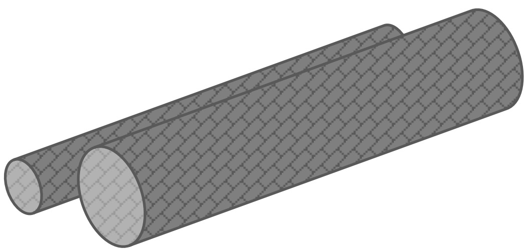
Add extra weight to the car and repeat the experiment. Do this several times, noting the overall weight (car + weight added) and the distance travelled each time.

Weight of the car [kg]	Distance travelled [cm]
empty car	
with ______ added	
with ______ added	

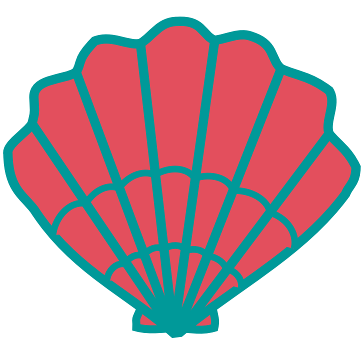
Discuss the results with your teacher.

Composite Materials in Engineering

Composite materials are key to modern mechanical engineering because they help make machines and components lighter, stronger, and more durable. By combining the advantages of different substances, composites deliver especially effective solutions. A good example is carbon-fibre reinforced plastic (CFRP), which is both lightweight and extremely tough.



A striking natural example that has inspired engineers in the development of composite materials is the structure of seashells. Seashells are built from a combination of mineral and organic components that deliver high strength while remaining very light. Their layers are arranged so cleverly that they can withstand extreme pressure, making seashells an ideal model for modern composite materials in engineering.



In this chapter, we will explore how natural structures like these can inspire engineers to create innovative materials for mechanical engineering.

Composite Materials

Loads on Components and Materials

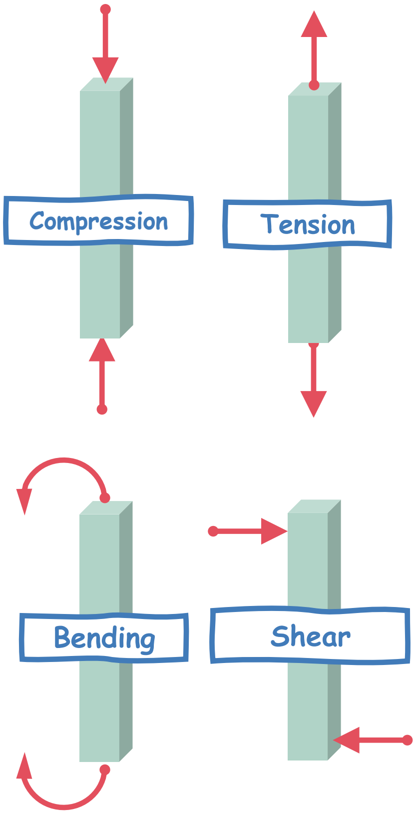
Imagine you are building a toy car. You need materials that are both light and strong, so the car survives many play sessions. That means the materials have to withstand several different kinds of forces:

Compression: imagine squeezing something together. Press a sponge between your hands.

Tension: the opposite of compression. Pull the two ends of a rubber band apart to stretch it.

Bending: what happens when you bend a plastic spoon? The top side is stretched while the underside is squashed.

Shear: think of cutting a sheet of paper with scissors. The blades slide past each other and shear the paper.



Very often, a single material on its own can't cope with all of these forces, and that's where composite materials come in.

Composites are like superhero materials. They are made by combining two or more different substances, so the result is both stronger and lighter. Picture mixing the hardness of stone with the lightness of plastic—the outcome is a material that offers the best of both worlds! Thanks to these advantages, composites are used in cars, aircraft, and even sports gear, because they keep things strong while reducing weight.

