Imaginata – Guide

English.

110 kV- Hall

Rumkugeln / Rolling around

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40 wooden balls are inside the frame. Do you find a way to make place for the additional ball?

Caesar-Scheibe / Wheel of Caesar or Caesar cipher

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This wheel enables you to encode texts.
Search the letters from your text on the outer wheel. Then write down the associated letter on the inner wheel.
Try to develop your own code.
Are you able to decode the texts of your partner?

Perfekte Zahlen / Perfect Numbers

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Arrange the parts of the circle in such a way, that the cirle-frame is filled completely.

Do you find the two possibilities to fill the circle, when all circle parts are different from each other?

This game helps to understand the meaning of “half”, “third”, “fifth” etc. It is a good way of learning, especially for younger students.

Somawürfel / Soma Cube

110 kV- Hall

Here you can see seven unit-cubes that can be put together to one cube.
Try to find out how to build this one single cube out of these seven pieces.
Is there only one solution or can you find more?

Do you also find solutions to build the other forms, presented on the card below?

Sieb des Eratosthenes / Sieve of Eratosthenes

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The numbers from 1 to 36 are pinned on a board.

Now take all multiples of 2 from the board. Continue with taking away the multiples of 3, 4, 5, … etc. Which numbers are caught in the sieve? What kind of anomaly do they have?

This procedure is named after Eratosthenes of Cyrene (276 BC – 194 BC). He was a Greece mathematician, geographer, historian, philologist and poet.

Vier-Farben-Problem / Four Colour Problem

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You see a frame in the form of the Thuringia map and a lot of coloured pieces, which form the counties of Thuringia. Each county is available in four different colours.
Can you find a way to arrange the counties in the map in such a way that no equal colours are bordering on each other?
Try to use as few colours as possible.

Kugellager / Ball Bearing

110 kV- Hall

Try to put as much balls as possible into the container. In the end the lid should still cover the container completely.
Each ball size has its own value – multiply the numbers of the balls with their according value. Who achieves the highest score?

Kleine Baumeister / Little Builders

110 kV- Hall

Try to pile up the building bricks in such a way that each one protrudes as far as possible.

Is it possible that the topmost brick protrudes completely over the brick at the bottom?

Ungehorsame Garnrolle / Disobedient Cotton Reel

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When you pull at the rope the cotton reel moves.
But why is it sometimes rolling towards you and sometimes away?

Do you have more ideas for similar illusions?

Die Macht der Dominosteine / The Power of Dominoes

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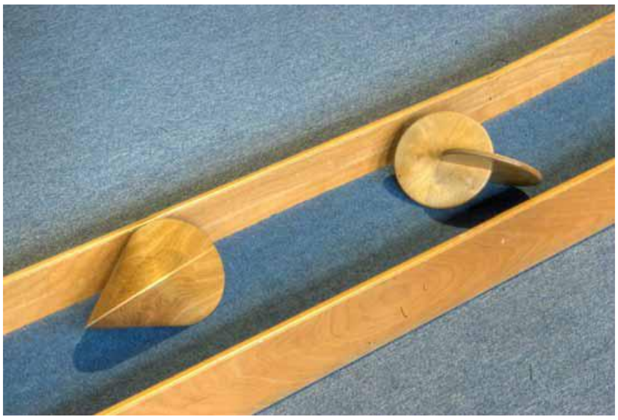
Is the smallest domino able to make the biggest fall?

- Do you need all stones or are you able to leave one out?

Das Oloid / The Oloid

110 kV- Hall

Put the Oloid on the inclined plane and watch its movement.



Reuleaux Räder / Reuleaux-Wheels

110 kV- Hall

Can the plank be rolled on these wheels, although they are not round?

- How does the axis of the wheels move while they are rolling?
- How many edges has a circle?

Dosenwettlauf / Can Competition

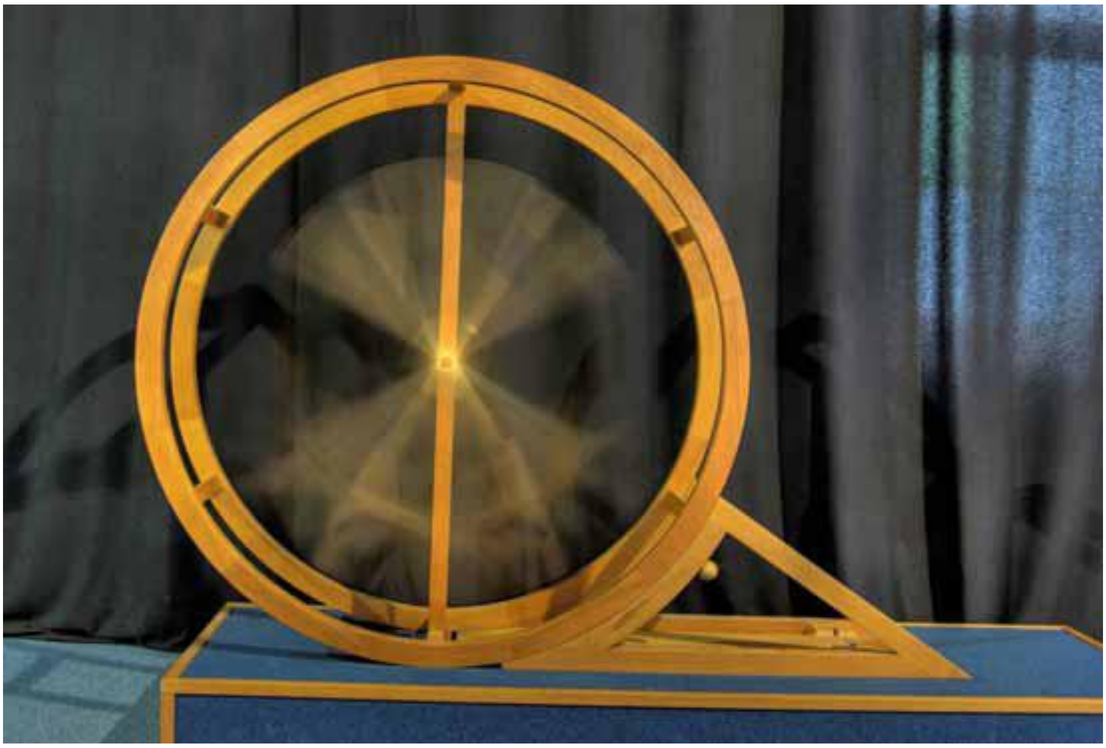
110 kV- Hall

The cans are filled with different materials. Which one is rolling the fastest, the slowest and the farthest?

Chaos-Pendel / Chaos Pendulum

110 kV- Hall

Steady and predictable a usual pendulum will swing back and forth.
But what happens when you add another pendulum-arm to it?



- What do you expect? Will both double pendulums move in the same way?
- Hold the bigger arm of the pendulum and push only the small pendulum. Now release the big pendulum arm. What do you see?

Usually a pendulum is the symbol for regularity. When you know the oscillating period of a pendulum you can predict the time it will need for one, hundred or thousand oscillations.

But as soon as you are connecting two pendulums to each other the situation gets very different. The movement of two connected pendulums is no longer steady but erratic and unpredictable.

The Chaos-Pendulum is often used to illustrate “complex” or “chaotic” systems, which seem to be absolutely random, though they also follow physical laws.
With one of the pendulums of the Chaos-pendulum you can demonstrate the difference between “predictable” and “chaotic” movements: Hold at first the longer pendulum and allow only the smaller pendulum to swing. You’ll see it swings in a steady movement like any usual pendulum.

Now, when you release the longer pendulum, it will start swinging as well, because the small pendulum transfers part of its kinetic energy to the bigger pendulum. This transfer goes in two directions as the bigger pendulum also transfers energy to the smaller one. So both pendulums repeatedly exchange their kinetic energy.

One characteristic of such linked systems is that they are very sensible to different initial conditions. You can see this when both double pendulums start swinging at the same time. Though their movements are rather simultaneous at the beginning they will soon begin to move absolutely different from each other and they will not return to a simultaneous movement. That’s because even a small difference in their initial condition will influence their movements. And both double pendulums are not completely the same – they might vary in length, weight or position and therefore they move differently.

Schwebender Ball / Hovering Ball

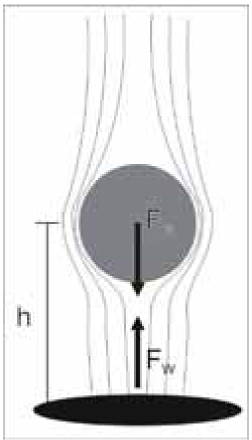
110 kV- Hall

A water-polo ball is made hovering in the airflow above a blower.

What will happen, when you incline the blower slowly to one side and back again?

- How does the ball move in the airflow?
- Try to push the ball carefully out of the airflow. What do you feel?
- What do you feel when you hold the ball next to the airflow?

At the Hovering Ball you can study the behaviour and effects of streaming air and figure out some basic principles of fluidics. When you put the ball into the airflow you will see two things: First, the ball hovers in a more or less constant height above the blower. Second, it remains very stable in its movement. Even when you incline the blower slowly to one side or nudge the ball from the side, it remains caught in the airflow.



The first observation can be explained by air resistance: The height in which the ball keeps hovering is exactly the point at which the ball’s air resistance (the force of the streaming air on the ball) is as strong as its weight force.
To understand the second observation you can try to pull the ball out of the airflow. You will feel a force that is acting on the ball vertically to the airflow. This force is caused by the differences in pressure and speed of the streaming air.

The Italian physicist Giovanni Batista Venturi discovered that liquids and gases are floating faster at a smaller cross-section of their stream. So the air which is streaming very close around the ball, is faster than the air that is streaming around it at a greater distance.

The Swiss mathematician Daniel Bernoulli explained the connection between pressure and speed of floating air and gases: the greater their speed, the smaller the static pressure that is acting vertically to the streaming direction.
Used at our Hovering Ball, that means: When the air is streaming past the ball, it gets faster, causing the pressure to get lower. As the air is streaming from all sides around the ball, a vacuum is created around the ball, which keeps it within the airflow. The resulting force is so strong, that the ball even remains steady within an inclined airflow.

This “Bernoulli effect” is the foundation for many physical developments. For example the lift at airplanes, the path of a cut ball, the spreading of fluids in a carburettor or a perfume bottle. All these things are based on the differences in speed and pressure of streaming air.

Balancestäbe / Balance Bars

110 kV- Hall

Balance the bar vertically on your finger. What happens when you turn the bar around and balance it on the other side?

Balancebesen / Balance Broom

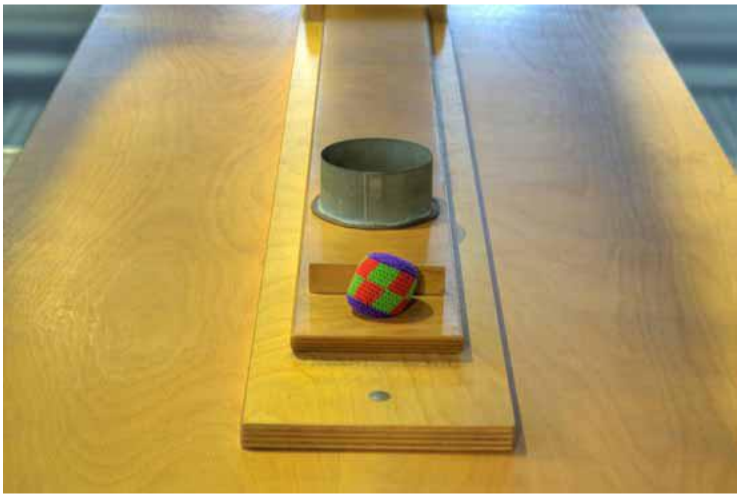
110 kV- Hall

Put the broom horizontally on your outstretched hands in such a way, that it lies on your first fingers. Now move your hands slowly towards each other.
Are you able to do this without dropping the broom?

Knall und Fall / Bang and Fall

110 kV- Hall

Put the ball behind the small wooden strip on the hinged board. Now lift the board and let it fall down, so that the ball will fall into the can.

