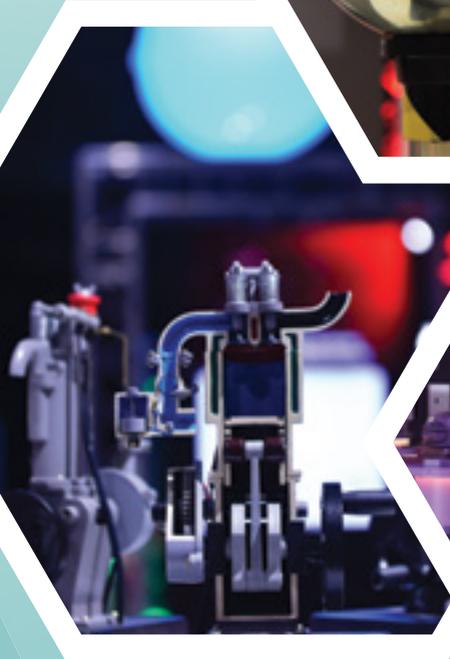
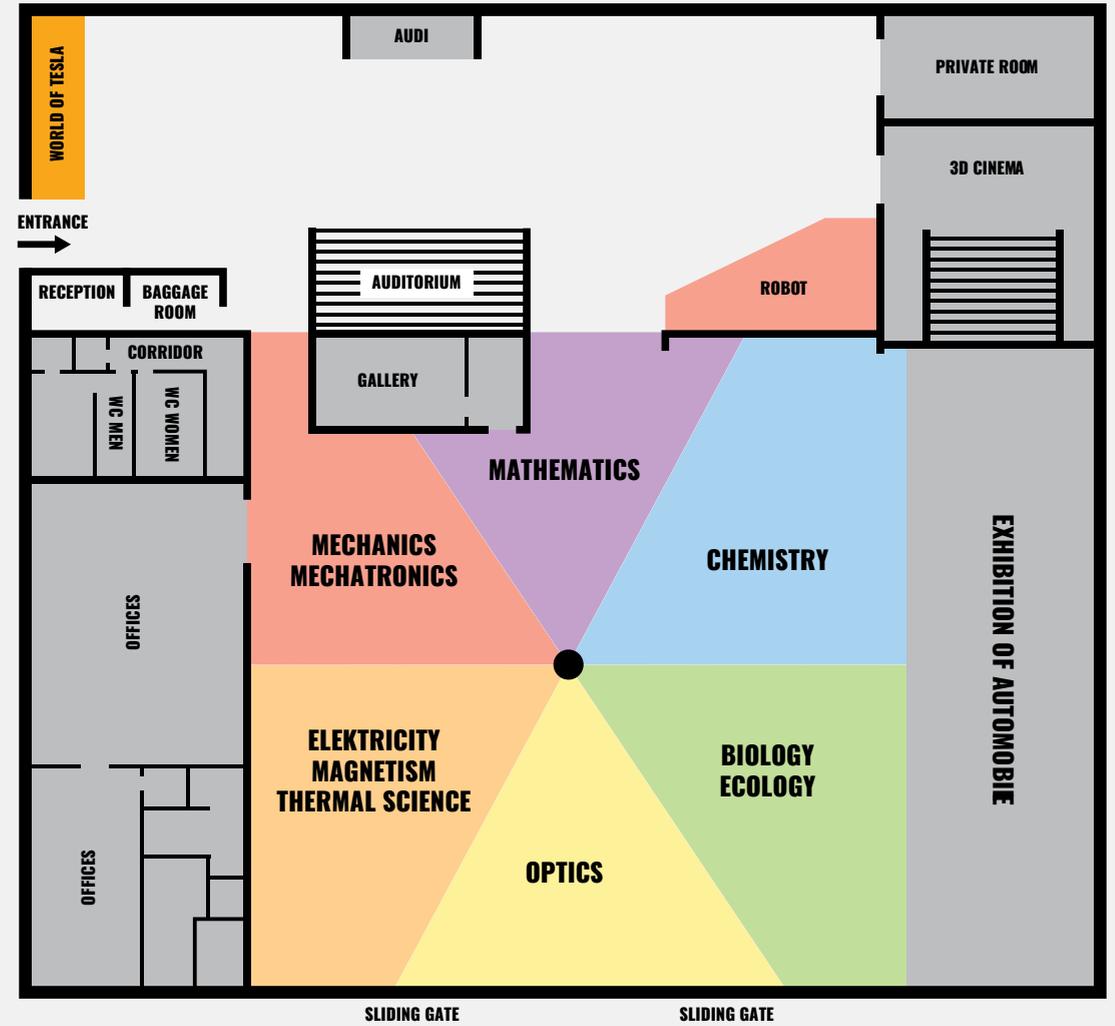




**INTERACTIVE
SCIENCE CENTER**



AURELIUM MAP



— REGISTER



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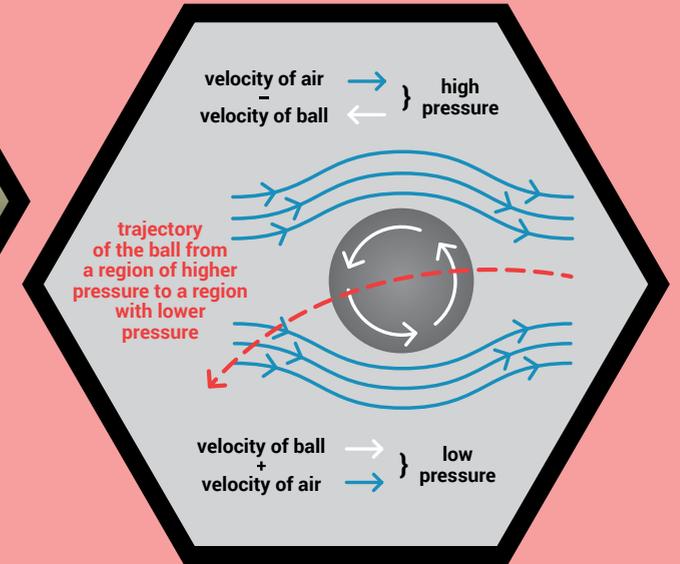
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01 BERNOULLI'S BALLS

Did you manage to keep the ball up in the air? How is it possible?

When the air flows around a body of a round shape, air vortices, as a manifestation of turbulent flow, are formed behind the body. This is caused by a negative pressure in the space behind the round body. The higher the airflow rate, the greater the lift of the body. The underpressure causes the body to float – an aerodynamic lift.

What happens when you insert your hands and then remove them from the immediate vicinity of a flying ball and a current of air? What happens when you interrupt the airflow with your palm or by pressing the STOP button? Do you know why?



Bernoulli's equation

The law of the conservation of energy in a steady flow of gas or liquid is expressed by Bernoulli's equation. It is one of the basic methods for calculating aerodynamic lift as a phenomenon describing the buoyancy of a body in a gas (or liquid).

Where does the Bernoulli principle apply?

Aerodynamic lift allows an aircraft to fly. Archimedes' law applies to a balloon or airship flight.

02 BRIDGE STRUCTURES

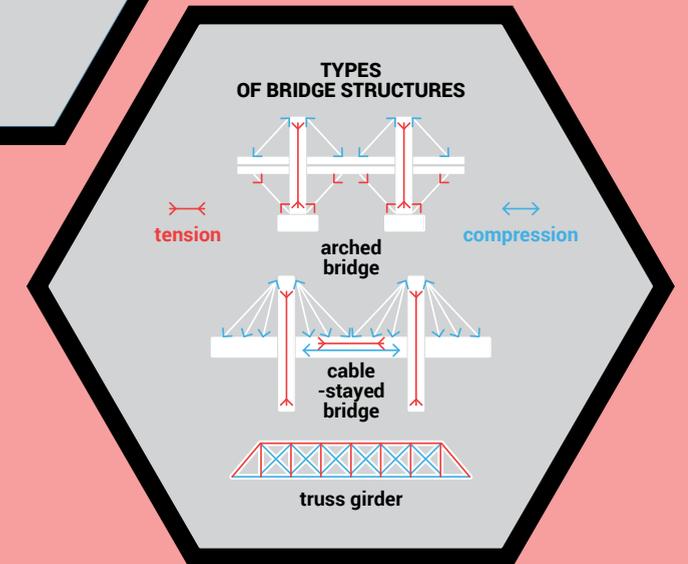
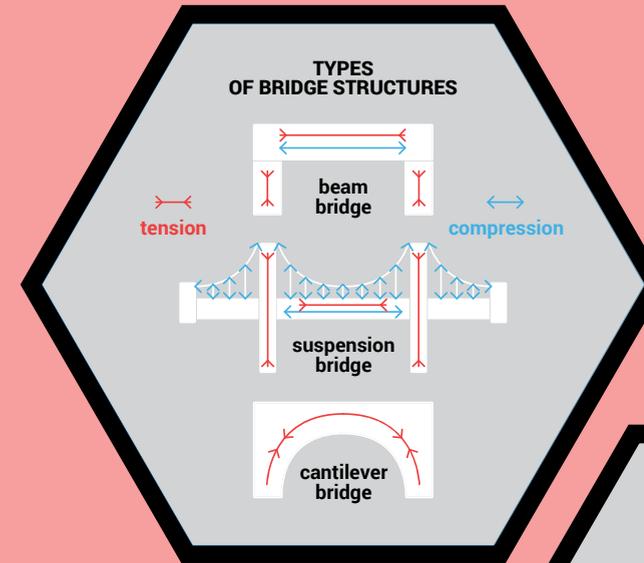
Try to remember if you have ever walked on an actual truss girder bridge.

How is it possible that the truss structure is so strong?

The construction of the truss girder consists of geometrically arranged elements. Due to this special arrangement, the truss girder is significantly lighter than a conventional girder with the same load capacity. In such a structure, the load is distributed effectively.

Of interest:

An important economic and ecological factor of the truss girder is its low mass, thanks to which a significant quantity of construction material is saved.



03 BRIDGE TENSION

**Do the values displayed on the screen represent your mass?
How is it possible?**

No, the values do not represent your mass. The information provided on the screen expresses the rope load relative to the location of the load on the platform.