Experiment 7: Applying Loads to Materials

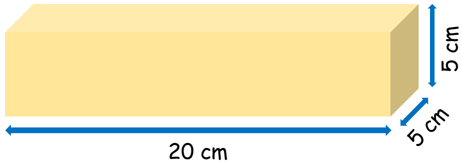
In this experiment, you'll make the different forces that can act on materials easy to see—and easy to understand.

Materials:

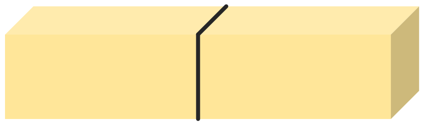
- Foam strips, about 20 cm long and 5 cm thick (≈ 5 cm high × 5 cm wide)
- Black felt-tip pen (e.g. a broad-tip marker)

Instructions:

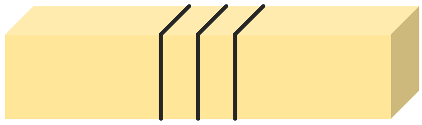
1. If you don't already have a foam strip in the right size, trim your foam to the required dimensions first.



2. Find the middle of your foam strip and use the marker to draw a line all the way around it.



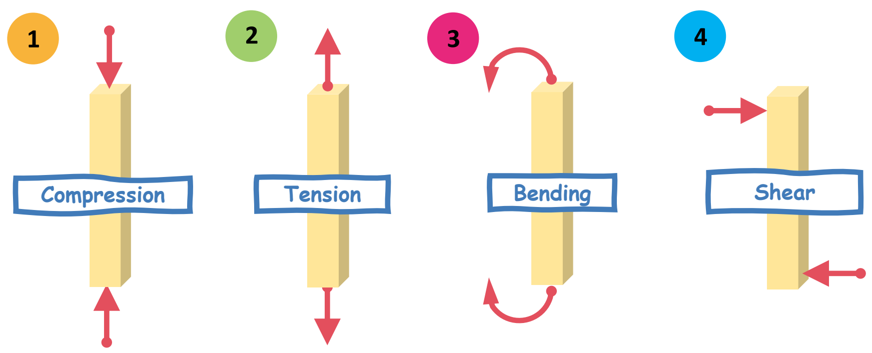
3. From that centre line, measure 2 cm to the left and 2 cm to the right. At each of those points, draw another line right around the strip with the marker.



Experiment 7: Applying Loads to Materials

Instructions (continued):

4. Now apply each of the four forces—compression, tension, bending, and shear—to the foam strip and watch what happens to the marker lines.



Results:

Use the space below to sketch how the marker lines move or change shape for every force you tried.

1 Compression	2 Tension	3 Bending	4 Shear

Experiment 7: Applying Loads to Materials

Results (continued):

Discuss what you have seen with your teacher.

- How do the felt-tip lines on the foam move or change when you apply each force?
- Look around your classroom. Can you find real-life examples where these forces—compression, tension, bending, or shear—are at work?

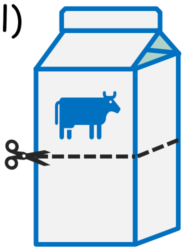
Composite Materials

Experiment 8: The Hardest Chocolate

In this experiment you can make the hardest chocolate in the world—or at least the hardest chocolate you've ever come across! It also shows how composite materials work. Unfortunately, eating the chocolate afterwards is not advised...

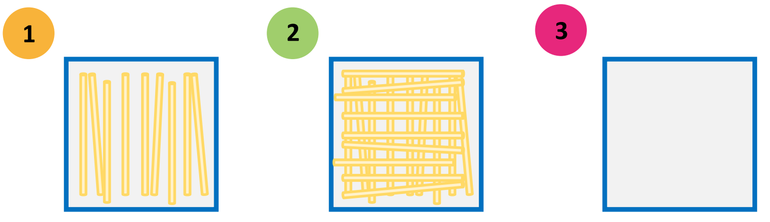
Materials:

- 2 bars of cooking chocolate
- 2 packs of spaghetti
- Saucepan
- Hot plate or kitchen stove top
- Wooden spoon
- 3 empty milk cartons (juice cartons work just as well)



Instructions:

1. Cut the milk cartons in half.
2. Lay dry spaghetti across the bottom of two of the carton halves as shown in the illustrations; leave the third carton half empty (this will be your control).