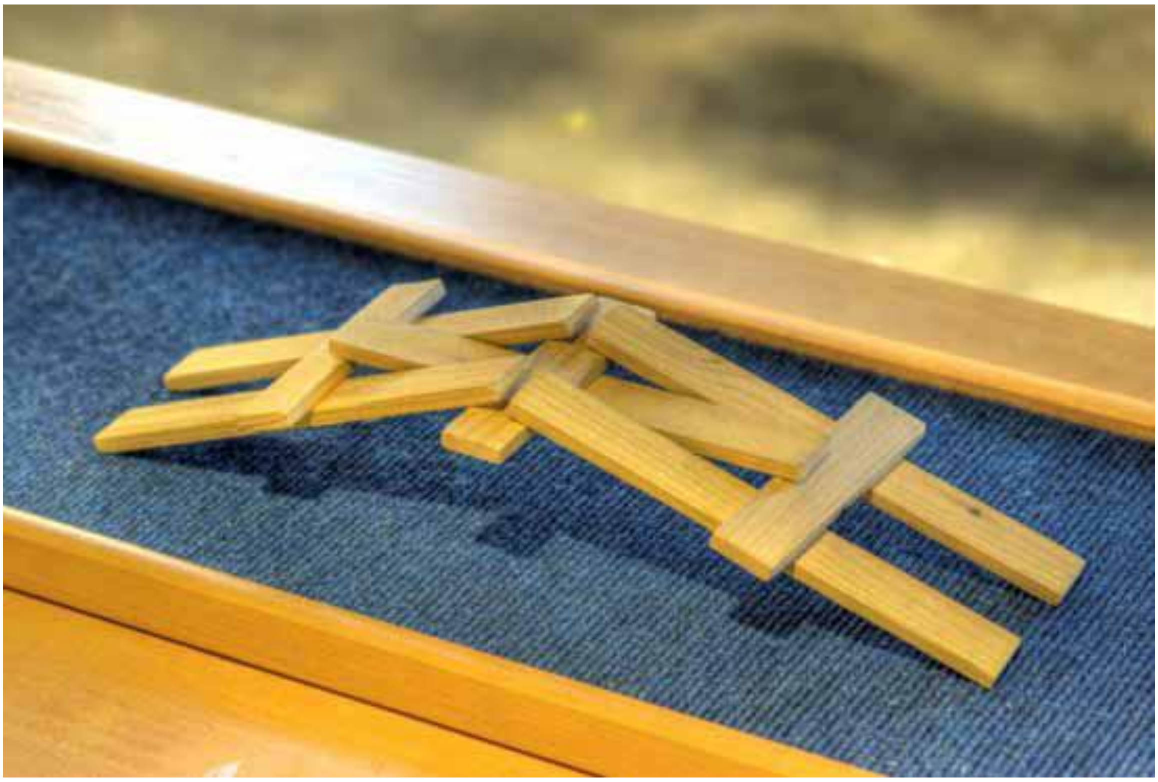


- Try to experiment with different starting heights.
- What is falling faster– The board or the ball?

Leonardo’s Brücke / Leonardo’s Bridge

110 kV- Hall

How can you cross a river with planks that are too short to reach from one river bank to the other? Without tools or any other material a bridge is to be built to cross the water.

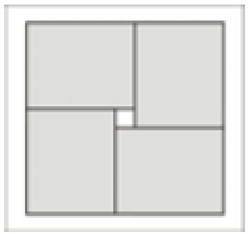


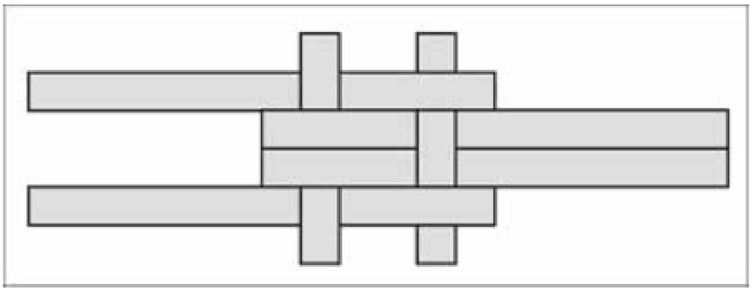
- Build a bridge out of four planks.
- Expand this bridge with four additional planks on each side.
- How large can you build the bridge?
- Can you build a bridge out of 8 planks and expand it with three?

Which constructional element do all of these bridges have in common?

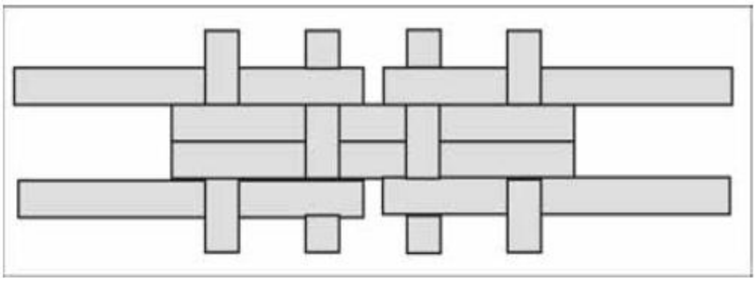
Explanation:

The basic constructional element for Leonardo's Bridge is also used for closing a cardboard box by folding the four sides on the top into each other. It's called the "Four-Strap-Closure" and you can find it in the construction of the bridge as well:

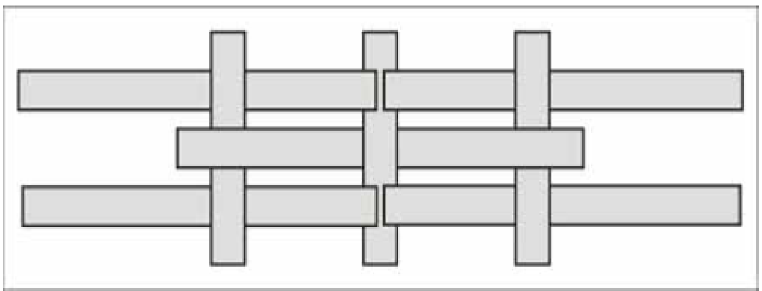




You can expand the bridge by adding four more planks:



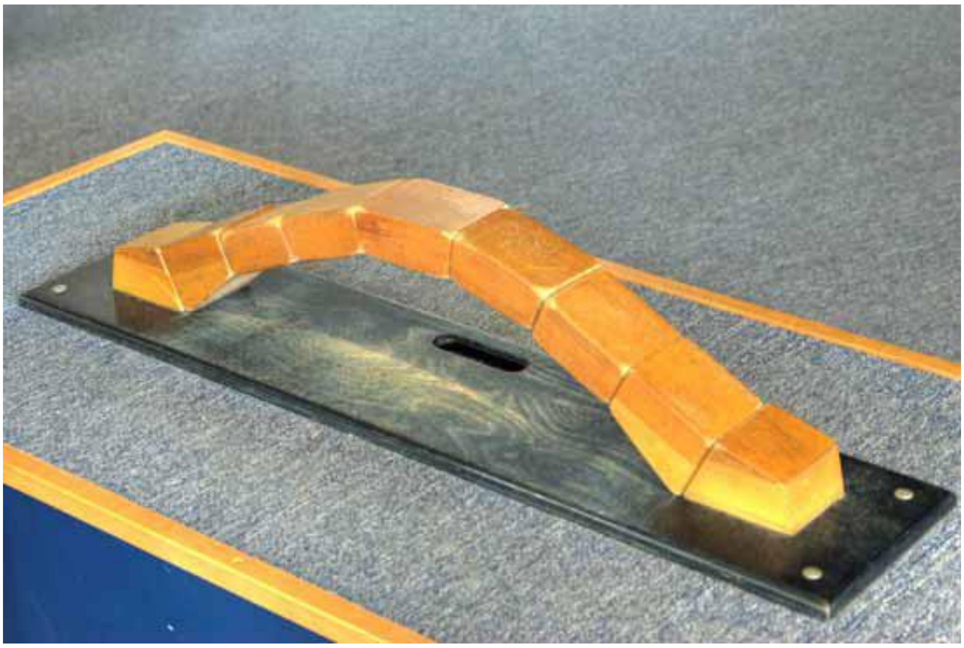
It is also possible to build the bridge with 8 planks and expanding it with 3 more planks:



Begehbarer Bogen / Walkable Arch

110 kV- Hall

Put the bricks together in the right order and the arch will be so strong that you can stand on it. At which point can the arch bear the most weight?



- The numbers on the side of the bricks can help you to find the right order and the template is useful to support the building process.
- But are you able to build the bridge without using the template?
- One of the bricks exists only once – which one is it?
- Try to press down the bricks at the finished arch. Which ones can be moved easily, which ones not?
- What would happen if the two outer bricks were not fixed on the board?

The building principle of this arch has been used for centuries to build bridges, archways or the arches in cathedrals. It is rather difficult to build the arch without using the template. Normally people would use a scaffolding; a so called “falsework” to support the building process of the arch. Only when the last stone at the top is put into the arch it becomes steady and the falsework can be removed. This last stone is called the keystone – it is also the only point at which the arch can bear your weight when you stand on it. Only at this point your weight is transferred from one stone to the next until it reaches the outer stones – which are called the “springers”.

Klick-Klack / Newton's Cradle

110 kV- Hall

Deflect one or more bowls and let them bounce against the other bowls.

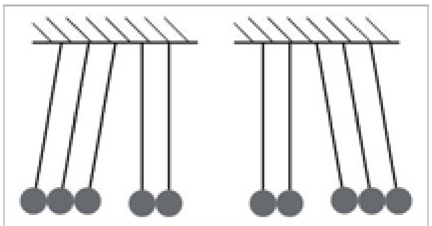
- What happens when only one bowl bounces against the others?
- Is the bowl in the middle moving?
- What happens when you deflect 2, 3 or 4 bowls?
- How long does it take until all bowls come to rest?
- Deflect at first two bowls on the one side and then one bowl on the other side.

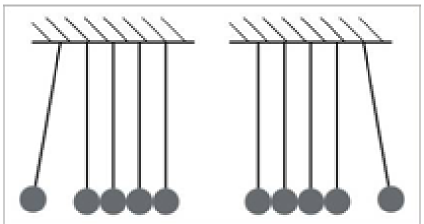
This experiment helps to understand some important physical principles.

When one bowl bounces against the others, only the last bowl in the line is set in motion. Also, when two bowls bounce against the others, only two bowls on the end of the line will start to swing as well. So the number of bowls which are set in motion is always the same on both sides.

A swinging bowl contains the so called “kinetic energy” and when it bounces against the other bowls it transfers this energy and momentum to the next bowl. The strength of the momentum or impulse depends on the mass and velocity of the first swinging bowl. The more mass and velocity the bowl has, the greater the momentum.

So at each impact there is an impulse repeating between two bowls. The bowls in Newton’s Cradle are very close and almost touching each other. So the momentum is transferred from one bowl to the next until the last bowl swings out. Actually it is a series of four separate impulses, which are succeeding so fast that we perceive them as one impulse through the whole line of bowls.





But this is only working as long as all bows are nearly of the same mass and hanging in one line. Under these circumstances the colliding bowls can “exchange” their velocity, so that the one bowl “takes over” the velocity of the other. You can see this very well when two bowls are deflected: In that case the inner bowls are the first to transfer their impulse to the next and become a static bowl themselves – but only to be pushed instantly by its outer neighbour and therefore receive again kinetic energy.

As well as the energy, the momentum (or impulse) is a conserved quantity: If there wouldn’t be any friction, the impulse of all bowls and with it their velocity would always remain the same. But as this is never the case and there are never absolutely frictionless conditions on the billiard table or in our experiment the bowls lose some of their velocity.

Waltenhofensches Pendel / Waltenhofen’s Pendulum

110 kV- Hall

A pendulum is swinging between the pole shoes of a strong permanent magnet. Put different materials (Copper, aluminium) and forms (full slab, slab with holes and slab with slots) into the pendulum.

When is the pendulum slowed down the most?