The exhibit consists of a stepping platform, which is attached to the hinge and its free end is suspended on two steel ropes. On these ropes are mounted sensors with a measuring range of up to 150 kilograms. The output data of the tension sensors are displayed on the screen.

What does the exhibit demonstrate?

The values displayed demonstrate what causes a point load on the platform, which is manifested by a change in these values.



The functional model allows to test the location of the point load on the platform so that both ropes are equally loaded - achieving equilibrium. This is the principle of security, such as the statics of bridges or similar structures.

How are load sensors used in practice?

The task of bridge designers is to design a bridge so that all its parts are loaded equally evenly. Load sensors are used to examine and monitor the load.

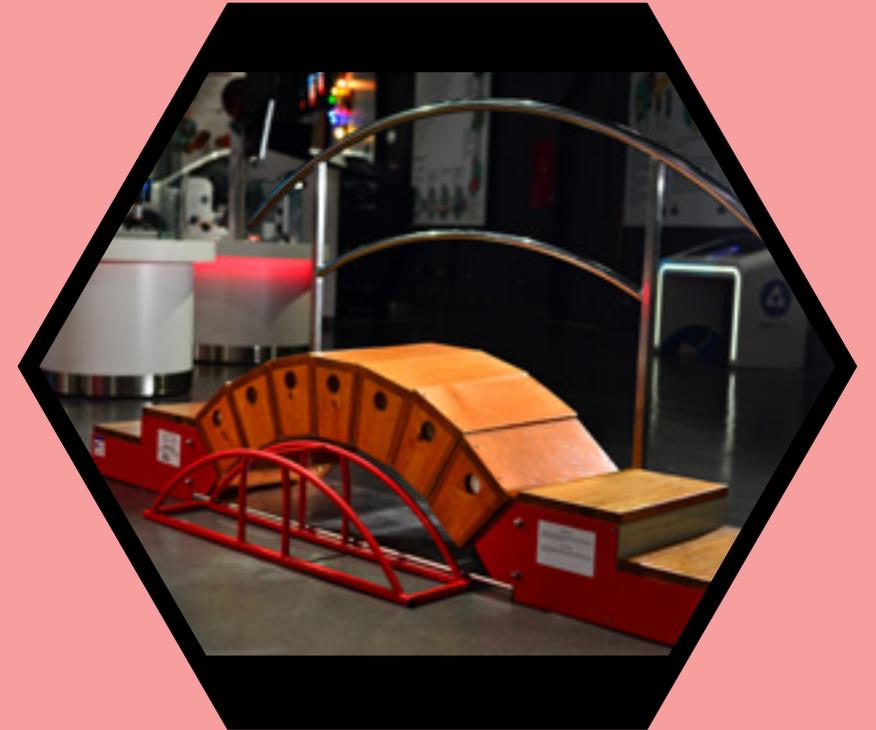
04 ARCHES BRIDGE

What does the exhibit demonstrate?

This arched bridge structure shows how forces are imposed on the vaults.

How is it possible that the arched bridge structure maintains its shape and does not collapse even when loaded?

The success of its strength lies in the fact that its component parts are wedge-shaped, thus forming a vault. The perpendicular forces acting in the vault are distributed sideways, thereby compressing the parts against each other. Since the lower part of the vault is solid, it does not fall apart. At the same time, the vault can withstand a heavy load without collapsing, because none of its parts can be pushed inside.



Do you know where an arched bridge structure can be found in Slovakia?

A well-known arched bridge structure is located near Telgárt, Chmarošský viaduct.

05 LASER PROFILOMETRY

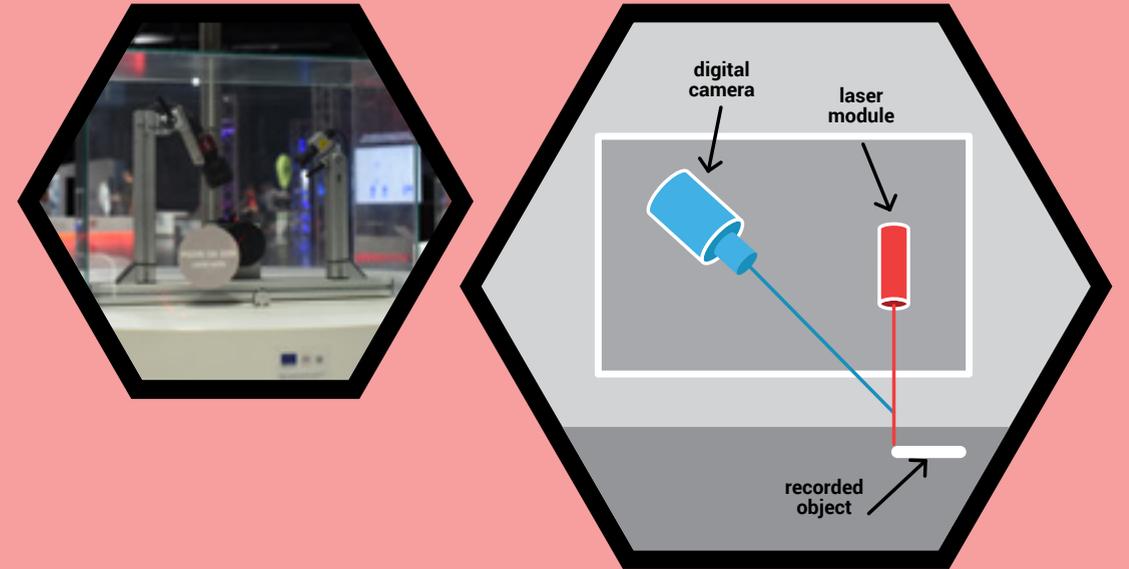
What is a laser profilometer? How does a laser profilometer work?

A laser profilometer is a device that is able to scan the surface of a three-dimensional (3D) object, then create its two-dimensional (2D) visualisation and evaluate its shape and quality and compare those with a sample model.

The device checks the dimensions of products using laser triangulation profilometry. A line produced by the laser is projected onto the surface measured, which is then recorded at a certain angle by a digital camera. This means that the 2D profile of the object is recorded along the laser-defined section line. By combining the 2D profiles created in this way, it is possible to reconstruct a 3D model of the scanned object.

What does this exhibit demonstrate?

12 The exhibit demonstrates how product quality control is performed. It is an example of the operation of laser profilometry, which can



scan both static as well as rotating objects and their surface. The profile of the scanned object is visualised on a screen.

Do you know where laser profilometry technology is used?

Laser profilometry is used in manufacturing processes for non-contact optical measurement of finished products or for measuring in the course of their production. It serves to examine their dimensions and the quality of their surface, thus determining whether they are within the prescribed limits of inaccuracy. Laser profilometry forms a part of computer numerical control (CNC) machine tools.

06 MOMENTUM – BILLIARD

What does the exhibit demonstrate on the billiard table?

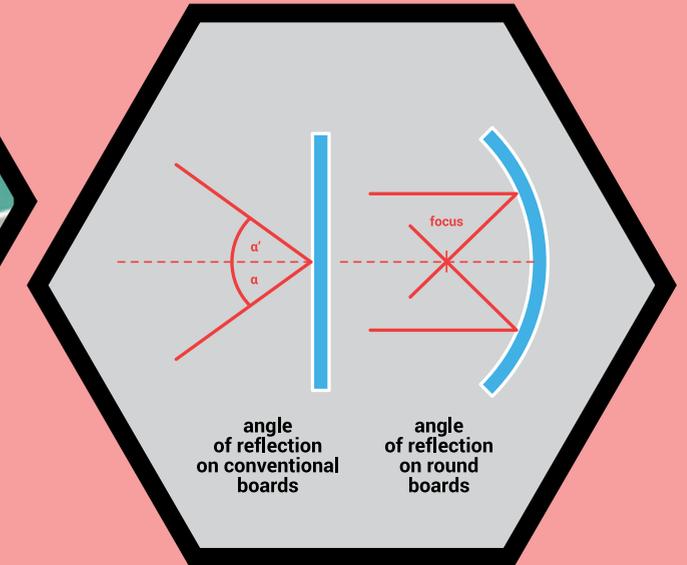
The exhibit demonstrates the impulse of force, the law of the conservation of momentum and the law of the conservation of the angle of incidence and reflection. The momentum of a body that does not move (its velocity is equal to zero) is also equal to zero. Momentum (H) is defined as the product of mass (m) and velocity (v), $H = m \cdot v$

If the body is at rest and needs to acquire a uniform rectilinear velocity, a force must act upon it for a certain time. The shorter the time the force acts on the body, the greater this force must be. If a force acts for some time, this is referred to as an impulse of force. When the body gains speed, it also gains momentum. This can be expressed in the form of an equation $F \cdot t = m \cdot v$, where the force pulse $I = F \cdot t$ or in words – the impulse of the force causes a change in the momentum of the body.

Do you know what the law of the conservation of momentum states?

What are its practical applications?

The law of the conservation of momentum states that a system of bodies retains its momentum unless an external force acts upon it. The law applies to resolving the collisions of bodies.



How does a body move when it hits an obstacle?

The body moves at a certain angle on a trajectory towards an obstacle. After colliding with an obstacle, it bounces at an angle. When a perpendicular is drawn from the point of impact on the obstacle, it is obvious that the angle of incidence and the angle of reflection are identical. This is the law of reflection: The law of reflection states that the angle of reflection is equal to the angle of incidence. The law of reflection is valid for all types of waves (mechanical, electromagnetic).

07 PERPETUUM MOBILE

How is it possible that this perpetuum mobile works?

It is not possible to build a machine that would endlessly supply mechanical energy without consuming an equivalent amount of energy of another type. Such a hypothetical machine is denoted as type I perpetuum mobile.

This perpetuum mobile is powered by an electric motor concealed within the construction.

Of interest:

Leonardo da Vinci attempted to construct a perpetuum mobile, but without success.

Can you or could you construct it? How?



08 GEAR

What could you observe? What did you find out?