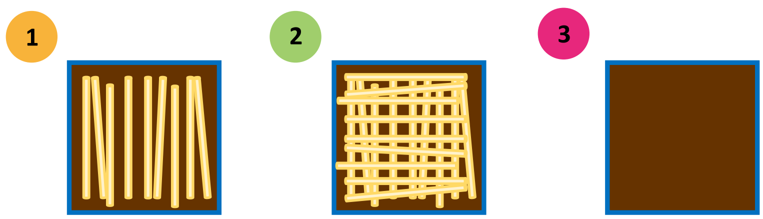


3. Melt the chocolate in the saucepan over a low heat, stirring constantly so it doesn't burn.

Experiment 8: The Hardest Chocolate

Instructions (continued):

4. Pour the melted chocolate carefully into the milk cartons. Make sure the chocolate completely covers the spaghetti and is the same height in every carton.



4. Let the chocolate cool completely, then carefully remove it from the cartons.

5. Take a handful of the dry spaghetti and try applying different forces to them (see Experiment 7). What happens? Under which force do the spaghetti break?

   a) Compression b) Tension c) Bending d) Shear

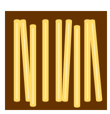
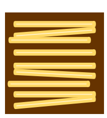
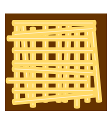
6. Now test all three types of chocolate blocks in the same way. Observe which forces each block can withstand—and which one breaks most easily.

Composite Materials

Experiment 8: The Hardest Chocolate

Results:

Fill your findings into the table below. Which material withstands which force (does not break: ✓, breaks: ✗).

	Compression	Tension	Bending	Shear
Dry spaghetti				
Plain chocolate 				
Chocolate with spaghetti aligned lengthwise 				
Chocolate with spaghetti aligned crosswise 				
Chocolate with spaghetti aligned lengthwise and crosswise 				

Discuss with your teacher what you have observed.

1. Which chocolate was the most stable?
2. Why do you think that is?
3. What role do the spaghetti strands play in the chocolate?

Experiment 9: Tensegrity Table

In this experiment, you'll build a floating table! We'll use the balance between tension and compression forces to create a stable structure.

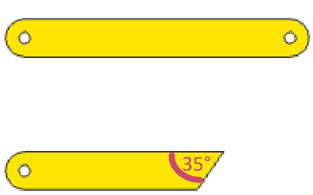
Materials:

- At least 8 wooden sticks (e.g. craft sticks or ice lolly sticks)
- 4 rubber bands or one elastic cord (approx. 30 cm long)
- Hot glue gun or superglue
- A tool for drilling small holes (e.g. hand drill or pin vise)

Instructions:

1. Take the 8 wooden sticks and drill a small hole at each end. Cut two of the sticks at about $\frac{3}{4}$ of their length, each at a 35° angle (see Illustration 1).
2. Glue together three full sticks and one angled stick to form a frame, as shown in Illustrations 2 and 3.
3. Make sure that the holes remain free of glue and the holes are positioned at the top and not blocked.

1



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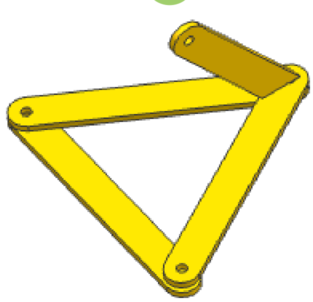