- Take the wooden, copper and aluminium slab and let them swing one after another between the magnet poles. Which one is swinging the longest and which one the shortest?
- Compare all of the copper slabs. Which one is slowed down the most, which one is slowed down the least?
- Are wood, copper or aluminium magnetic? Find it out by putting each of the slabs against the magnet.
- Take the copper slab in one hand and move it fast between the magnets. What do you feel?

When you put each of the slabs against the magnet you will see that none of them are attracted by the magnet. But the copper and the aluminium slab are both slowed down when they swing between the magnets. How is that possible if they are not magnetic?
Copper and Aluminium are both metals. All metals are able to conduct electricity because they have free electrons. Whenever a conductor is moving within a magnetic field, the electrons are diverted and start moving – so electricity is flowing.
This induced electricity is also called eddy current. Now, this current creates a new magnetic field and the copper plate itself becomes a magnet. Because two opposed magnets attract each other, the copper slab is slowed down by the attracting pull between the magnetic fields – but only as long as the copper slab is moving within the magnetic field and the electric current is induced.
The toothed copper slab is different: Because of its form it cannot induce eddy currents and therefore no magnetic field is created, so this slab swings almost unbraked between the magnets.
Carl von Waltenhofen used this principle as a basic element to develop so called "eddy current brakes". These brakes are used until today in trams and the ICE train (Inter City Express).

Kugelwettlauf / Bowl Race

110 kV- Hall

Both bowls have the same starting point and the same goal. One bowl rolls on the inclined plane, the other one takes the longer way.

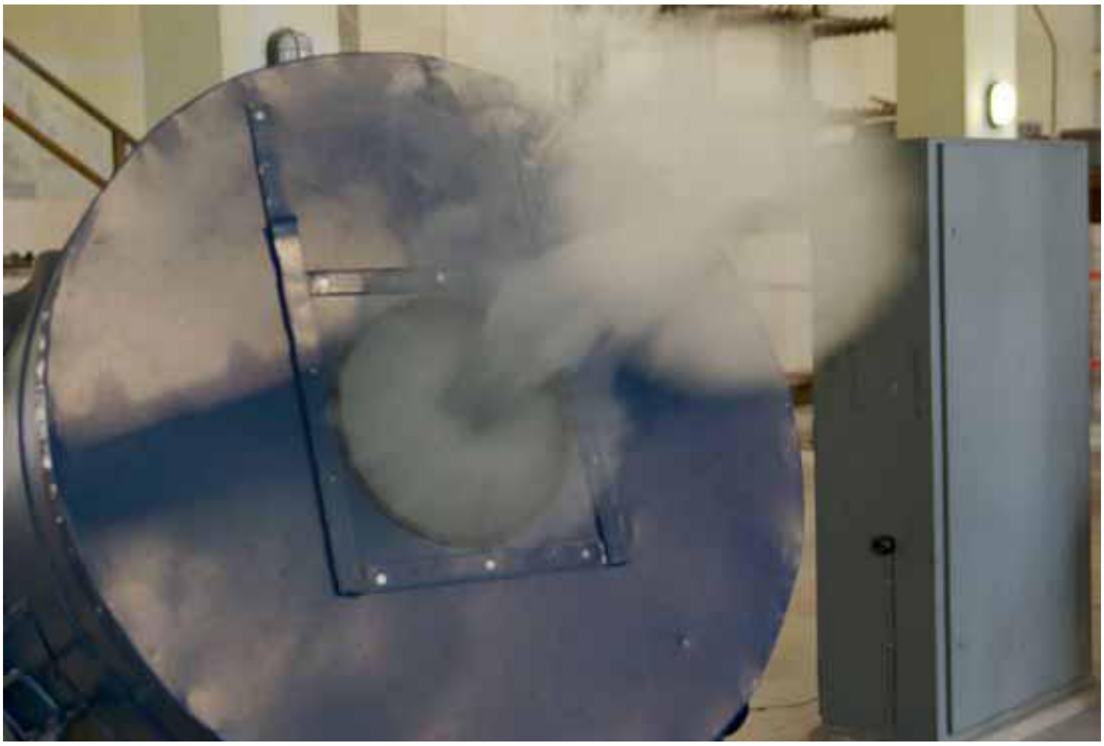
Which one reaches the goal at first?

Wirbelkanone / Whirl Cannon

110 kV- Hall

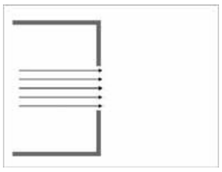
With the cannon we can produce beautiful coils of smoke which will spread through the whole hall.

Attention: Please ask one of the staff members for help with this experiment.

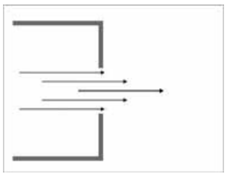


- What do you feel in front of the cannon?
- Watch the smoke rings while they are floating through the air.
- Do they remain the same in form and speed?
- What will happen when the opening is closed to a quarter or half?

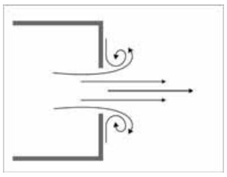
When you stand in front of the cannon and a staff member beats on the cannon’s membrane you will feel a strong blast of air. Even at a distance of 7 to 10 meter the air blast is strong enough to blow out a candle. What is happening at the Whirl Cannon becomes visible when we fill it with artificial smoke. Now we see beautiful coils of smoke coming out of the cannon when someone beats on its back. These rotating smoke rings or “annular vortexes” are formed because of friction.



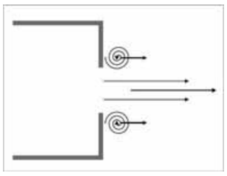
By beating on the membrane a lot of air is pushed through the opening, which is much smaller than the membrane. Therefore the air flows out very fast.



The escaping air is slowed down because of the friction at the margins of the opening. This causes different flow speeds in the middle (fast) and at the margins (slow) of the opening.



The faster air in the middle carries off the slower air at the margin, so that the air at the margins starts rotating.



This rotation stabilises itself into a big circular vortex (whirl).
In the end the escaping air split up into two different movements: The rotation and the slow forward movement of the ring.

Farbige Schatten / Coloured Shadows

110 kV- Hall

Stand in front of the coloured lamps.

How are your shadows changing when you move?

- How many lamps do you see?
- How many shadows do you see?
- Which colours can you see?

Hörspiegelohren / Hörlampe
Hearing Ears/ Hearing Lamps

110 kV- Hall

Take the Hearing Ears at their wooden handles into your hands. Hold them to your ears and walk through the room.
Listen at the opening of the smaller Hearing lamps.

- What do you hear?

Holzknoten / Wooden Knot

110 kV- Hall

The separate wooden parts can form one knot.

Do you find different ways to put the knot together?

Turm von Hanoi / The Tower of Hanoi

110-kV

A stack of wooden discs of different sizes is to be moved from one rod to another.
There are the following rules:

- Only one disc may be moved at a time.
- No bigger disc may be placed on a smaller disc.

- At first, try to move only a stack of three discs from one rod to the next. How many moves does it take?
- When you solved the task with three discs successfully, take a stack with more discs.
- Can you find the “three-disc-task” again?
- Count the moves you need to solve the task.

Geheimbotschaften / Cipher Messages

110 kV- Hall

Two players sit opposite each other, without seeing each other's building area. Each player has a set of building bricks.

Build something out of your bricks, that can't be seen by your partner.

Now, give your partner the construction plan without speaking.

Is your partner able to reconstruct the figure on your table with his/her own building bricks?

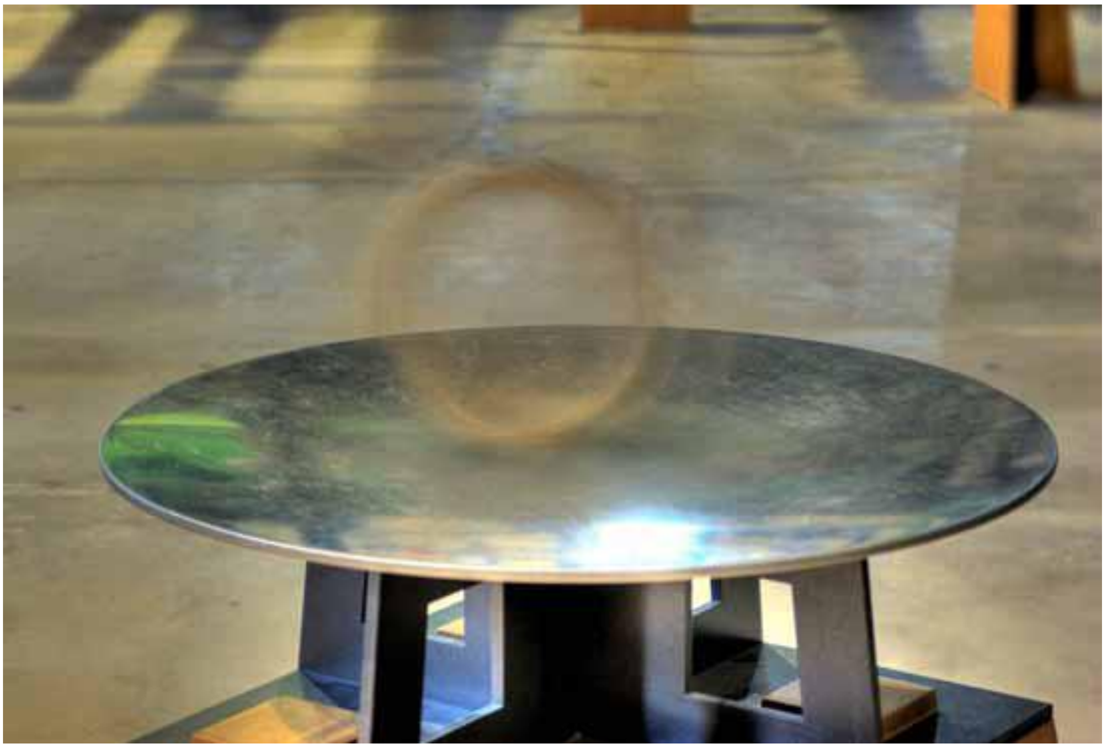
Most players invent some sort of sign language for communication. As a spectator – are you able to understand the sign language of the players and to "overhear" their conversation?

- Start with only four building bricks at the beginning.
- How often do you have to play until you understand each other easily?
- Which "words" has your developed language?

Mara-Ton / Mara-Sound

110 kV- Hall

The Ring is put into rotation on the curved surface.
How long may it keep spinning?



- How does the ring move? What different kinds of movement can you see?
- What do you hear?
- Try to guess the weight of the ring.

The “Mara-Ton” often fascinates our visitors. Even rather restless people take the time to wait and see when the ring will come to rest again. But instead of getting slower the ring moves increasingly faster and louder. So, time enough to watch the ring and its movements a bit closer.

Due to its round shape the ring has multiple centre lines. In a vertical position the rotational axis and the centre line are falling together and the balance point is right above the support point.

But after some time the ring starts to wobble because of the gravitation. Therefore the rotation axis is no longer vertical but starts to rotate itself. This movement is called “precession” and is also occurring at the earth’s axis.

One full rotation of the earth’s axis – the so called “Platonic Year” - takes about 25780 years.

As the ring is rotating it rubs on the ground. This friction between the metals is not very big, but sufficient enough to slow down the movement, so that the ring will eventually tilt to the side.

This goes together with a decrease of the potential energy which is transformed into the kinetic energy of the procession movement. The increasing procession movement becomes visible in the fast wobbling of the ring and the noisy sound when the ring dashes against the plate.

At this point of time the rotation movement has almost ceased and the ring is hardly rotating any more around its own axis.

The long rotation time of the ring is not so much connected with its initial rotating speed but more with its huge mass. You can test this easily with a coin: Even when you put the coin into rotation very fast its movement won’t last very long.

Klangmikroskop / Sound Microscope

110 kV- Hall

Put on one of the gloves.

Put your hand on one of the aluminium bars and stroke slowly with thumb and forefinger from the inner part of the bar to its end. Vary in pressure and pace.