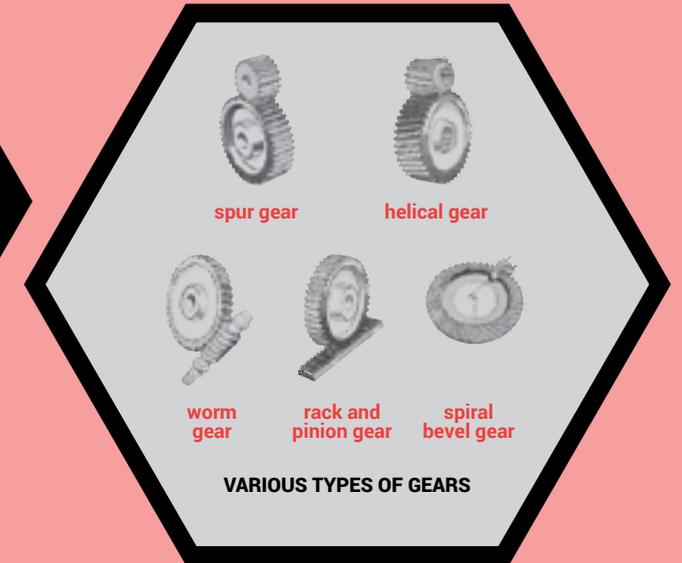
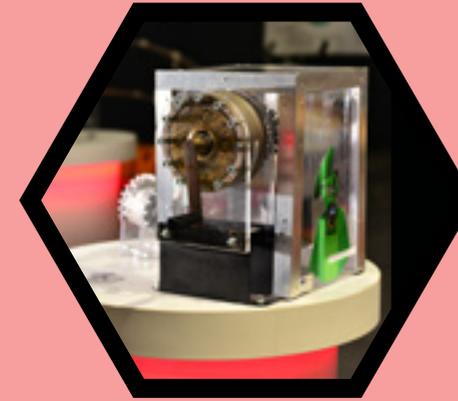
When you turn the crank, you try to transfer the force within creased torque depending on the pre-set gear ratio. You test the effect of gears on lifting loads which you can move without much effort.

What does the exhibit demonstrate?

The exhibit demonstrates the operation of the reduction gear – a type of gear that works with high precision. Such a reduction gear is used to transmit force in high-precision devices such as robots.

Do you know what a reduction gear is and what is it used for? Where can the reduction gear be used?

The reduction gear is used to change the speed of the output shaft, for example in cars.



A reduction gear is widely used in technical practice. Its accuracy is determined by the device in which it is intended for use. A reduction gear is used in mechanical engineering, it can be found in cars, bicycles, grass mowers, food processors and medical equipment.

09 WIND FROM THE BREATH

Did you manage to make the wind turbine rotate? How is it possible?

When you breathe into the anemometer, your breath simulates the wind and the energy of the flowing wind (breath) is converted into electrical energy. This causes the electric motor to rotate a wind turbine.

What is an anemometer?

An anemometer is a device for measuring the velocity of wind and it forms a part of every weather station. The anemometer exhibited in Aurelium has a measuring range of 0-30m/s.

What can you observe with this exhibit?

The exhibit allows you to follow the principle of a wind plant, which uses wind, i.e. air-flow to produce electricity.



10 HOW THE ENGINE WORKS

What does the exhibit demonstrate?

The exhibit demonstrates the operation of combustion engines by displaying cross-sections of their three models. It makes it possible to observe the mechanical movement of the rotating parts of the models and the operation of the valves of combustion engines, i.e. the mixture suction, ignition and gas explosion.

The heat engine obtains the energy for its operation by burning substances such as petrol, diesel oil or gas. Piston combustion engines make use of internal combustion. There are two types of piston internal combustion engines. What types can be distinguished depending on the principle of their operation? Can you name the phases of the principle of their function?

Piston internal combustion engines are two-stroke and four-stroke and most commonly use petrol or diesel as fuel.

The four-stroke engine has the following operating cycles: intake, compression, explosion, exhaust.



To complete all four strokes, the engine performs two revolutions. The two-stroke engine is designed so that two operating cycles are performed simultaneously: intake - compression, explosion - exhaust.

To complete the operating cycle (two strokes) the engine performs a single revolution.

Engines that burn a mixture of petrol and air are called ignition engines, because the fuel mixture is ignited by a spark from a spark plug.

In diesel engines, the piston compresses the air in the cylinder to reach a temperature of 850 - 1050°C, at which point the high-pressure pump injects diesel into the cylinder of the engine where the fuel ignites.

11 CURIE ENGINE

Why does a wire wheel spin under the action of a flame burning beneath it? What is the principle of this phenomenon?

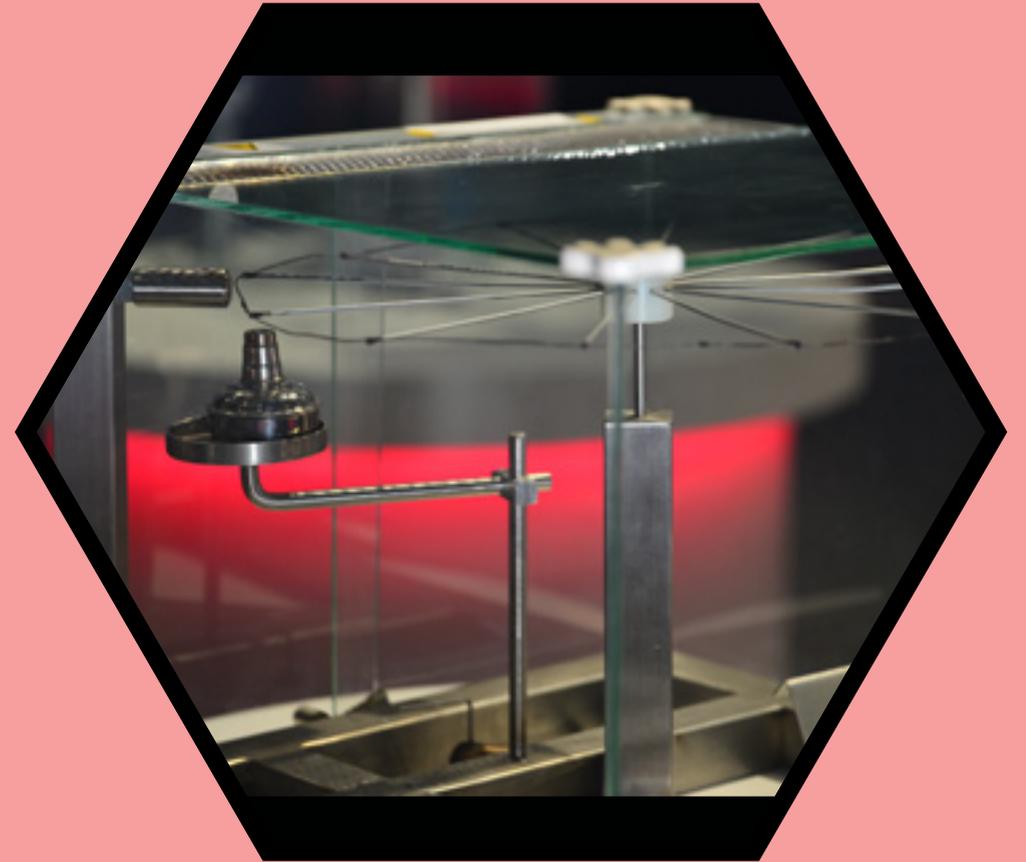
The metal from which the wire wheel is made loses its ferromagnetic properties at high temperatures. Hence, the magnet attracts the cooler part of the wheel's periphery, resulting in its circular motion.

What does this exhibit demonstrate?

This is a demonstration of the properties of ferromagnetic substances at Curie temperature. When this temperature is exceeded, the substance loses its ferromagnetic properties.

At what temperature does iron lose its magnetic properties?

Curie temperature for iron is 768°C .



12 SOLAR AIRCRAFTS

Did you manage to set the planes in motion? How is it possible?

The photovoltaic panel produces electricity which supplies an electric motor with a propeller, which subsequently sets the aircraft in motion. The number of revolutions depends on the amount of light hitting the photovoltaic cell.

What does the exhibit demonstrate? What can you see on it?

You can interact with the exhibit with the help of light from the spotlights that “start” the aircraft. This demonstrates the application of the principles and technologies used in a solar aircraft. Thus, in an entertaining way, you become familiar with the laws of physics associated with aviation.

How is it possible that a solar panel converts the energy of light into electricity? What is the principle of a solar panel?

26 A photovoltaic panel or solar panel works on the photoelectric effect



principle. Through it, light energy can be directly converted into electricity.

What is the principle of the photoelectric effect?

When a light or a photon of a certain wavelength collides with the semiconductor from which this solar panel is made, it repels electrons from atoms. Subsequently, the electrons, by moving to the respective electrodes, increase the conductivity of the substance and create an electric current.

13 DRONE

What can you influence by manipulating the joystick?

Moving the joystick affects the direction of flight and accelerates or decelerates the flight.

What does the exhibit demonstrate?

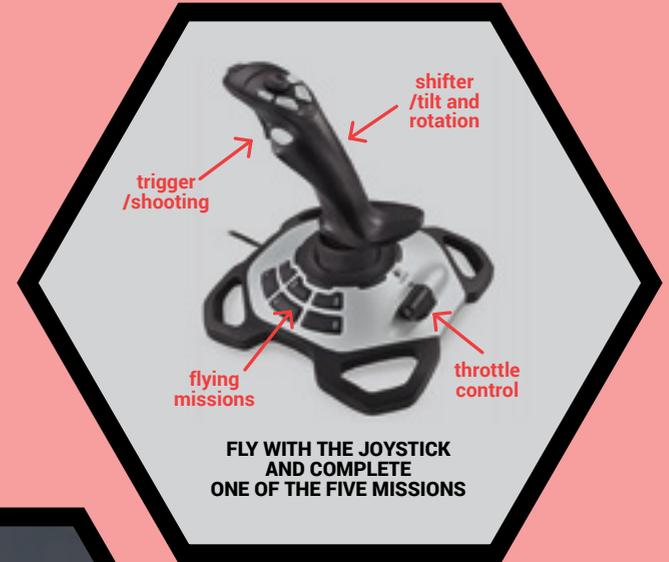
The exhibit demonstrates the use of technologies deployed in drones.