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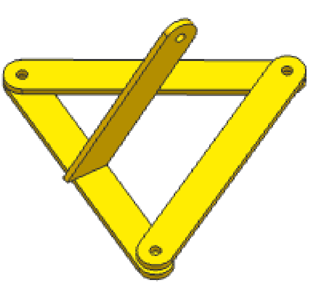
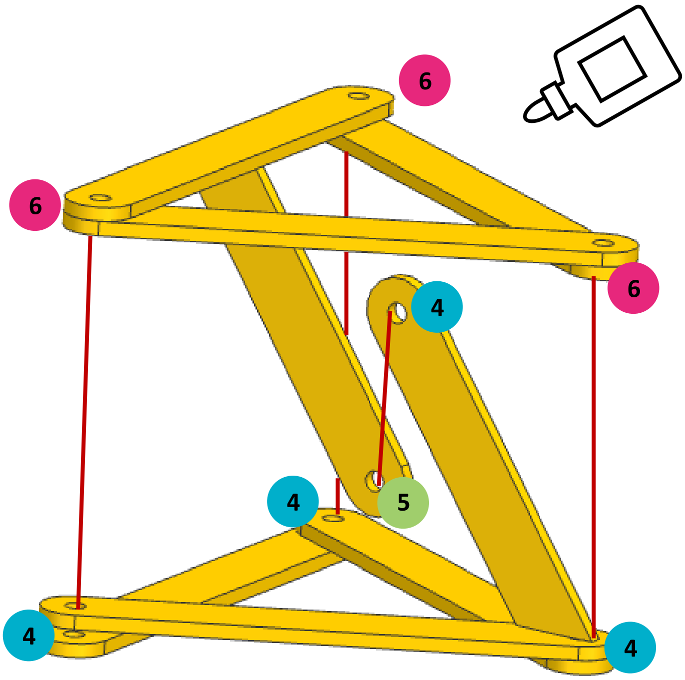


Experiment 9: Tensegrity Table

Instructions (continued):

4. Once the glue has dried, it's time to add the rubber bands (or elastic cords) between the holes. ix the cords in the holes on the lower part of the structure (shown in red in the illustration). Use a small amount of glue to hold them in place (4).
5. Then place the top section of the table onto the structure and stretch the middle cord upward. Fix it in place with glue (5).
6. Finally, stretch and attach the remaining three cords to the upper section (6). Make sure all three are exactly the same length so the table stays balanced. Trim off any extra cord with scissors.



Experiment 9: Tensegrity Table

Results:

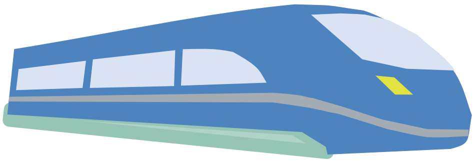
Test your table by placing small weights on top—see how much it can hold before it wobbles or collapses!

Discuss with your teacher what you have observed.

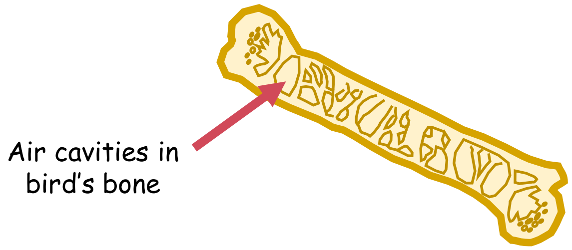
❓ Why is this system so stable?

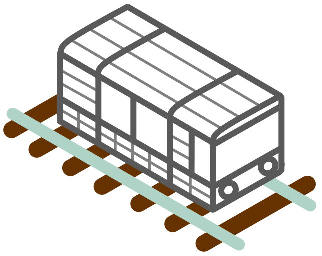
Flying at Zero Altitude with Magnetism and Lightweight Design!

Imagine a train that can fly—without ever leaving the ground! That's exactly what happens with trains that use magnetism to float. These special trains, called maglevs (short for magnetic levitation), use powerful magnets placed under the train cars and along the tracks to make them hover above the rails. It might feel like magic, but it's all science! Since there's no contact with the tracks, maglev trains can travel very fast and almost silently.



These trains also need to be very light in order to make the most of magnetic levitation. Engineers use special materials like aluminium and composite materials, which don't weigh much but are still very strong. These lightweight materials help the train use less energy while still travelling at high speed. It's a bit like birds: their bones are light but strong, allowing them to fly efficiently. In the same way, maglev trains use light yet tough structures to carry passengers quickly and safely from place to place—almost as if they're gliding through the air....