- Where is it the easiest to produce a sound?
- How do the sounds between the different bars differ from each other?
- Listen along the topmost bar. Where is the sound the loudest?
- Touch a sounding bar softly with your fingertip. What do you feel?
- What do you feel when you put your finger only on the round part of the bar?

Most stringed instruments are made of strings that are spanned on a corpus. The corpus works as a sound box which takes up the sounds from the strings and increases them.

At the Sound Microscope you can recognize a similar construction: The sound is produced at the aluminium bars and the stainless steel sheets reinforce the sound.

But there is a fundamental difference between string instruments and the Sound Microscope in the production of sounds: String instruments are plucked, stroked or bowed across the strings. Therefore the strings will vibrate across their longitudinal axis – these vibrations are also called “transverse waves”.

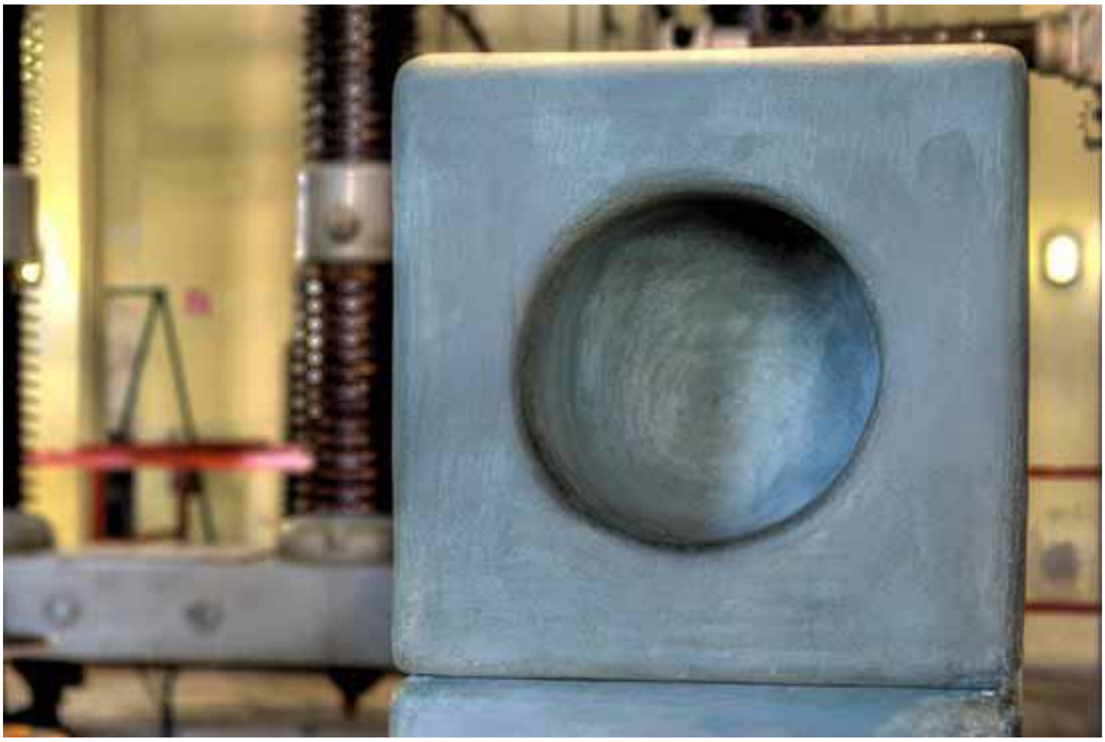
At the Sound Microscope you are stroking in a longitudinal direction over the bar. As the glove is rather sticky it will often get caught on the surface of the bar, only to slide further after a short moment. With the right pressure, some luck, exercise and skill you will manage to get a fast and regular succession of slides and stops on the aluminium bar, so that the bar will eventually get into vibration. This vibration is moving in a longitudinal direction and therefore called “longitudinal waves”. You can even hear it when you put your ear directly to the bar – there the sound is the loudest.

Summsteine / Humming Stones

110 kV- Hall

Put your head into the opening of one of the humming stones and hum for yourself: loud, soft, high, low, clear or false notes.

Meanwhile, a partner can put his hands on your shoulders – what does he or she feel?



- What do you hear while you're humming inside the stones? What do you hear?
- Try different tone pitches. Do all sound the same?
- What does your partner feel, when he/she puts the hands on your shoulder?

The effect in this experiment can be explained by resonance. The hole in the stone is working as sound box for the echo of certain wavelengths. Compared to the Hearing Ears the Humming Stones are not just reinforcing the sound of your surrounding, but rather certain frequencies of your own voice. Which frequencies that are, you can test yourself by humming in different high and low notes.

Licht-Labyrinth / Light-Labyrinth

110 kV- Hall

A way of 7 meter is blocked by several light barriers. You have to get through the labyrinth without setting off the alarm.

Exercise: For easier recognition the cords will show you the direction of the light barriers.

Emergency: After removing the cords, you are alone with your imagination. Can you find the right way?

- Which part is especially difficult for you?
- How many attempts do you need until you pass the labyrinth without any mistake?
- After how many exercise-passages do you dare to try it without the cords?
- Watch other visitors at this experiment.

Drehstuhl / Swivel Chair

110 kV- Hall

Sit on the chair and spin around.
What happens when you spread out your arms or put them close to your body?
To increase the effect you can take the weights into your hands.

The pirouette-machine outside on the yard operates in a similar way.

- What happens when you pull your arms to your body while you're spinning around on the chair?
- What happens when you spread out your arms?
- Ask your partner to take the weights and sit on the chair.
  Put the chair into rotation and ask your partner to spread out the arms.

When you spread out your arms on the spinning chair the rotation will slow down. As soon as you pull your arms to your body the rotation speed will increase again.

So the rotation speed depends on how the rotating mass is distributed around the rotation centre (which is in this case your body). The physical quantity that describes mass, form and mass distribution is called “moment of inertia”.

The greater the moment of inertia, the smaller is your rotation speed.
And the smaller the moment of inertia, the greater your speed.
This is also a good example for the principle of conservation of angular momentum: According to this principle the angular momentum of a rotating body stays always the same, as long as there is no interference from the outside. The angular momentum depends on the moment of inertia and the angular speed. The angular momentum is a conserved quantity, which means that the product of moment of inertia and angular speed is always the same.

There are also some examples from everyday life where you can find this principle:
The moment before a figure skater starts to pirouette he/she will gather the necessary momentum with widespread arms. By pulling the arms to the body, he or she reduces the moment of inertia and increases the own rotation speed.
The same happens at a somersault: by pulling the legs close to the body the acrobat reduces the moment of inertia.

Finally even a cat alights mostly on its four paws (provided there is a sufficient height of fall). Without knowing anything of the theory and by skilled movements the cat uses instinctively the principle of the conservation of angular momentum.

Dauerwelle / Permanent Wave

110 kV- Hall

Put the barrel into rotation.
Then pluck one of the strings and watch it.

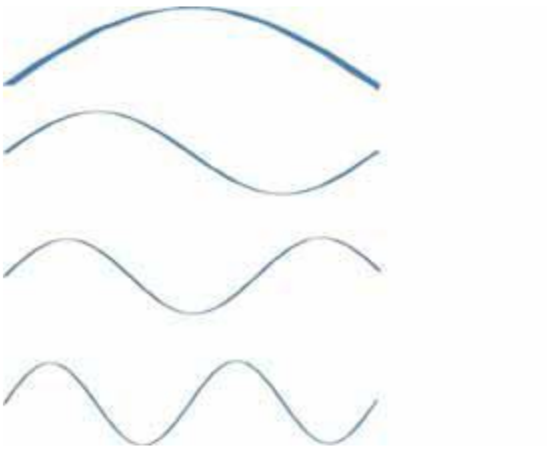
What do you see when the barrel is rotating slower or faster?

- Pluck one of the strings. What do you see? What do you hear?
- What do you see when the barrel is rotating?
- What happens when the barrel rotates slowly?
- How do the strings differ from each other?

Usually we don't see very much when we look at a vibrating string, because the movement is to fast for our eyes. But it is very different when you watch a string against the backdrop of a fast moving black-white pattern. When you put the barrel into rotation the string seems to stand still in the shape of a wave. The faster the barrel is rotating the longer and bigger are the waves.

In front of the black background the black strings are almost invisible. They can only be seen in front of the thin white stripes in the background. So when the barrel is rotating you'll actually see a fast succession of single images, which are put together to a consecutive motion. (You can see the same principle at the Wundertrommel and the Lebensräder).

When you now pluck a string you can see a standing wave. This effect of a seemingly slowed down motion of periodical processes is also called stroboscobic effect: It happens always when a periodical event is illuminated within regular consecutive distances.



Due to friction the rotation speed of the barrel will slow down after some time and the frequency of white stripes is no longer synchronic with the string's vibration. That's why the image begins to wander and blur.

Sandfiguren-Pendel / Sand-Figures-Pendulum

110 kV- Hall

A long and heavy pendulum is being initiated.
Take some time to watch the developing pattern in the sand.

- Look at the movements of the pendulum. How do they change over the time?
- How long does it take until the pendulum comes to rest again?
- Which basic forms do you find in the pattern in the sand?

Ich bin drei! / I am three!

110 kV- Hall

How might a child feel on the furniture of the big people?

- Guess how big is a three-year-old child?
- How big would someone have to be to fit on these furniture?
- How do you feel on the chair?
- Watch other visitors at this experiment!

"Tastatour" / The dark passageway

110 kV- Hall

A dark tunnel with some surprising obstacles is waiting to be discovered by you. Go ahead and grope your way through the dark.

Attention:
This experiment should not be done unsupervised. Please ask one of our staff members to explain it to you.

- What do you expect in the passageway?
- What do you see, hear and feel?
- What do you imagine by yourself while you're walking through the tunnel?

Black Box

110 kV- Hall

An orientation game in the dark.
Take your time to walk the dark way several times.
After every passage try to reconstruct the ground plan of the Black Box with the little sticks on the table.

- What do you think how big is the room?
- Walk several times through the box – you can start as well from the entrance on the back.
- Guess how long do you need to walk through the box?

Imaginata – Guide

English.

Boxengasse

Farben? Blind!

Colour? Blind!

Boxengasse

The light in this room comes from a sodium vapour lamp. Do you recognize the colours in the pictures on the wall or in your clothing? What happens when you switch on the hand lamp?

- What colours are in the pictures on the wall or in your clothing?
- What colour has normal day-light or the light of the hand lamp?
- What does the colours look like in white light?
- What colour has the sodium vapour lamp in this room?

„Rays are not colored.“
Isaac Newton (1642-1827)

By entering this room it becomes difficult to tell the true colours of the pictures on the wall or in the clothing of people. The light of the sodium vapour lamp makes it difficult to recognize colours. By switching on the hand lamp the true variety of the picture’s colours becomes visible.

Light can be described as electromagnetic waves which are visible for animals and human beings. The human eye is able to perceive light in the wavelengths between 380 and 780 nm. Depending on the wavelength of perceived light, different colour sensations are caused in the human eye. The sunlight is perceived as white light because it consists of rays with different wavelengths. When light falls on coloured objects some wavelengths are absorbed and others are reflected. Therefore we can see objects in different colours depending on the reflected wavelengths.

The sodium vapour lamp emits only light in the wavelength of 589 nm, which appears to us as yellow light. In this light the pigments of colours can only reflect this single yellow wavelength and appear like yellow to us, or they absorb the yellow wavelength and appear like black or grey to our human eyes.

The white light of the hand lamp is different. It consists of a great variety of different wavelengths and therefore consists of different colours. You can see this when day light is refracted in raindrops or a prism – the rainbow shows us all the different colours which make up the white daylight. In this light the pigments of colours absorb part of the wavelengths and reflect the others and therefore appear in their true colour to our human eyes.

Spiegelwürfel

Mirror Cube

Boxengasse

This special kaleidoscope consists of a cube with mirrors at its inner walls.
Look into it from above – which symmetries can you see?

What happens to the different reflections when you rotate the cube slowly?

- How many reflections can you see?
- Look at the planes, edges and corners of the cube.
- Which reflections are rotating and which are not?
- Put your head inside the rotating cube.