What is a pilotless aircraft?

A pilotless aircraft is a drone.

What is a flight simulator?

A flight simulator simulates the flight of a real aircraft, i.e. a drone in a virtual environment.



14 CAR SIMULATOR

Try controlling a car and driving in compliance with traffic regulations.

The average journey time per person is 7 minutes.



15 WHAT IS IT MADE OF?

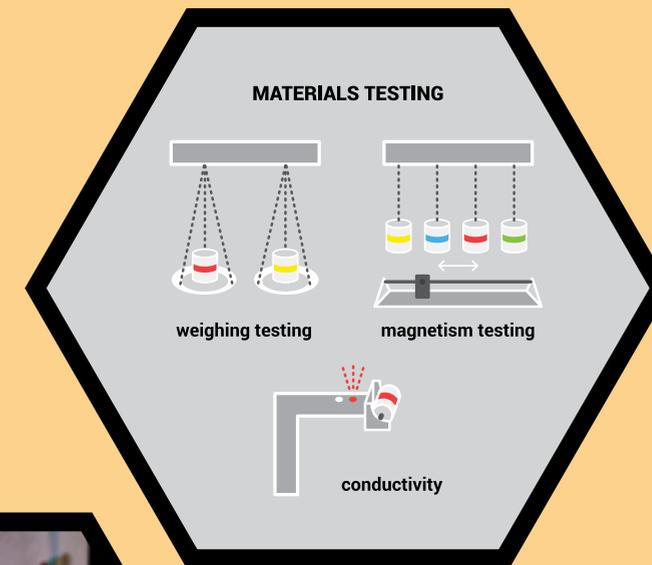
Find out what type of material is hidden in which cylinder.
Assign the following materials to each of the four colours: wood, iron, aluminium, and aluminium foam. Explore your observation of the physical properties of the cylinders.

What are the physical properties of each material: wood, iron, aluminium and aluminium foam? What colours are assigned to them?

Yellow – wood: not conductive or magnetic;
red – iron: both conductive and magnetic;
blue – aluminium: conductive and non-magnetic;
green – aluminium foam: conductive, non-magnetic;
and lighter than a piece of aluminium of the same volume.

Do you know what aluminium foam is?

32 You can find the answer in the Chemistry section.



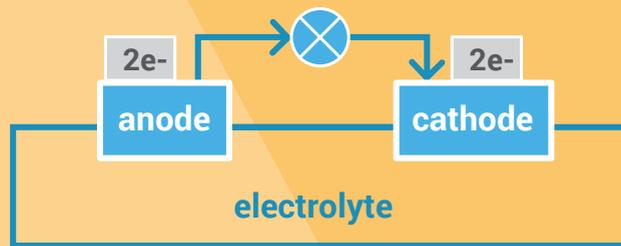
16 POTENTIAL OF METALS

How can you create an electric circuit by using your own body as an electrolyte?

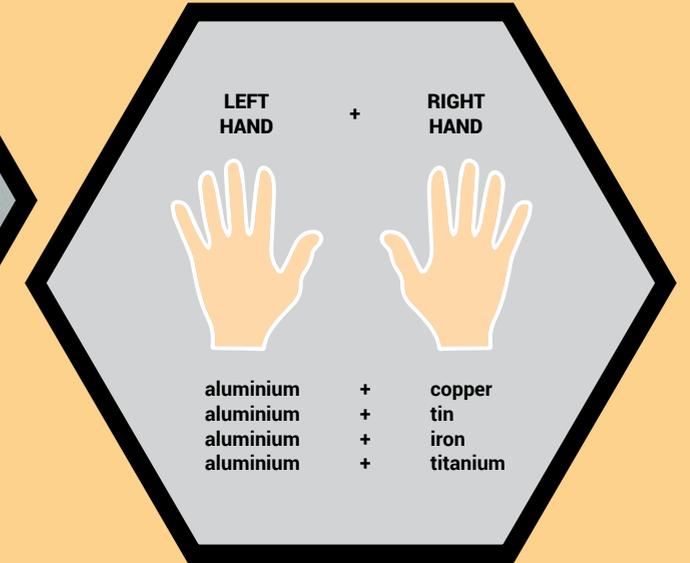
Do you know what an electrolyte is?

An electrolyte is a liquid whose electrical conductivity is caused by movement of its ions.

How does a battery work?



Why does the milliamp meter show different values after connecting different electrodes?



Electrochemical series of metal potentials - Beketov's metal displacement series:

Li, K, Ba, Sr, Ca, Na, Mg, Be, Al, Mn, Zn, Cr, Fe, Cd, Co, Ni, Sn, Pb, H, Cu, Ag, Hg, Au, Pt

Capacity to donate electrons

Capacity to gain electrons

The exhibit demonstrates the principle of potential difference on different electrodes.

The greater the distance between the metals in Beketov's series, the better the battery.

17 ELECTROMAGNETIC CANNON

Use the button to activate the magnet and note the reaction of the metal ring located on the tube.

What is happening?

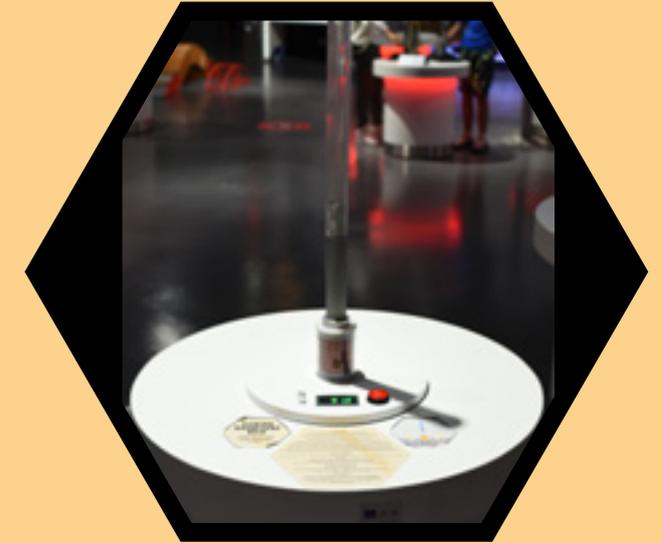
When you press the button, you initiate a current pulse. The ring is propelled upwards and stops at a certain height, depending on the magnitude of the charge relative to the gravitational force. Then the ring returns freely to its original position.

Why is the metal ring propelled? How is it possible?

The exhibit consists of a table base with a guide cylinder, on which a metal (aluminium) ring is placed and can move freely. At the bottom are two solenoids (coils) with a joint magnetic core. One of the solenoids is fed by a direct current and is hidden within the construction of the exhibit. When the current is introduced into the circuit with the solenoid, a magnetic field is induced in it, which is guided by the magnetic core through the metal ring. A rapid change in the magnetic field in the ring induces a current pulse which acts against the magnetic field of the coil. The coil and the ring then function for a moment as two magnets of opposite polarity, resulting in the upward propulsion of the ring.

What is a solenoid?

A solenoid is a type of coil, in this case in the form of an electromagnet, whose magnetic field can be controlled.



What does the height to which the metal ring is propelled depend on?

It depends on the charge level of the capacitor, i.e. on the magnitude of the electric charge that is stored in it.

What does the exhibit demonstrate?

The exhibit demonstrates Lenz's law and introduces the fundamentals of electromagnetic induction (as described by Faraday's law).

Lenz's law:

The law in physics describes the relationship between electric current and the change in magnetic induction flux. The electric current induced in a closed circuit by a changing magnetic field is such that the magnetic field created by the induced current opposes changes in the initial magnetic field.

18 LEVITATION

If the UFO is aloft, take a close look at it.

How is this phenomenon possible?

If the UFO is placed on a table, try to place it in a space just above the centre of the table.

CAUTION: Do not place your mobile phones on the table!

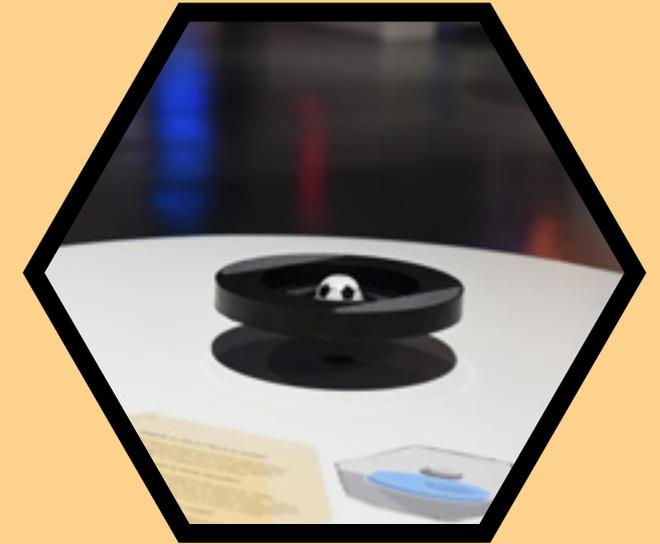
There is a risk of damage to the device.

Did you succeed? How is it possible?

Levitation of the UFO works on the principle of magnetic forces of the structure in the centre of the table. The structure consists of an electromagnet with a magnetic field sensor and a permanent magnet, which is concealed in the UFO.

What can you observe in this exhibit?

The exhibit demonstrates the fundamentals of electromagnetic induction. Due to the non-stationary magnetic field, an induced electric



field is generated - electromagnetic induction. It also demonstrates the superposition of forces, when a gravitational force and magnetic repulsive force act on the UFO at the same time. The gravitational force acts in a downward direction, the magnetic force upwards. At the appropriate position, the sum of these forces is zero and the UFO hovers.

Where is it possible to use magnetic levitation in practice?

High-speed trains use maglev technology (magnetic levitation) to hover a few millimetres above the track in order to minimise friction. This type of train is able to reach speeds of up to 600km/h.

19 VAN DE GRAEFF GENERATOR

Can you generate static electricity?

Is this exhibit dangerous? Can static electricity hurt you?