Over the next few pages, you'll find some exciting experiments that will help you explore magnetism and show you what else it can do—besides making trains float!

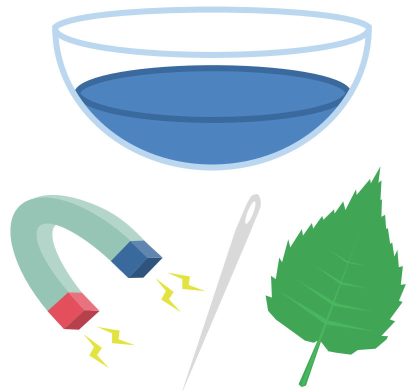
Magnetism

Experiment 10: A Simple Compass

In the days before smartphones and in-car navigation systems, people had to find their way using simple tools. Most often, they relied on maps—whether hiking maps, road maps, or nautical charts. But no matter the map, it was always important to know which direction you were heading, so people often used a compass. A compass is a small needle that can spin freely and always points north—because it reacts to the Earth's magnetic field. Now, let's build a simple compass of our own!

Materials:

- A needle
- A small container filled with water
- A leaf (e.g. from a maple or birch tree)
- A magnet



Instructions:

1. Get a small bowl.
2. Find a leaf in the garden—it shouldn't be too big, but it needs to be large enough to hold the needle without it falling off.
3. Put some water into the bowl and gently place the leaf on the surface so that it floats freely on the water.
4. Now take the needle and the magnet. Carefully rub the magnet along the needle 5 to 8 times, always in the same direction.
5. Gently place the needle on top of the leaf, ideally lining it up with the direction of the leaf's stem. Be careful not to tip the leaf or let the needle fall into the water.

Experiment 10: A Simple Compass

Results:

1. Describe your observations.

2. Now place the magnet next to one side of the bowl. What do you observe?

3. Take the magnet and slowly move it in a circle around the bowl. What happens now?

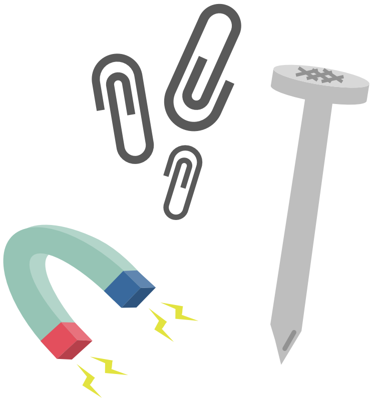
Iron Magnet

Experiment 11: The Nail Magnet

Now we're going to turn a simple nail into a magnet! As you learned in Experiment 10, it's possible to make a piece of iron magnetic. This time, we'll take an ordinary nail—and turn it into a magnet ourselves!

Materials:

- A larger iron nail
- Several paper clips or small nails
- A magnet



Instructions:

1. Rub the nail across the paper clips. You'll notice—nothing happens yet, but we're about to change that!
2. Take the nail in one hand and the magnet in the other. Now rub the magnet over the nail about 10 times, always in the same direction.

   IMPORTANT: When moving the magnet forward, make sure it touches the nail, but when pulling it back, lift it away from the nail slightly.
3. Now hold the nail near the paper clips again. What happens this time?

Iron Magnet

Experiment 11: The Nail Magnet

Results:

Describe what you observed happen to the paper clips after the nail was magnetised:

Discuss with your teacher what you have observed.

- Why don’t the paper clips move when you hold the nail near them at the beginning?
- Why do the paper clips move when the nail has been magnetized?

Electromagnet

Experiment 12: A Simple Electromagnet

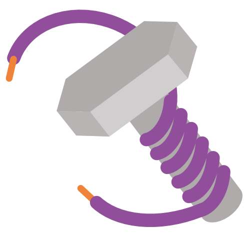
Today we're going to build an electromagnet. But why do we need one? In industry, electromagnets are used to lift materials like steel or iron without needing to attach a hook. They're also used in waste sorting, to separate iron from non-magnetic materials like plastic. The key advantage of an electromagnet is that it can be switched on and off. Otherwise, you wouldn't be able to remove the iron once it sticks to the magnet!.