The cube consists of plane mirrors, two-sided mirrors and triple mirrors.
On the plane sides of the cube you can see simple reflections which do not change their position when the cube is rotating.

At the edges of the cube you can see a two-sided reflection which is rotating with the double speed of the cube rotation.
The corners of the cube are triple mirrors which reflect your image three times. As in the Triple-Mirror your image is always standing on its head and keeps its position.
When you put your head inside the cube, you can see more multiple reflections, because the cube sides are parallel to each other and reflect your image again and again. You can experience this effect as well at the “Spiegeltunnel” and “Spiegelallee”

Tripel-Spiegel

Triple Mirror

Boxengasse

Three mirrors are standing in pairs and vertically to each other. Is it possible to get a mirror image in such a construction?

What can you see at the centre, where all three mirrors meet each other?

- How many reflections can you see?
- Move in front of the triple mirror and look into the centre. What can you see?

Looking into the Triple Mirror you can see seven mirror images which come from simple or multiple reflections. At the three plane mirrors you see the first three mirror images. The other three images can be seen at the edges of the mirrors and the seventh image is in the centre.
By moving in front of the mirror and looking into the centre of it you will always see only yourself. That is because the reflected lightrays of all three room levels

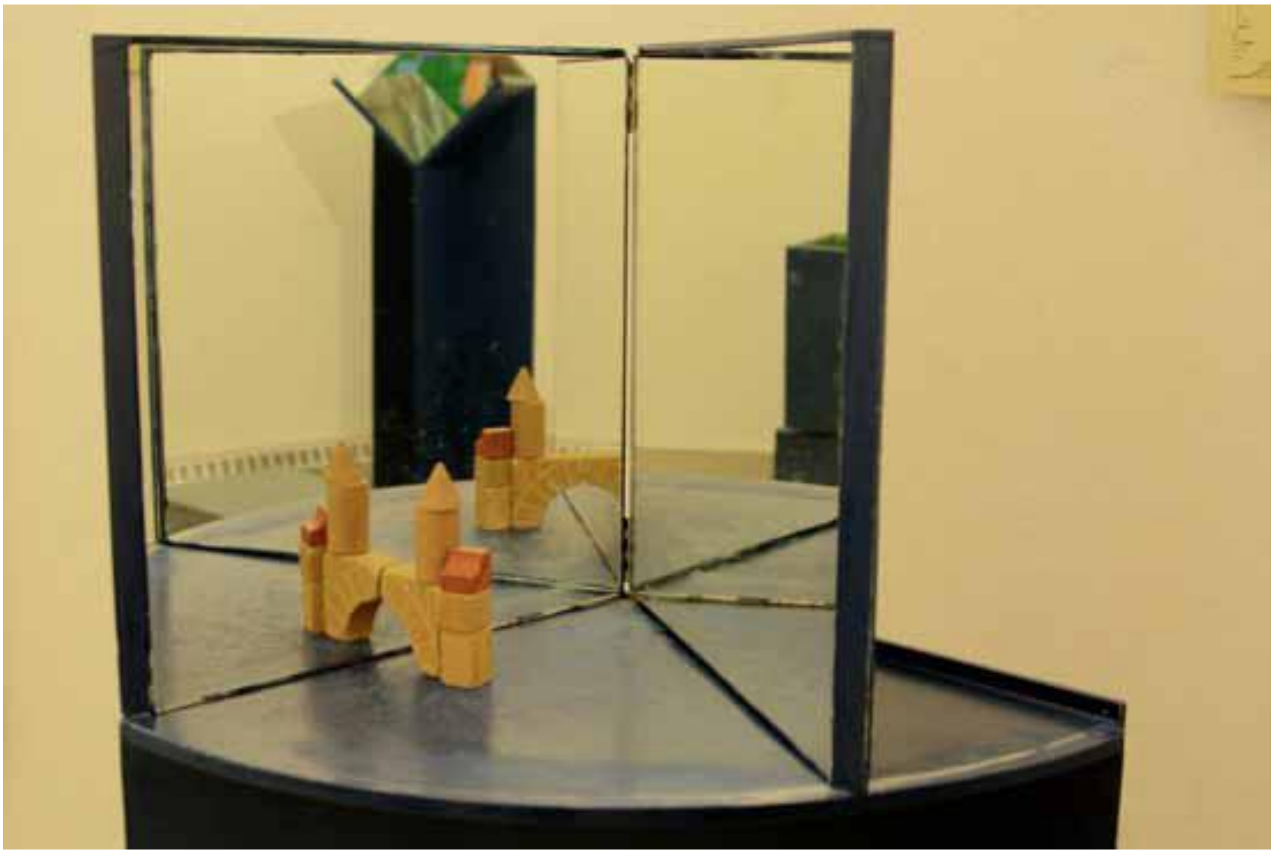
will always be adjusted parallel to the incoming lightrays. This effect is called retroreflection and is used in instruments for exact measurements.

Spiegelbuch

Mirror Book

Boxengasse

Put the toy blocks into the mirror book and change the angle between the two mirrors.



- Look into the Mirror Book. At which angle of the two mirrors can you see your face properly?
- Open the book to a right angle and put the toy blocks into it. How many mirror images can you see?
- Now close the book slowly. At which angles can you see complete mirror images?

When you open the mirror book in a right angle you can see three mirror images: One in each of the mirrors and one in the corner where both mirrors meet each other.

At slowly closing the Mirror Book the mirror image is pulled apart until it divides itself into two separate images. Using the toy blocks, you can test at which opening angles you can see complete mirror images.
The smaller the opening angle, the more mirror images you can see.

Kreuz.Wort.Weise

Cross.Words.Wise

Boxengasse

Use the letters from the box and form as many words as possible. You can play together or against each other.

Drehscheiben

Wheels

Boxengasse

Bring the wooden disc into slow rotation and look at it from a distance of 2 meter.

- What kind of patterns can you see on the disc?
- What does the patterns look like while the disc is rotating?

Drehscheibe „Spirale”

Wooden Disc “Spiral”

Boxengasse

Bring the disc into slow rotation. Concentrate your gaze on the centre of the spiral for approximately one minute. Then turn your look onto a motionless object: your hand or the wall.

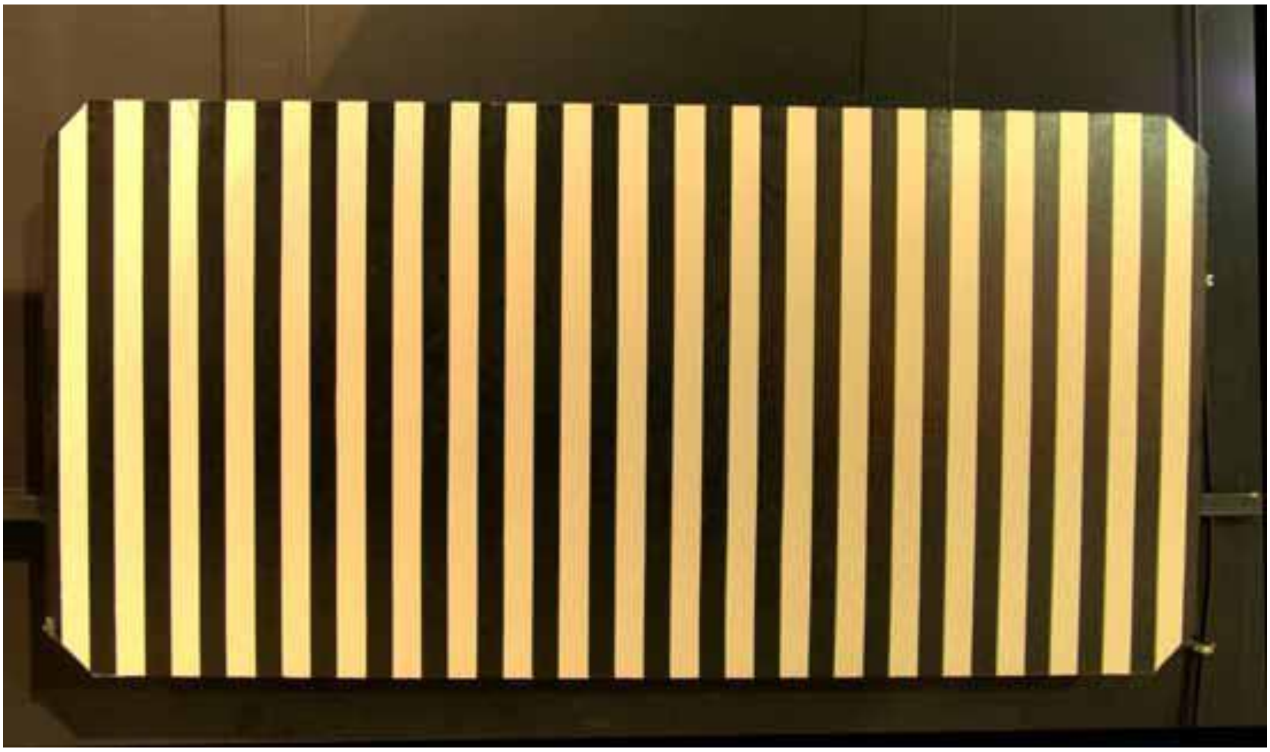
- What can you see?
- What happens when the spiral is moving into the other direction?

Seekrank

Seasick

Boxengasse

Concentrate your gaze on the striped wall and balance on one leg at the same time.
Now your partner makes the wall swinging sideways.



- How long are you able to stand on one leg?
- What happens when you close your eyes?

Normally, standing on one leg is an easy exercise. Your equilibrium organ helps you to constantly readjust your balance. Your sight supports these readjustments of your body, as it perceives your position in your surrounding.
But in this case it’s not that easy anymore to balance on one leg while looking at a swinging wall. That’s because your eyes are looking at the moving wall and therefore conveying a conflicting sensation to your sense of balance. According to your eyes it seems that your body is moving in the room. Therefore your body tries to compensate this movement until you fall to one side.
By closing your eyes it becomes easier to stand on one leg, because you are only concentrating on your sense of balance now and you are no longer disturbed by your visual perception.

Historische Reproduktionskamera

Historic Reproduction Camera

Boxengasse

Reproduction cameras are used to duplicate even master copies.

Compare this camera with the Big Camera and the accessible camera on the courtyard.

Look at the images on the screen and compare them to the original in the front of the camera. Are the images on the screen turned or mirrored?

- How does the image on the screen change while moving the camera on its camera sledge?

This camera has been used at the observatory Tautenburg until 2007. It was used to copy photographs of the starry sky. We thank the observatory for giving us this reproduction camera as a permanent loan.

Sechzehnfaches Spiegelbild

Sixteen-fold Mirror Image

Boxengasse

Can you see your mirror image in each of the sixteen mirrors?

Stand very close in front of the mirror collection. What can you see in each of the mirrors?

- Now walk backwards – how do your mirror images change?
- Is there a point at which you can see the same image in each of the sixteen mirrors?

Schwebespiegel

Free-Floating Mirror

Boxengasse

Two persons stand at the margins of the mirror facing each other.
Now stand at the margin of the mirror in such a way, that one leg is behind and one leg is in front of the mirror, so that only half of your body is seen. To keep your balance you can also hold on to the bar behind the mirror. Now raise your leg in front of the mirror and watch each other's mirror image.

Do you have more ideas for similar illusions?

- What do you see yourself? What are the others seeing?
- Watch the bystanders – how do they react?

At the Flotation Mirror it is sometimes more fun to watch than to do it by oneself. So it would be best if you try this together with other people, sometimes as "half person" at the mirror and sometimes as irritated or amused observer.