No, it will not hurt you. The resulting discharge can make you feel uncomfortable. If you are wondering if the globe is charged (or not), you had better ask the instructor.

Option 1: Turn the crank and charge the globe with static electricity. The charge is manifested by the lifting of hair in the upper part of the globe. If you approach a charged globe with a grounded striker, an electrostatic discharge will occur, accompanied by a sound and light effect.

Option 2: Take a striker and touch the globe to discharge it. Then touch the discharged globe with your hand. Turn the crank to charge the globe (static electricity) and notice how the electrostatic charge is transferred onto you. This can cause the hair on your head to stand on end or can generate sparks.

What is the name of the exhibit and what does it demonstrate?

The exhibit consists of a Van de Graaff generator, which demonstrates the generation of static electricity and the effects of electricity.

When you turn the outer crank on the belt pulley, you drive the moving non-conductive belt in the column. By rubbing you create an electrostatic charge and transfer it to the surface of the metal globe located at the top end of the column.



If you bring a grounded striker closer to a charged globe, you cause an electrostatic discharge.

If you touch a charged metal globe with your hand, the charge will be transferred to your body and can also cause a discharge.

What is static electricity?

Static electricity is a phenomenon that arises when an electric charge accumulates on the surface of a body. When such a body approaches or comes into contact with another body, an electrostatic discharge is generated.

An electric charge is generated by the friction of two materials which consist of atoms. Each material consists of atoms that can contain free electrons. During friction, these electrons pass from one atom to another.

20 MAGNETIC FIELD LINES

Can you see the magnetic field?

Press the button to activate the magnetic field. Turn the button and adjust the magnitude of the magnetic induction (and thus the intensity) of the activated field.

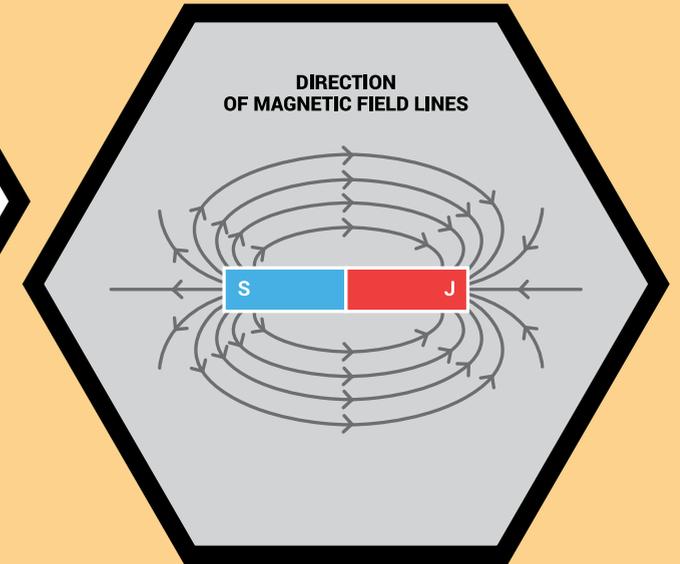
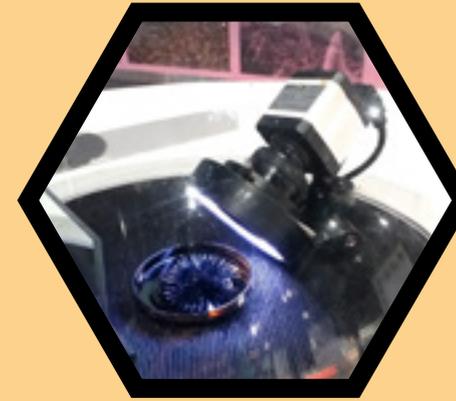
Observe what is happening in the liquid.

What happens to the liquid? Is the liquid just water?

The liquid moves according to the orientation of the magnetic field lines, which show the direction in which the magnetic field force acts. The magnetic liquid contains iron nanoparticles which, in the magnetic field, try to adapt to the magnetic field lines. You can move the liquid by changing the intensity of the magnetic field. The effect is also multiplied by the interaction between the iron objects in the liquid.

What happens when the intensity of the generated magnetic field is regulated?

By rotating the button, a so-called potentiometer, you can regulate the intensity of the magnetic field, and thus the degree of force effects on the magnetic liquid. A potentiometer is a voltage divider that reduces the voltage in an electric circuit.



What does this exhibit demonstrate?

The exhibit demonstrates the basic phenomena of electromagnetism by visualising magnetic field lines in a magnetic liquid.

What is a magnetic field and how is it possible that you can see it?

Magnets or iron ore can attract iron objects and other substances of the same ability. A magnetic field is generated around such substances. A stationary magnetic field is a physical field whose properties do not change over time. Its source can be a permanent magnet or a so-called electromagnet, i.e. a stationary conductor through which a constant electric current passes. The field of a permanent magnet is created by the movement of charges inside atoms. Magnetic field lines are used to represent the magnetic field. You can see them in the exhibit thanks to the iron particles in the liquid that react to these magnetic field lines.

21 ELECTROMAGNETIC SMOG

Try to measure the intensity of the electromagnetic field generated by the available devices.

Instructions: Start the exhibit by pressing the green button. Each button represents one electrical device, which switches on for a certain time. Move the instrument for measuring the electromagnetic field of the devices that are activated. Move the measuring instrument over the devices to measure electromagnetic smog. Observe the measured values on the screen.

What is electromagnetic smog or an electromagnetic field?

Electromagnetic fields can have natural or artificial origins. Electromagnetic smog or electrosmog does not occur naturally.

Electrical devices generate an electromagnetic field that causes electromagnetic smog, so-called electrosmog. You cannot see it with the naked eye, but you can detect it with a special detector that measures its magnitude.

In the electromagnetic field, one observes the simultaneous action of the effects of the electric and magnetic forces in the space investigated.



The magnetic field is generated by the movement of an electric charge. An electric current generates a magnetic field. A voltage is induced in the conductor that moves in the magnetic field, and the conductor through which the current passes can move in the magnetic field because a certain force acts on it.

Are they dangerous to the environment and man?

Sources of electromagnetic pollution are various electrical appliances, communication transmitters, motors or electric current. The electromagnetic field can operate at various frequencies which act on the surroundings to different degrees. In order to minimise the risk of its negative effects, standards have been introduced that manufactured appliances must meet.

22 INTERCOM

– TRANSFER OF INFORMATION

How is the signal with image information transmitted? How does this simple telegraph work? How is the signal carrying the audio information transmitted so that the parties involved can communicate with each other?

Send a message using Morse code by pressing the telegraph key. Use the alphabet table as a guide. In Morse code, a dot means a short signal and a dash means a long signal. Try using Morse code and the telegraph key to record the word "AURELIUM".

What does the exhibit demonstrate?

The exhibit demonstrates the development of communication technology. The communication technologies are also compared through their different communication methods.

What communication methods and technologies does this exhibit present?

The exhibit makes possible the transmission of various forms of signal, such as sound or images, which are propagated through an electric cable or laser beam. It demonstrates the contactless transmission of information through the environment and the contact transmission of information via an electrical conductor.

What is Morse code?

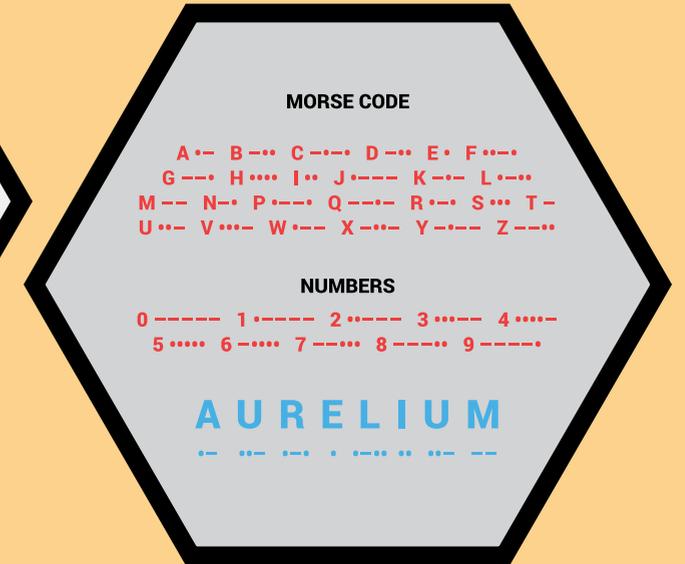
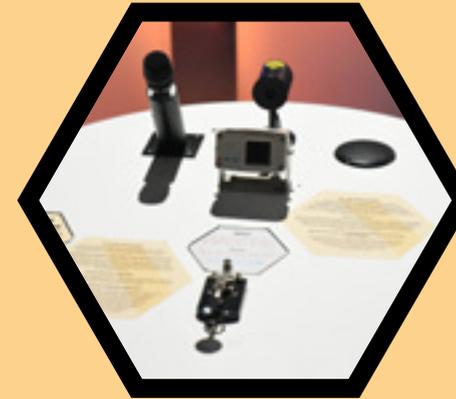
It is a system of telegraphic signals that correspond to letters, numbers and other characters. In graphic design, it is a system of dots and dashes. A dot represents a short signal and a dash represents a long signal.

What is the application of Morse code today?

Morse code is used in crisis situations where it is not possible to use the usual methods of communication. In addition to graphic design, Morse code can take the form of sound or light signals.

What is the name of the device you use to send messages in Morse code?

The device is called a telegraph. It is a simple electrical device for data transmission via electrical pulses. A message sent via a telegraph is called a telegraphic message.



How does a telegraph work?

A single telegraph consists of a telegraph key or a switch on the transmitting side, and a coil with a moveable magnet on the receiving side. It further consists of a pair of conductors connecting the receiving and transmitting sides and also a power supply. When the key is pressed, the electric circuit closes and the passing current generates an induced magnetic field in the coil which deflects the magnet.

What is InterCom?

InterCom is a device that is used to directly send and receive information between communicating parties over a short distance. The device consists of a transmitting station and a receiving station, which can be connected by wires or wirelessly.

InterCom in practice: doorbell with telephone, sometimes with a camera and remote door opening; security camera system; radio transmitter; headset.