Materials:

- A nail or screw (not too small)
- A piece of insulated wire, about 40 cm or longer (you can always trim it 😊)
- A battery or rechargeable battery—ideally 9 V
- Paper clips or small nails

Instructions:

1. Take the screw or nail and wrap the wire tightly around it, leaving about 10 cm of wire free at both ends.



2. Now carry out the four experiments described on the following pages.

Electromagnet

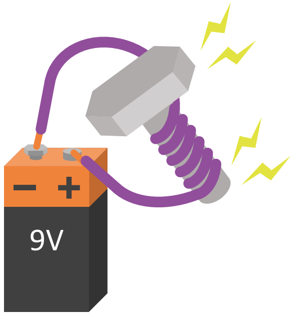
Experiment 12: A Simple Electromagnet

Experiment 1:

Hold the screw above the paper clips. What happens?

Experiment 2:

Now connect the battery to the two ends of the wire and repeat the experiment. What happens now?



Experiment 3:

Disconnect the battery. What do you observe?

Magnetism

Experiment 12: A Simple Electromagnet

Experiment 4:

If you built the compass from Experiment 10, try this: hold your electromagnet close to the compass and then connect the battery. Describe what you observe:

Discuss with your teacher what you observed.

- Why does the screw become magnetic?
- Why does the compass needle turn toward the electromagnet?

Space for your notes

Space for your notes

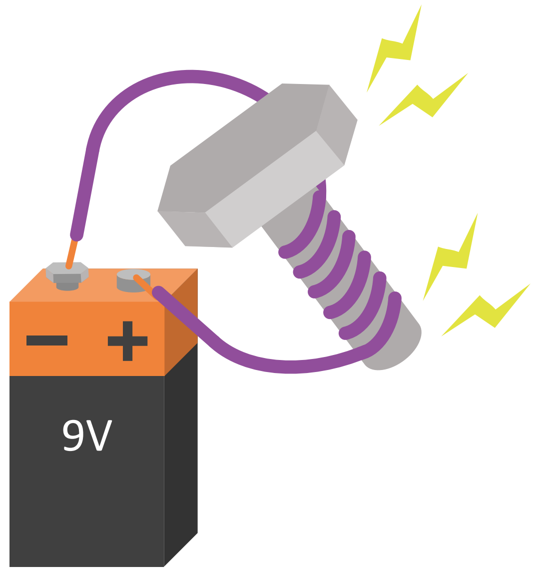
Introducing the Project Team

The Institute of Automotive Engineering at FH JOANNEUM is part of the Department of Engineering and follows the guiding principle: "Dynamics begin in the mind."The institute's research and development activities are based on a three-part approach that includes analytical and technical calculations, numerical simulations, as well as measurements, testing, and real-world trials. The main focus of its research is on the complete vehicle system.

The Institute of Educational Research and Teacher Education at the University of Graz is an inter- and transdisciplinary institution within the field of educational sciences. It combines innovative research on school and teaching development with high-quality teacher education. The institute focuses on questions related to professional approaches to heterogeneity and diversity, particularly in light of current social challenges, as well as the development of schools and teaching within institutional contexts. The institute is divided into six areas of specialisation.

The Styrian company HAGE Sondermaschinenbau GmbH specialises in automation technology solutions, with a focus on machining systems for aluminium and steel profiles, friction stir welding machines, and 3D printing systems.Founded in 1982, the company has grown into a successful international enterprise, operating across a wide range of industries including automotive engineering, the rail sector, the construction industry and aerospace.

Carbon-solutions Hintsteiner GmbH is part of the Hintsteiner Group, an internationally active family business headquartered in Kindberg, Styria.Since its founding in 1981, the company has specialised in the development and production of high-quality lightweight components made from fibre-reinforced composites. These components are used across a range of industries, including automotive, aerospace, and pharmaceutical engineering.



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