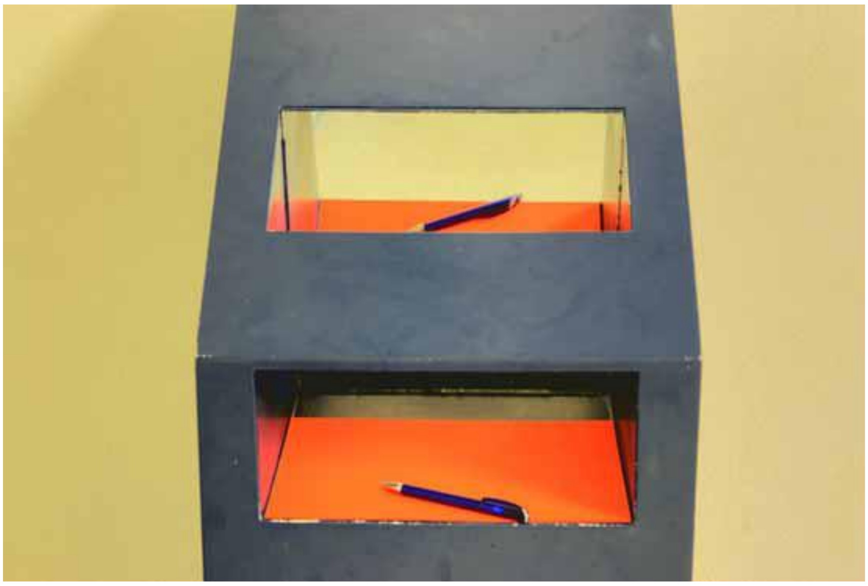
The source for the irritation is found in the fact that human beings have a longitudinal symmetry. If we duplicate one half of a body it looks like a complete body.

Spiegelzeichner

Mirror Illustrator

Boxengasse

Look in the mirror and draw or write in such a way that you can see and read it correctly in the mirror.
Try to draw a cross or a house.
Professionals can even draw the Olympic rings (remember: three rings on top, two rings below!).



- Start with drawing vertical and horizontal lines – which ones are causing you more difficulties?
- Try to draw with closed eyes. Can you see the picture correctly in the mirror?
- How long do you need until you can write your name correctly so that you can read it in the mirror?

Your eye-hand-coordination is very important for a lot of tasks in everyday life. For example to take up a cup of tea or to play with a ball. Your mind has to coordinate what you see, with the movement of your arm and hand.

Maybe you remember the difficulties when you learned how to write in primary school. This was a very special challenge for your eye-hand-coordination. But with

a lot of practice you trained your brain and developed new routines, so that your writing became more and more fluent.
But at the Mirror Illustrator your brain is not able to coordinate the image in the mirror with the movements of your hand. Only after some time of training you might discover that you get better at writing with the mirror illustrator. That’s because your brain is very fast at developing new routines for this task.

Große Kamera

Big Camera

Boxengasse

Look at the screen of the camera. What do you see? What happens when you push or pull the lever below the screen?

- Look at the picture while you are moving the lever. Which parts of the image are focused which ones are blurred?
- Is the image on the screen rotated or mirrored?
- Compare this camera with the walk-in camera on the courtyard!

This Camera is working with a collecting lens, through which the incoming light rays are collected and then projected onto the screen. If an object is within the right focus distance you can see it focused on the screen. The point of the right focus distance depends on the object's distance from the lens and the distance between lens and screen. The closer an object is to the camera, the greater the distance between lens and screen has to be, to get the image focused. The distance between lens and screen can be adjusted by pushing or pulling the lever below the screen.

Kugelspiegel

Spherical Mirror

Boxengasse

Two mirrors are arched hemispherical.
Which part of the surrounding area can you see? Compare these mirrors to the mirror image in a usual mirror.

Change your distance in front of the mirrors. How does your mirror image change when you get closer to the spherical mirror?

Your mirror image gets more and more distorted, the closer you move towards the mirrors. But don't get too much distracted by this effect. Choose different places in your surroundings and find out if you can see them in the spherical mirror.

Soon you will notice, that you can overlook the whole room within the mirror, except the parts directly in front of you. As in all mirrors, incoming light rays are always reflected within the same angle as they came in. The arched surface of the spherical mirror takes in light rays from all corners of the room. Therefore, as you look into the mirror, there is always a light ray from every corner of the room that is directly reflected into your eyes – so you have the complete overview of your surroundings.

But there is yet another difference to the image in a plane mirror: Straight lines appear curved and the proportions are not represented correctly. So you are getting the complete overview of your surroundings only at the cost of a distorted image.

Partnerkaleidoskop

Partner Kaleidoscope

Boxengasse

Choose a Partner whom you want to see infinitely often and look at each other through the kaleidoscope.
Are all mirror images the same?

- Ask your partner to close one eye – which eye is closed now in your partner's mirror images?

A kaleidoscope is made of three mirrors, which make up the sides of a prism. Because of the parallel arrangement of the mirror edges, the mirror images are reflecting each other multiple times, and you see countless images of your partner.

The repeated reflection is also changing the sides of the mirror image. For instance, when your partner is closing the right eye, some mirror images will have the closed eye on the left side (these are first-order reflections) and other images will have the closed eye on the right side (these are second-order reflections).

Wölbspiegel

Curved Mirror

Boxengasse

Spin the mirror around its axis. What happens to the mirror image? Move towards the mirror and watch your face and your surroundings while doing so.

- Stand about 3 meter in front of the mirror and lift your right hand. Which hand is lifted now in your mirror image?
- Spin the mirror and watch your mirror image. How often is the mirror turning around, how often your mirror image?
- Move slowly towards the mirror – can you find a point at which you see your mirror image without distortion?
- Watch other visitors when they stand in front of the mirror.
- What do you notice when you stand inside the curve of the mirror?

Spiegeltunnel

Mirror Tunnel

Boxengasse

Two mirrors are standing parallel to each other and a small slot allows the view into the infinite.

- Hold your hand into the Mirror Tunnel, while you are looking through the slot – how often can you see it?

Between the parallel mirrors the light rays are reflected almost infinitely. But due to the mirrors degree of reflection the light is loosing its strength each time it is reflected. Therefore, the mirror image becomes increasingly darker.

Lebensräder

“Life Wheel” or Phenakistoscope

Boxengasse

Take one of the wheels out of its slot and hold it in front of your face, so that you look at its black back. Now look with one eye through the uppermost slot to the mirror. Bring the wheel into rotation – one time slow, then faster. One time to the right then to the left.

- What do you see on the disc?
- What do you see in the mirror when you look through the slots in the disc, while it is rotating? What happens when the rotation is very slow?
- What do you see by looking directly onto the rotating disc?

Maybe you’ve already used a flip-book: When you flip fast enough through that little book, the successive pictures are put together to a running movement.
The “Life wheel” is working almost in the same way: When the disc is rotating and you look through the slots you’ll see an animated cartoon. But it is only working if the pictures are separated from each other. When you look directly onto the moving disc you’ll see nothing.

By looking through the slots the pictures are separated from each other and at a speed of 15 to 18 images per second your visual cortex puts them together into a flowing movement.
Even today this principle is the foundation of all film and movie technology.

Pyramiden-Kaleidoskop

Pyramid Kaleidoscope

Boxengasse

Which shapes emerge when you look inside the pyramid kaleidoscope?
Why is it called “Pyramid Kaleidoscope”?

- Look with a partner at each other through the kaleidoscope. Then change the sides.

How do your mirror images change?

Spiegelallee

Mirror Avenue

Boxengasse

Boxengasse

Stand between both mirrors. Compare this experiment with the mirror tunnel – what are similarities, what are differences?

- Look at your mirror images – how often can you see yourself from the front and from the back?
- What would you see if the mirrors were standing parallel to each other?

Fresnel Linsen

Fresnel – Lens

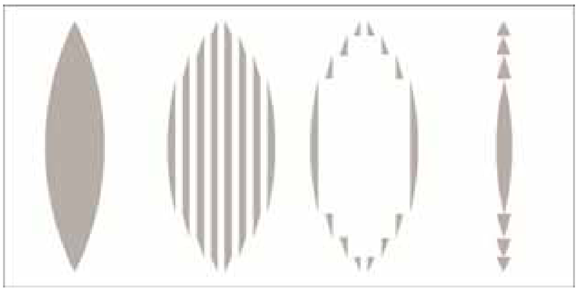
Boxengasse

Lenses can also be very flat! This one will expand, reduce, deform and turn around the world.

Where do you and your partner have to stand to see each other through the lens?

- Stand with your partner on both sides of the lens, looking at each other. At which point can your partner see you clearly, at which point not?
- What happens when your partner walks slowly away from the lens?
- Look at the lenses at the window. Are they all looking the same or different?

The effect of light refraction is only taking place at the boundary layers of glass and air. This led to the idea to replace conventional bulky lenses with thinner lenses made of concentric rings of glass.



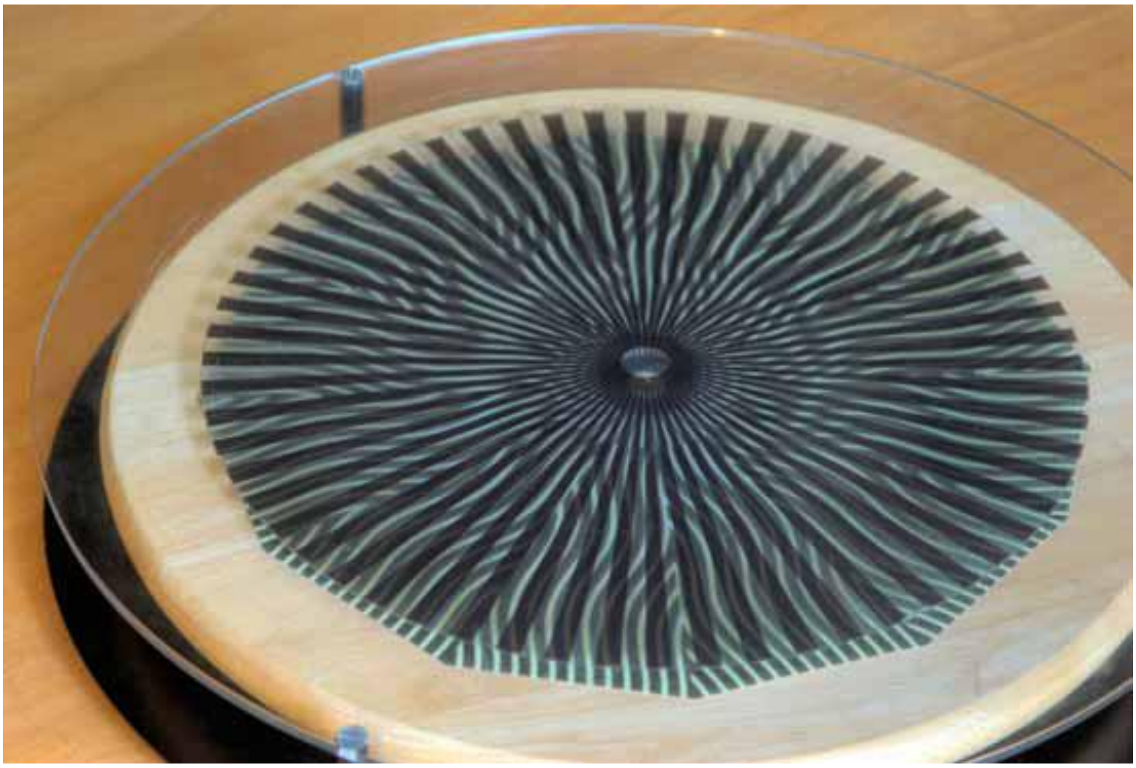
The physicist Augustin-Jean Fresnel developed these lenses to improve the light signal in lighthouses. The point at which you can still see your partner clearly through the Fresnel lens is the focal point of the lens. In a lighthouse this would be the position to place the lamp, so that it can always be seen clearly by any ship, no matter from which direction it is coming.

Moiré-Effekt

Moiré-Effect

Boxengasse

Two high-contrast patterns overlay each other.
Rotate the lower wheel slowly. What can you see?



- Slowly rotate the disc to the right. What kind of pattern do you see? How does it move?
- What happens when you rotate the disc to the other direction?

When two periodical patterns overlay each other, a third pattern is formed. This is called the moiré effect. Imagine you are looking through a fence towards a striped wall. In the spaces of the fence you'll see either white stripes or black stripes of the wall. Both patterns overlay each other and depending on your viewing direction they form different new patterns.