What type of InterCom is demonstrated by the laser beam exhibit and how does it work?

In this case, it is an example of a device communicating via air. The transmitter transmits information from the camera via a laser beam that is received by the sensor on the opposite side. It thus receives information about the image, which it displays on the screen on the receiver's side.

23 HEADLAMP ANATOMY

Switch between different types of lights and observe how the beam of light changes on the opposite wall.

Instructions: SWITCH THE EXHIBIT ON BY PRESSING THE GREEN BUTTON -> PRESS THE LIGHT MODE WHEN THE MOTOR IS ON -> SWITCH BETWEEN VARIOUS LIGHTING TYPES -> OBSERVE THE WHITE SURFACE ON THE WALL

Have you ever noticed different scattering of propagating light? If not, you can observe it now on the white area on the wall opposite the headlamp.

Tip: If you want to set the lights on your car correctly, align the car against a pale single-coloured wall and let the lights shine on it during adjustment. Do not forget to observe the reflection of the adjusted lights and its scattering on the wall.

What is a headlamp?

The headlamp and rear lamps form a complex assembly of lights in vehicles, located in their front and rear parts.



What does the exhibit demonstrate?

The functional exposed car headlamp demonstrates the use of mechatronic and electronic components as an integral part of modern automotive light sources.

What can you see?

The partially exposed headlamp allows you to see what is normally not visible, hidden beneath the car bonnet. You see what the headlamp is composed of and how its mechatronic and optical components work. These mechatronic and optical systems respond and function according to your stimulus, thanks to your switching between different types of lighting designed to serve different purposes.

24 SPECTROSCOPY

Can you decompose the light beam? Turn the prism towards one of the light sources and observe what happens on the screen. **What can we see?**

What did you see?

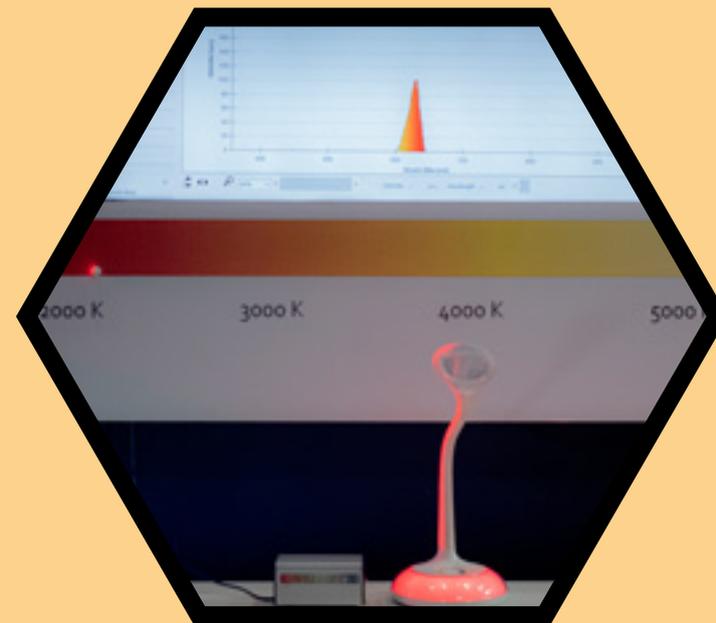
When turning the prism towards one of the light sources, you direct the light beam into the spectrometer which is able to decompose the light beam. You can then see the real-time image from the camera on the screen and a graph of the intensity of light versus the wavelength of light. As a result, you can see the spectral characteristics of the various light sources on the screen.

What does the on-screen graph demonstrate?

The graph on the screen demonstrates the optical spectrum of different light sources, i.e. the relationship between colour and wavelength of light.

Why does the graph change when the prism is turned relative to each light source?

If you turn the prism towards the white bulb, you see the spectrum of the white light, which is similar to a rainbow. If an LED light passes through the prism, you observe its dispersion into the individual primary colours of this light source. The monochromatic laser light does not decompose when passing through the prism. Light sources such as light bulbs, fluorescent lamps, LEDs or lasers



have different properties, such as colour and wavelength of light, which are manifested by their different optical spectra shown in the graph.

How is it possible that you can decompose the light beam and determine its spectrum?

Using a Hartl disc and a prism, direct the beam of light from a light bulb, laser or LED, whose colour changes automatically, into the input slot of the spectrometer. When light passes through an optical prism, it decomposes into a spectrum. You can determine the light spectrum using a spectrometer. The spectrometer is equipped with elements which enable it to accurately measure the visible part of the light spectrum from 360 nm to 940 nm with sufficient sensitivity.

25 THERMAL-IMAGING CAMERA

Can you find out the temperature on the surface of your body?

Stand in front of the screen so that you can see your body as captured by the thermal-imaging camera. Assign a temperature in °C (degrees Celsius) to the colours you see on the screen. You can use the colour scale displayed on the information panel.

Did you manage to make an image of your body? Did you see your body on the screen? If so, what temperatures were associated with your body?

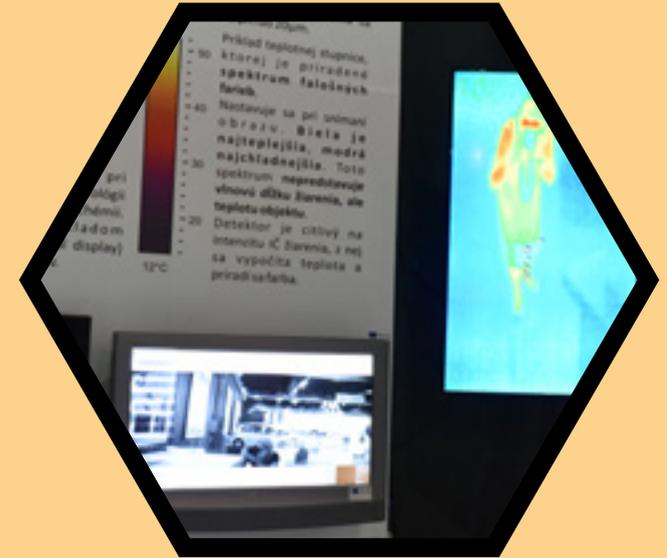
The temperature is determined by the colour scale on the information panel.

Use the thermal-imaging camera to capture your palms and note their colour on the screen. What happens if you rub your palms together then let them be captured with a thermal camera again?

When you rub your palms together, their temperature is increased by friction. You can prove this on the screen where you can see how their colour changes. You can determine the temperature using the colour scale.

What is the principle of the thermal-imaging camera?

The thermal camera works on the principle of thermal imaging. This means that the camera creates an image using thermography, recording infrared radiation. Infrared radiation has a wavelength in the range from 780 nanometers (nm)



to 1 millimeter (mm). Infrared radiation is adjacent to the visible light spectrum, so sometimes the term “infrared light” is used.

How do the operating principles of a thermal-imaging camera differ from those of a conventional camera?

The thermal-imaging camera detects infrared radiation, which has a wavelength in the range from 780nm to 1mm. A conventional camera captures the visible spectrum of light, i.e. wavelengths in the range from approximately 400 nm to 700 nm.

How are thermal-imaging cameras used in technical practice?

Thermal cameras are used to enable night vision, for detection of energy leaks, quarantine monitoring, production quality control, monitoring of premises and buildings, analysis of the technical condition of components and walls and roofs.

26 MICROSCOPY

**Do you know what a scanning probe microscope is?
Have you ever encountered a microscope of this type in practice?**

A real scanning probe microscope is a very expensive instrument. What is presented here is its three-dimensional (3D) model and a functioning model of its principle. The poster above the exhibit contains information detailing the operation of this type of microscope.

What is a probe microscope? What is it used for and where?

A scanning probe microscope is a scanning instrument that is designed to determine the structure of a surface with nanometric resolution perpendicularly to the surface. In addition to topography, it is possible to use it to measure the local physico-chemical properties of a given surface. This microscope is designed mainly for the characterisation of materials at the atomic level and to supplement the electron microscope. The probe microscope is used in mechanical engineering, materials research, measuring technology, or in quality control.

What is an electron microscope?

You can read about the electron microscope in the information panel above the exhibit.



What is a microscope in its commonest meaning?

A microscope is used to optically magnify small objects so that their details, otherwise invisible to the naked eye, can be discerned.

What microscopes do you recognise?

There are: optical microscope, electron microscope and scanning probe microscope. The optical microscope can be found in the Human and Ecology section.

27 HOLOGRAMS

What happens to the images when you move in front of them while you observe them? Observe holographic images from different angles and note what happens to them.

What was happening to the images? How is it possible?

The images were spatial, thanks to the way in which they were illuminated. If the angle at which the images are illuminated is the same as the angle of the beam of light in the course of recording the images, this leads to an optical illusion of their being spatial. The images change depending on the angle from which the viewer observes them.

What is a holographic image?

A holographic image or hologram is a three-dimensional image that is generated by holography. The holographic image is an advanced form of a photograph.

What is holography?

Holography is a technique for the generation of holograms. The image of an object is recorded by continuous illumination and by light waves reflected from the object.



What does the exhibit demonstrate?

The exhibit demonstrates a three-dimensional image of the object recorded in the hologram. Demonstration of this phenomenon of three-dimensional image is possible due to the diffraction of light (reconstruction beam), i.e. due to the bending of light waves when passing around an obstacle. When illuminating a hologram, it is important that the light falling onto it has the same angle of incidence as the (reference beam) light during recording. Simply put, only those beams of light that correspond to the beams of light reflected from the recorded object pass through the hologram, resulting in an apparent spatial image.