In addition our brain is involved as well – our visual system is trained to see lines or to construct lines out of an arrangement of points. So, sometimes we see patterns that do not even exist.

Wundertrommel

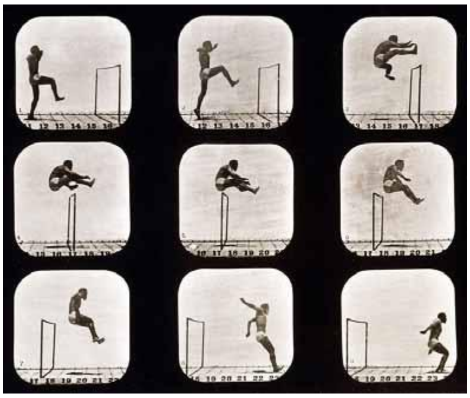
Cylinder of Wonders, also known as Zoetrope

Boxengasse

Put a picture strip into the cylinder. Bring the cylinder into rotation – but not too fast. What can you see, when you look through the slots?

- What happens when you rotate the cylinder to the other direction?

This is the same effect of moving pictures that you can experience with the "life wheels". At a rate of 15 to18 single pictures per second, it appears to us like a continuous movement. In the 19th century a lot of similar instruments have been built. Together with the development of photosensitive materials and projection cameras, this led to the development of the cinema.



serial photography of Eadweard Muybridge

Seitenrichtiger Spiegel

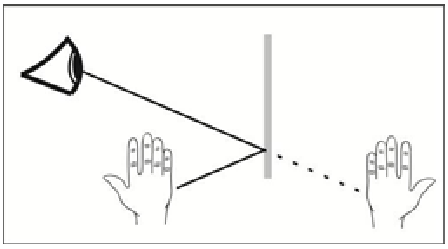
True-sided Mirror

Boxengasse

Step between the two mirrors and look into them. How many mirror images do you see? Are all of them the same?

- Lift your right hand. What are your mirror images doing?
- In what angle are the mirrors placed to each other?
- Look carefully at your face in the mirrors.

Usually every mirror is a true-sided mirror. When you lift up your right hand, your mirror image is also lifting up the right hand, seen from your perspective. When you are facing another person you know, that from your point of view, his right hand is on the left side.



We are automatically transferring this knowledge to our mirror image. But what happens when you are looking into two mirrors that are connected at one side?
At first you can see in both mirrors one normal mirror image that is lifting up the right hand from your point of view. Close to the corner between both mirrors you can see two other mirror images – but they lift up the left hand! We tend to see such mirror images as true-sided because they lift the true hand, from their point of position. But in reality the right-left-orientation is inverted – you lift up the right hand, the mirror images lift up the left hand, seen from your perspective. This happens because both mirrors are placed towards each other in a right angle and therefore

causing a double reflection. Your first mirror image is reflected again in both mirrors and by that instance it is inverted.

Imaginata – Guide

English.

Courtyard

Haus der Riesenzwerge / House of the Giant-dwarfs

Courtyard

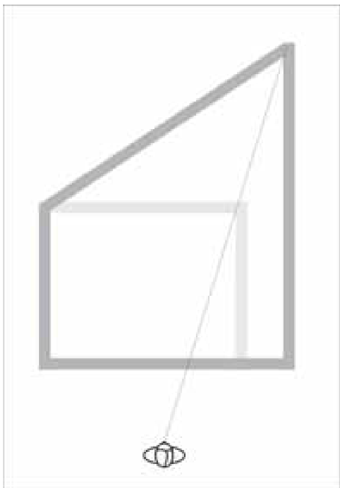
Two People enter the room – each one stands in one of the corners at the back of the room.
The other people look from the outside into the house – who of the two people in the house is bigger?

- Look at the form of the room. What kind of angles and surfaces can you see?
- Who of the two people in the room stands closer to you? Who looks bigger?

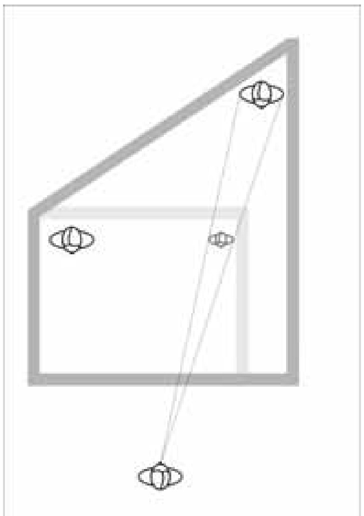
At the House of the Giant-Dwarfs it is best to experiment with a group of people.
When you stand in front of the open side of the little house you will see, that the floor is diagonally inclined, the sidewalls are not in right angle to each other and almost all surfaces are trapezoid. If two people stand in each corner at the

back of the room their body sizes seem to change: In the left corner one becomes a giant, in the right corner one becomes a dwarf.
The reasons for this effect are to be found on the one hand in the perception of our eye and on the other hand in the way our brain processes the perceived information.

When light enters into our eyes it produces simply a two-dimensional picture on the retina at the back of your eyeball. Stereoscopic Vision (the ability to perceive our world in three dimensions) is a complex process which needs the comparison of information from both eyes (with only one eye one cannot see 3-dimensionally).



To process this information, the experiences in perceiving our world, which we already made throughout our life, are of great importance: So far most of the rooms, windows and doors that we saw have been rectangular. Now, our brain interprets the perceived two-dimensional perception of our eyes and deduces the likeliest layout of the room.



If there are two people in each corner of the room our brain will try to fit them into its interpretation of a rectangular room – even at the cost that their perceived body size is obviously incorrect.

This experiment illustrates how our brain constructs and interprets images on the basis of the experiences in perception that we made so far in our life – and how these perceptions can contradict each other under certain circumstances.

Tuschelmuschel / Whispering Clam

Courtyard

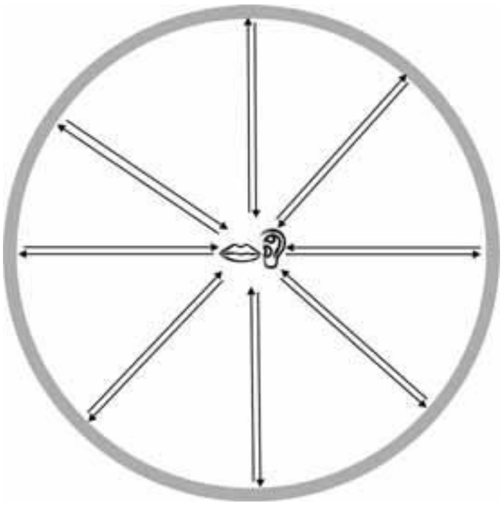
Take a seat opposite each other and whisper against the wall.
One person stands in the middle and tries to talk to the other people in the circle or to overhear their conversation.

- Do you understand your partner better when he is looking directly at you or when he is whispering to the side?
- Walk slowly through the Whispering Shell while you're speaking in a loud or low voice. What do you hear? What do the others hear?
- Stand in the middle and say some words. How does your voice sound to you, how does it sound to the others?
- Do you have any idea why there is an opening in the ceiling?

Visitors, who enter the Whispering Shell, soon soften their voices. They realize that they don't have to talk very loud to be heard. You will notice that it is enough to talk softly against the wall in order to be heard by a person who is sitting on the opposite side. But it is a completely different case when you step into the middle of the circle: While you're struggling to follow the conversations of the others, you'll hear your own voice muffled and distorted.

These effects are appearing in all rooms with a circular or elliptical layout and a plain wall. In such rooms the sound waves coming from your mouth are reflected repeatedly at the surface and in this way are forwarded along the wall until they reach your partner's ear on the opposite side. Such waves that "stick" to the surface are also called "Rayleigh Waves".

So, as the sound waves from a person at the edge of the circle are forwarded along the wall you can't hear them while you are standing in the middle. But when you say something in the middle of the circle the sound waves are reflected at the wall – almost directly back to your ears. That's why you can hear your own voice unnaturally loud. You might notice that you're voice sounds different – but only you are experiencing it that way.



For all others your voice does sound as usual. That's because you are hearing the increased echo of your outgoing voice. Normally you hear another voice when you are speaking: When you are speaking your echo is transferred inside your body from your vocal folds through the bones to your ears and you are used to this sound of your voice. But your outgoing voice is transferred through the air and therefore it sounds differently. In the middle of the Whispering Shell your "inside-voice" is superimposed by your "outside-voice" echo. Many people react surprised and irritated because they are not used to this sound of their voice.

Remains the question for the opening in the ceiling… Well you can answer this one to yourself when you imagine what happens to an opened umbrella on a stormy day…

Hochseilrad / Tightrope Bike

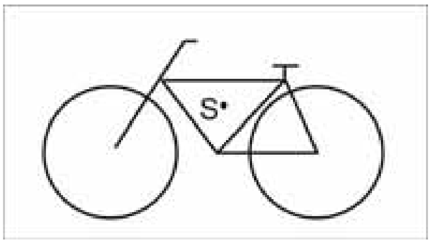
Courtyard

On this bicycle even you can turn into a tightrope artist!

- What do you guess: How heavy is the outrigger below the bicycle? How long is it?
- Where is the centre of mass at a normal bike? Where is it at the Tightrope Bike?

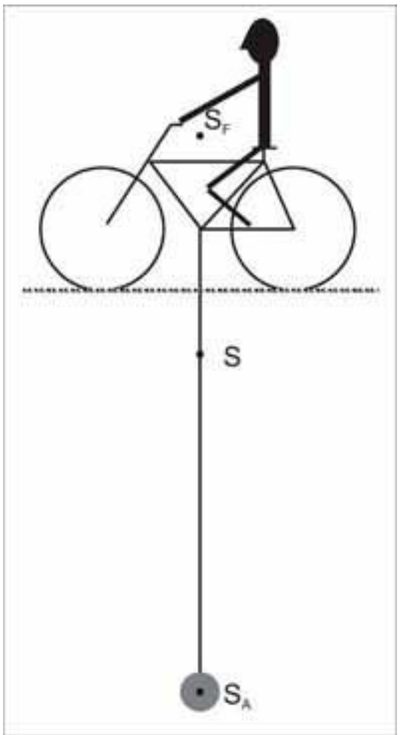
Is this safe? Don’t you fall off of the bike? These are the usual questions, that visitors will ask when they look at our Tightrope Bike for the first time. For those who are not satisfied with the answer – “This has been proved by the Technical Control Board” – it might be reassuring to get an understanding of the physics of our Tightrope Bike. Then you might gain enough confidence and dare to drive five metre above the ground on a thin tightrope.

The stability of an object's position can be estimated by a physicist when he looks at the position of the centre of mass of the object. An object is always safely positioned when its centre of mass has reached the lowest point - at this point the physicist will talk about a balanced object.



At a normal bicycle the centre of mass is found inside the frame's front triangle – that means that a lying bicycle is in a more stable position than a standing one.

That's entirely different at the tightrope bike: Here an outrigger has been attached, whose centre of mass lies 3 metre below the bike. The iron weight at the end of the outrigger weighs 50 kg and it keeps the bicycle always in an upright position. When a person sits on the bike the centre of mass will move a little upwards but it remains still below the point of support, so that the whole system is in a stable balance.



Could this explanation convince you to try a ride on our tightrope bike? If so, you might notice that even at a low speed you'll drive calmer and more steadily than usual. Every little tilt and deflection would move the mass centre upwards. But such labile positions will soon turn back into a stable position at which the centre of mass is below and you and the bike on top.