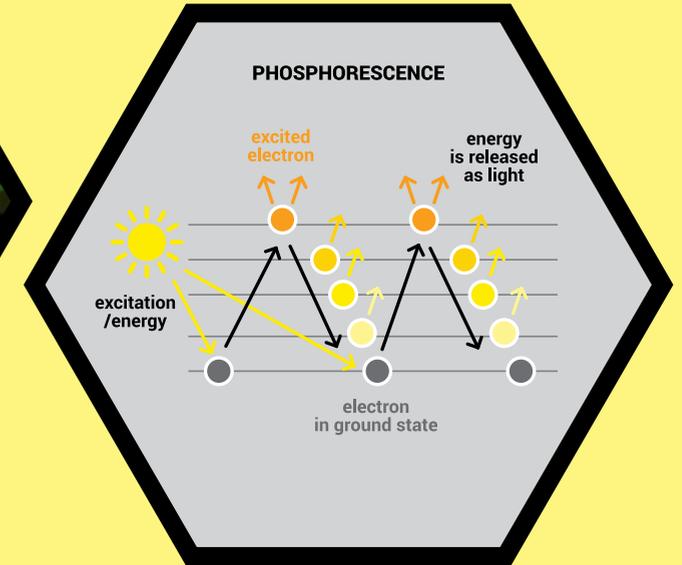
28 DRAWING BY LIGHT

How is it possible that you can use a light that leaves a trace on the board? Why does the light trace gradually disappear?

An effect called phosphorescence is used to deploy the light for drawing.

Phosphorescence belongs to the group of phenomena called luminescence. This includes all those phenomena in which a substance emits radiation upon the action of light. A characteristic feature of phosphorescence is that a substance irradiated by light emits light for a certain period of time even after the illumination stops.

By illuminating the substance, excitation occurs. This causes the electrons in atoms of the substance to absorb the radiation and hence achieve a higher energy level. The subsequent emission of energy in the form of light of a certain wavelength is caused by electrons returning from a higher energy level to a lower energy level.



**What happens if the source of light is close to the board?
What happens if you move the source of light away from the board?**

When the distance between the source of light and the board is short, the light strikes directly on the surface of the board and the trace the light leaves is very clear. Conversely, if you move the light source away, the light will scatter. It does not fall on the board and leaves no luminescent trace.

29 GEOMETRICAL OPTICS

What types of lenses are known?

Do you know how lenses affect the propagation of light?

A concave lens causes the parallel beam that passes through it to scatter. Concave lenses can be biconcave, plano-concave, negative meniscus.

A convex lens causes the parallel beam that passes through it to converge to a spot, the so-called focus. Convex lenses can be biconvex, plano-convex, positive meniscus.

Have you managed to create at least one optical system?

Did you manage to correct defects of vision? How can myopia or hyperopia be corrected?

Nearsightedness (myopia) is a condition when vision at a distance is impaired. The cause is the lens of the eye, which creates a sharp image of the object in front of the retina and the image on the retina is blurred. This can be corrected with concave lenses or concave contact lenses.



The concave lens adjusts the path of the rays so that a sharp image is created on the retina.

Farsightedness (hyperopia) means impaired vision over short distances. The sharp image of the object is created behind the retina instead of on it. This vision defect can be eliminated by spectacles with convex lenses or convex contact lenses. The convex lens shortens the path of a beam of light so that a sharp image is created on the retina.

What does the exhibit demonstrate?

The exhibit demonstrates the principles of basic optical systems, which are: Galileo's telescope, Kepler's telescope, mirror camera and eye, as well as the principles of correction of eye defects, myopia and far-sightedness.

30 GENERATOR OF LIGHT

Use the sliding switches to adjust the desired colourshade on the RGB display. You can further adjust the colour by placing different filters in front of the light source. Use the remaining switches to control various light sources such as discharge lamps, fluorescent tubes and neon lights. You can investigate any of the available lights using the paper spectroscope.

What can you observe in this exhibit?

The exhibit demonstrates the basic properties of light in a simple way. Almost any shade of colour can be created on the RGB display using red, green and blue LEDs and a diffuser. By using filters of different colours, we can try colour mixing in practice. The diffuser demonstrates light scattering. We can also experiment with light absorption and diffraction (bending). Using a simple paper spectroscope, we are able to analyse the light emitted from various sources.

What is an RGB display?

In this case, it is a system of thirty-six light-emitting diodes, so-called LEDs. Three basic colour components are represented: red (Red = R), green (Green = G) and blue (Blue = B). Each of the LEDs can change the light intensity from off to maximum. By combining lights of different intensities one can mix white light (the lights emitted by all LEDs are of the same intensity), and also “black” – all LEDs are switched off. If you want to display yellow, for example, adjust the same intensity of green and red LEDs and leave the blue off. By increasing the intensity of the green LEDs, the colour shifts more to green; the same pertains for the red which shifts more toward the red. If light from the blue LEDs is gradually added to the yellow, it gradually fades and turns white. This is also the basic procedure in additive colour mixing.

What is subtractive colour mixing?

Here the process is the opposite: perceptions of the colours are blocked with the help of filters. These are represented in the exhibit by translucent coloured plates. Take, for example, the red plate and place it on the RGB display that has mixed white light. White turns to red and notice



that the lights of the blue and green LEDs have “gone out”. This is because the red filter blocks all colours as we perceive them except for red. Try other colour filters in a similar way. There is also a multi-coloured plate, a CMYK filter. It consists of cyan (C), magenta (M) and yellow (Y). When these are mixed at the same ratio, black (K) is produced. Note that the basic RGB colours are obtained by mixing the following: magenta + yellow = red; yellow + cyan = green; cyan + magenta = blue.

How and where do these phenomena apply in practice?

We encounter **additive** colour mixing when we want to achieve a strong light sensation on a dark background. The addition of colours makes the resulting colour brighter. For example, screens and displays where red, green and blue lights of different intensities are combined can produce any colour shade. Black is actually achieved when colour elements are extinguished; white is achieved by mixing light of the maximum intensity and shades of grey by gradual attenuation. **Subtractive** colour mixing is used when a strong dark colour perception on a pale background is to be achieved. Subtracting the colours makes the result darker. For example, in colour inkjet printing on office paper, where layers of colours are gradually applied to block white light that would reflect from a clean paper. Nothing is applied in order to achieve the white colour and the black colour is achieved by a combination of all the CMYK colours. However, this combination is not perfect and the result is more like grey, so printers make use of a separate cartridge filled with black ink, which is mainly used for printing texts.

31 SPECTROSCOPY

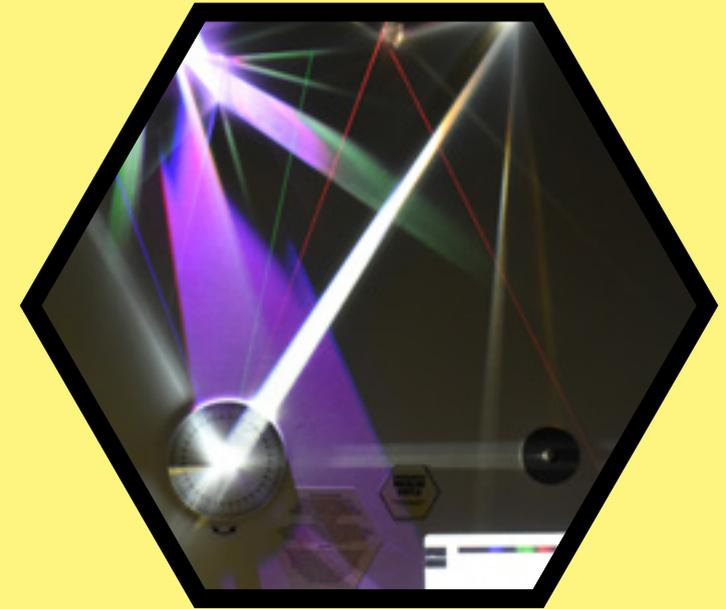
– DECOMPOSITION OF LIGHT

What could you observe?

If you rotate the optical prism against one of the light sources so that the beam is directed towards the spectroscope connected to the monitor, the light beam will be decomposed in the spectroscope and the spectrum will be displayed on the monitor. You can examine all the light sources in such a way. The beam of visible light is displayed in real-time as a range of colours from violet to red. You can also observe the intensity of the light depending on the wavelength.

What do you see on the monitor?

You can see the spectral characteristics of different light sources. Monochromatic light cannot be decomposed any further. The optical spectrum of light displayed from different light sources shows the relationship between the colour of light and its wavelength. Light sources such as light bulbs, fluorescent lights, LEDs or lasers have different properties. This is demonstrated by their different spectra in the graph on the screen. It shows the intensity of the individual components of the spectrum. This spectrometer is able to display light wave lengths from 360 nanometers to 940 nanometers (nm) with sufficient sensitivity.



Of interest:

We are surrounded by electromagnetic waves of a very wide range of wavelengths. The human eye, however, can only sense a narrow band of waves of wavelengths from 350 to 750 nm, hence its name: visible light. The light of the shortest wavelength but also the highest frequency is violet (from 380 to 430 nm). With increasing wavelengths and decreasing frequency, violet is followed by blue (430 to 500 nm), cyan (500 to 520 nm), green (520 to 565 nm), yellow (565 to 590 nm), orange (590 to 625 nm) and red (625 to 740 nm). The human eye is most sensitive to wavelengths around 555 nm (green). Visible light is, therefore, a polychromatic light and can be decomposed into individual colours using an optical prism or a diffraction grating.

32 INTERFEROMETRY

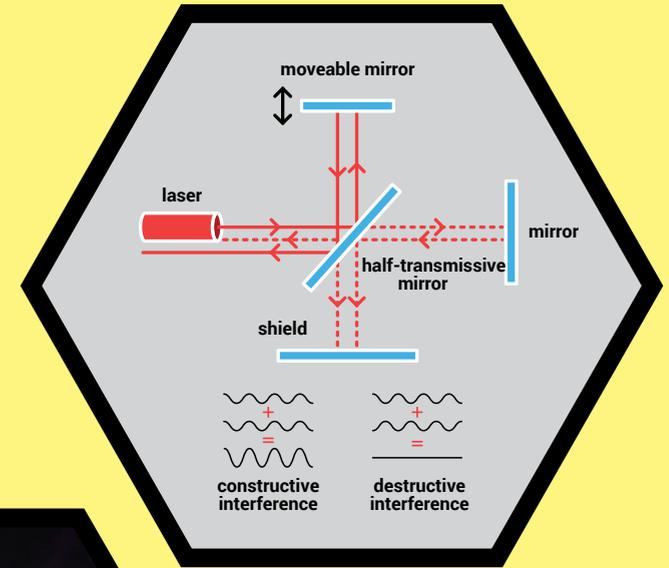
What is interferometry?