Möbiusbahn / Möbius Rail

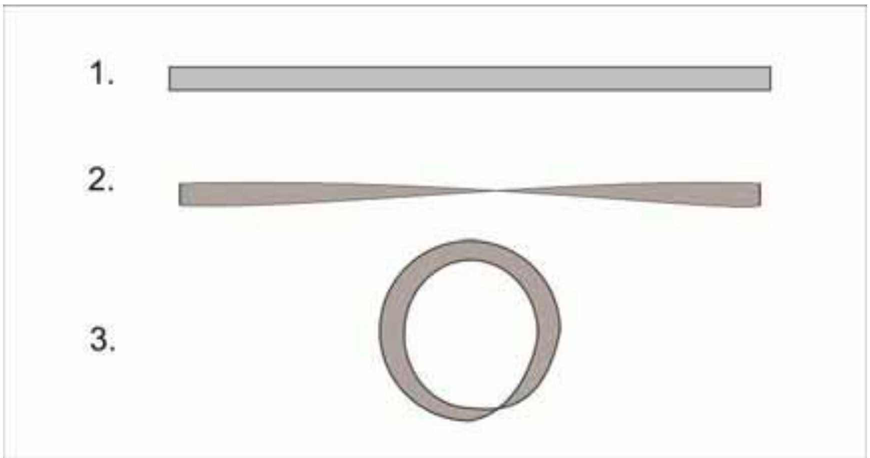
Courtyard

A circular section of track and a car seat that's driving on it. But will it return to its starting position after one round on the tracks?

- How many tracks do you see at the Möbius Rail?
- In which position would you arrive, if the car seat could not be turned around?

Asked how many tracks they see, visitors often tend to see two tracks on which the car seat is driving. But it is worth the time to take a closer look at the Train: At the Möbius Train there is indeed only one single track that runs parallel to itself.

When a person drives one round on the track he or she will arrive contrary to his/her original viewing direction.
In 1765 the mathematician and astronomer August Ferdinand Möbius published a description of a one-sided surface – the later so-called "Möbius strip". This mathematical figure has been our inspiration for the Möbius Train.

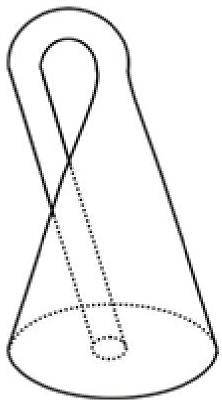


It is rather easy to reconstruct a Möbius-Strip: Take a strip of paper and turn one end 180 degree – then stick both ends together. (When you stick both ends together without turning one end, you will get a usual paper ring.)

There are some characteristics which you can discover with the Möbius-strip: Move your finger along the edge of the Möbius Strip. You will notice that the Strip has only a single self-contained edge – which corresponds to our track at the Möbius Train. A paper ring, on the other side, has two separate edges and surfaces – an inner surface and an outer surface (in mathematics you call such objects "orientable").

The surface of the Möbius Strip is closed in itself – there is no front- or backside (the surface is non-orientable). Instead, you can move your finger in two rounds alongside the whole surface – in the same way as the car seat at the Möbius Train will return to its original position after two rounds on the track.

Another Example for an "non-orientable" object is the "Kleinsche Bottle".



Hörspiegelstrecke / Audio-Mirrors

Courtyard

Stand in front of one of the audio mirrors and your partner in front of the other one. Now speak towards the Audio Mirror.

What is the best position of your heads, so that you can hear your partner and be heard as well?

- Have you ever looked into a shaving mirror?
- Position yourself in such a way, that you look towards the middle of the Audio Mirror.
- Move slowly backwards.
- At which point can you hear your partner particularly well?

Curved surfaces can produce interesting acoustic effects – as you can also hear inside the Whispering Shell (Tuschelmuschel). Our Audio Mirrors are nothing else than parabolic mirrors from two satellite dishes. Such antennas are used to receive radio signals and our Audio Mirrors operate after the same principle, only that they receive sound waves instead of radio waves.

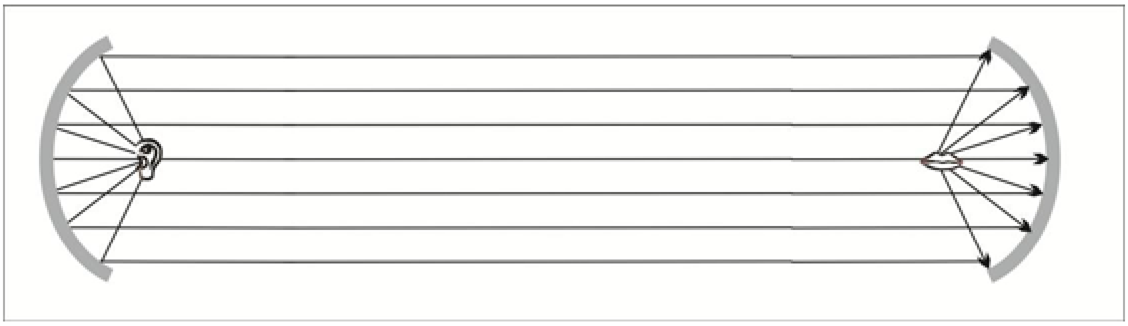
Sound waves are produced inside your glottis and leave your mouth when you speak; you can hear them with your ears.

If you and your partner speak towards the Audio Mirrors in the correct distance, you can communicate with each other over a long distance – even when you turn your backs towards each other.

Sound waves are reflected at all plane surfaces and the angle with which they hit the surface is also the same angle in which they are reflected. (As with a ball that you throw against a wall).

If the surface is not plane but circularly or parabolically curved the arriving sound waves are reflected in such a way that all of them meet in one point. You can find this point when you experiment with different positions in front of the Audio Mirror – it is the point at which you hear your partner especially good.

In the same way all sound waves which are coming from you are reflected at the Audio Mirror in such a way, that they leave the mirror in parallel lines. At the opposite Mirror, the parallel sound waves are again bundled in one point, so that your partner can hear what you said.
The point, in which all parallel sound waves are focused, is called focal point. A dish antenna will have its reception head in this position.



Begehbare Kamera / Walk-in Pinhole Camera

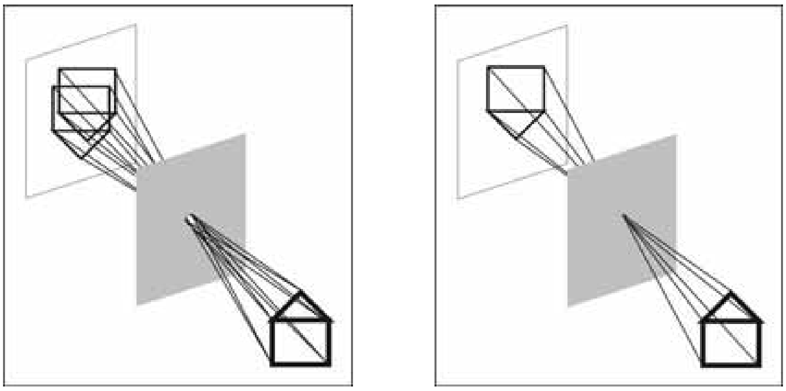
Courtyard

Through a small opening in the door light gets into the camera. Watch the projection on the screen. How does the picture change when the opening gets smaller or a lens is put in front of it?

- Step into the camera and close the door. How long does it take for your eyes to se something?
- Open the shutter in the door wide and close it slowly. What can you see?
- How does the image change when you use the different circular openings?
- Open the door and look at the courtyard. Close the door again and look at the image on the screen. Is it rotated or mirrored?

Maybe you've already enjoyed a sunny afternoon in the shadow of a tree, watching the sunny spots on the ground (in German we call them "Sonnentaler": sun-thaler). The rays of the sun which fall through the small openings in the forest canopy, paint bright ovals on the ground which are all looking quiet the same.
In the same way our Pinhole Camera reveals its secrets best at a sunny day: As soon as your eyes get used to the darkness in the room you can open the slide

shutter in the door and then close it slowly. The smaller the opening gets, the better you will recognize the panorama of our Imaginata-courtyard on the screen. However, not all visitors do recognize it at first, as it is projected upside down: the sky can be seen as a circular arc at the bottom of the screen and the Imaginata-ball on the roof of the main building is projected on the floor. So, top and bottom are interchanged.



How does this fit into our idea of the sunbeam? Well, all light inside the camera enters through the opening in the door (the pinhole). However, this is not just a single sunbeam, but from every point of the courtyard several rays of light get through the hole onto the screen inside the camera.

The smaller the aperture (pinhole), the less light can enter. Thereby, the image gets darker but also sharper, as only very concentrated rays of light are now shining onto the screen and painting there a sharp image without overlapping. This correlation between the size of the pinhole, light intensity and image sharpness also applies to a usual photo camera: The bigger the aperture, the more light can enter and the shorter is our length of exposure. At the same time the depth of focus will be lesser and the image can appear blurry. On the other side, with a smaller aperture the image will be more in focus but might be underexposed.

Now inside our Camera you should take a closer look at the orientation of the projected image: Take, for example, the fence to our neighbour. Looking out of the Camera the fence is on the left side of the door. When you turn around and look at the screen, the fence is also projected on the left side. But when you keep your viewing direction (and with it your own orientation), by standing with your back to the screen, the fence is projected on the right side of the screen. As the rays of light enter through the opening they cross each other and therefore change the complete orientation of the image. This is rather obvious at the top-down-orientation but it is more difficult to recognize for the left-right orientation.
Now, what has our Pinhole Camera to do with the ovals of sunlight under a tree? The gaps between the leaves are working like the pinhole of our camera: they project the sky onto the forest floor: the bright ovals we see are actually a projection of the sun.

Hörspirale / Audio Helix

Courtyard

Speak slowly and distinctly into the tube and hold your ear to the other end of it.

- Speak short and loud words!
- What do you guess – how long is the interval between the spoken and the heard word?
- Guess – how long is the Audio Helix?

Visitors who see the Audio Helix the first time, often ask at first for its purpose and then for its size. The first question is answered quickly: When you hold your ear to one end of the helix and speak loudly into the other end, you will hear the spoken words with some delay.

To answer the second question, we can use the sonic speed: The longer the tube, the more time does the echo need from one end to the other. Within air and at a temperature of 20°C the echo covers a distance of 324m in one second. To calculate the length of the tube you need to know how long it takes for the echo to get from one end of the tube to the other. The speculations of our visitors range from half a second to two seconds. Obviously, it is difficult to estimate such short times. But we can take it as a point of reference, that the human ear can hear sounds separately, only if they are divided by at least a decisecond. Given, that you experience the spoken and the heard word at the Audio helix as two separate events, the tube has to be at least 32 m long.

However, our calculation is still forged due to the fact that the tube is curved and the sound waves are reflected frequently at the tube's inner sides. Therefore the echo takes a longer way than the actual tube length. So, even if you could measure the time span accurately the calculated tube length would still be too long.

In the end we can only ask the constructors of the Audio Helix: According to them the tube has a length of 160 m.

Schiefes Haus von Jena / Leaning House of Jena

Courtyard

Are you able to stand straight inside the house? Check yourself and the others – are you really standing vertically to the floor?

- Marble Scale: Adjust the wooden channel in such a way that it is horizontal. Whether you guessed right, you can prove with a marble that you put in the middle of the channel: If the channel is horizontal, the marble won't roll away.

- Pendulum: As soon as you detach the pendulum it will point vertically to the floor. To which of the small boxes will it point? Place a bet, by putting a ball into the box.

- Marble run: Where is the starting point for the marble, so that it will roll through the whole marble run?

Some visitors feel as if they were on a wavering ship, when they enter the Leaning House. And it is almost impossible to walk in a circle without tottering and stumbling.

Everything looks normal but it doesn't feel normal, when you are inside the house. Ask your partner to close the eyes and to stand relaxed. To your eyes he or she will stand noticeably at an angle. On the other side it might feel better for you to stand with closed eyes yourself – even though the others will believe that you might tumble over in a moment.

It is our self-awareness or proprioception, which is irritated here. The muscles, sinews and joints in our body have receptors which inform our brain about our body's position and movement in the room. Through these receptors we can feel whether our muscles are tensed or our knees are bended. Even with closed eyes we simply "know" what our left arm is just doing, so that we can move it easily to the tip of our nose without looking at it. This proprioceptive sensibility is closely related to our sense of balance (equilibrioception) and both enable us to perform complex movements or simply to stand up straight.

Inside the Leaning House it becomes obvious how our senses – which most of the time cooperate perfectly – suddenly get into conflict with each other under certain circumstances. Our tensed muscles indicate that the floor is inclined. But our eyes lead us to believe that everything is straight, even when marble run, scale and pendulum indicate something else.