Interferometry is a technique that uses the superposition of electromagnetic waves to obtain information about these waves.

What is an interferometer, what does it consist of and how does it work?

The picture displays the components of the Michelson interferometer.

The light beam from the source of light is split into two equal beams, which are then reflected on the mirrors and recombined by passing through a semi-transmissive plate.

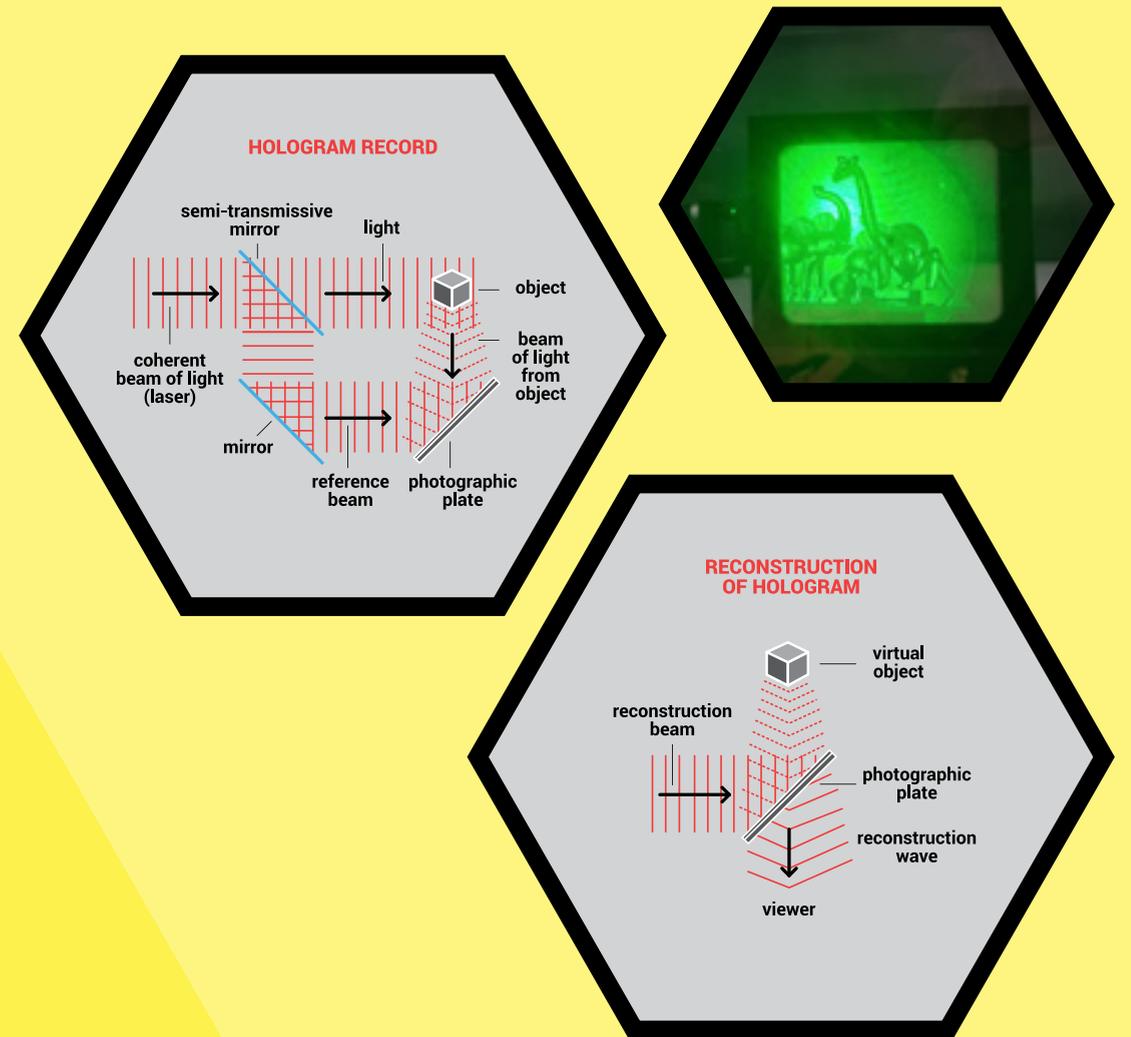


33 HOLOGRAPHY

What is holography?

Holography provides an actual reconstruction of three-dimensional (3D) objects.

The principle of holography consists in the diffraction (i.e. change in the direction of propagation of light caused by an obstacle) and the interference of light waves (i.e. in the superposition of several continuous waves into one), which are carriers of optical information about the object displayed. The part of the light emitted directly by the light source interferes with the light reflected from the object. When they hit a photographic plate, they together form a diffraction pattern called a hologram. When this pattern is illuminated with coherent light, the beams of light are reconstructed to form the same image as if there was a real object behind the hologram.



34 LASER PROJECTION IN THE AQUARIUM

What does the exhibit demonstrate?

The exhibit demonstrates the phenomenon of the reflection and refraction of light that passes through different environments. The laser beams from the outside pass into an aquarium filled with water which represents an obstacle. The phenomena of reflection and refraction of laser beams create interesting light effects.



35 PROPAGATION OF LIGHT IN WATER

What can you observe in the aquarium?

You can observe an optical system based on the principles of geometrical optics and the phenomena of refraction and reflection of light.

What does the exhibit demonstrate?

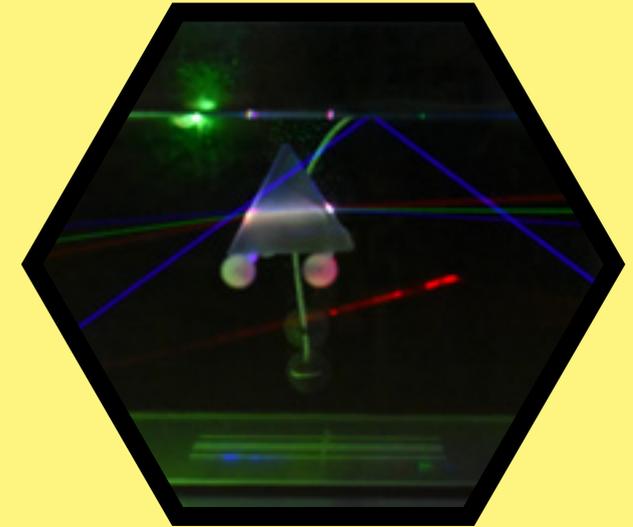
The exhibit demonstrates the passage of light through a liquid and the reflection and refraction of light.

Why are the paths of the propagating light of the laser beams different?

How is it possible?

The blue laser beam passes through the liquid at a certain angle, falls on the water - air optical interface, from which the laser beam is reflected back into the liquid (the angle of incidence is equal to the angle of reflection).

The green laser beam passes through the optical fibre. The optical fibre consists of a cylindrical core with a diameter of several units to tens of micrometres (μm) and is made of a material of a certain refractive index. The core is covered with a sheath of material with a lower refractive index. The light propagates through the fibre via a series of total reflections from the core-sheath interface along the entire length of the fibre.



The red laser beam is reflected from the sidewall of the aquarium (from the water-glass optical interface) and continues through the liquid at the same angle as fallen on the aquarium wall (measured relative to the perpendicular to the interface).

A beam of three laser beams (red, green and blue), each of a different colour and hence of a different wavelength, falls on the optical triangular prism. The rays enter the prism through the water-glass optical interface and exit the prism through the glass - water optical interface. As the rays pass into an environment with a different refractive index, they are refracted depending on the wavelength (colour) of the individual rays (red is the least refracted).

Of interest:

If a beam at a certain angle of incidence is not refracted on the optical interface, this is called a total reflection.

36 3D DISPLAY

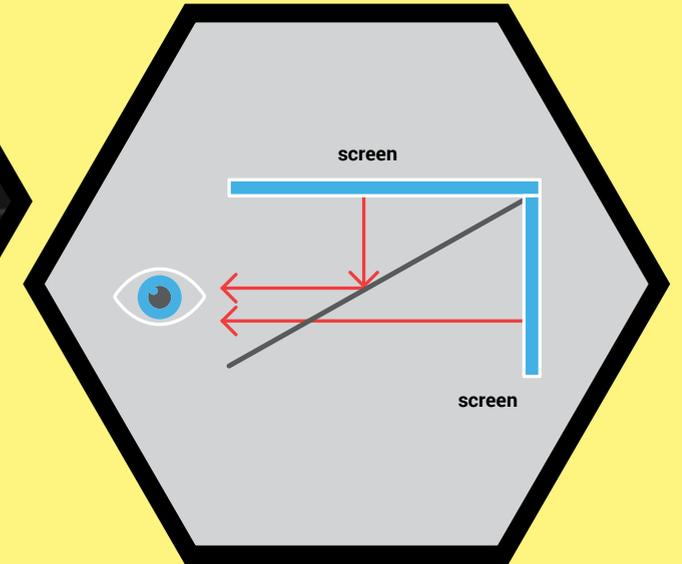
Watch the 3D computer animation of the principle of operation of a Spinea-made high-precision reduction gear. Spinea is a Slovak manufacturer and supplier of gearing components.

How is it possible that you see animation in space?

You can see the animation from the top screen in space thanks to a combination of two independent perceptions of light: one is created by reflection from a semi-transmissive mirror and the other is created by passing light from a screen in the background through the same area of the semi-transmissive mirror.

Where is such a space-projection of an image used in practice?

Reading devices in front of the camera (teleprompter) work on this principle. Thanks to such a device, a person is able to look at the camera, which captures him/her and at the same time read the text. The semi-transmissive mirror is also the basis of the head-up display. They are deployed in modern vehicles and fighter aircraft.



What does the exhibit demonstrate?

The exhibit shows the operation of the reduction gear, a device manufactured with high precision. Such a reduction gear is used to transmit mechanical energy in equipment that must be very precise. The reduction gear finds its application, e.g. in robots or transportation systems.

For more information on the reduction gear, see the Transmission exhibit.

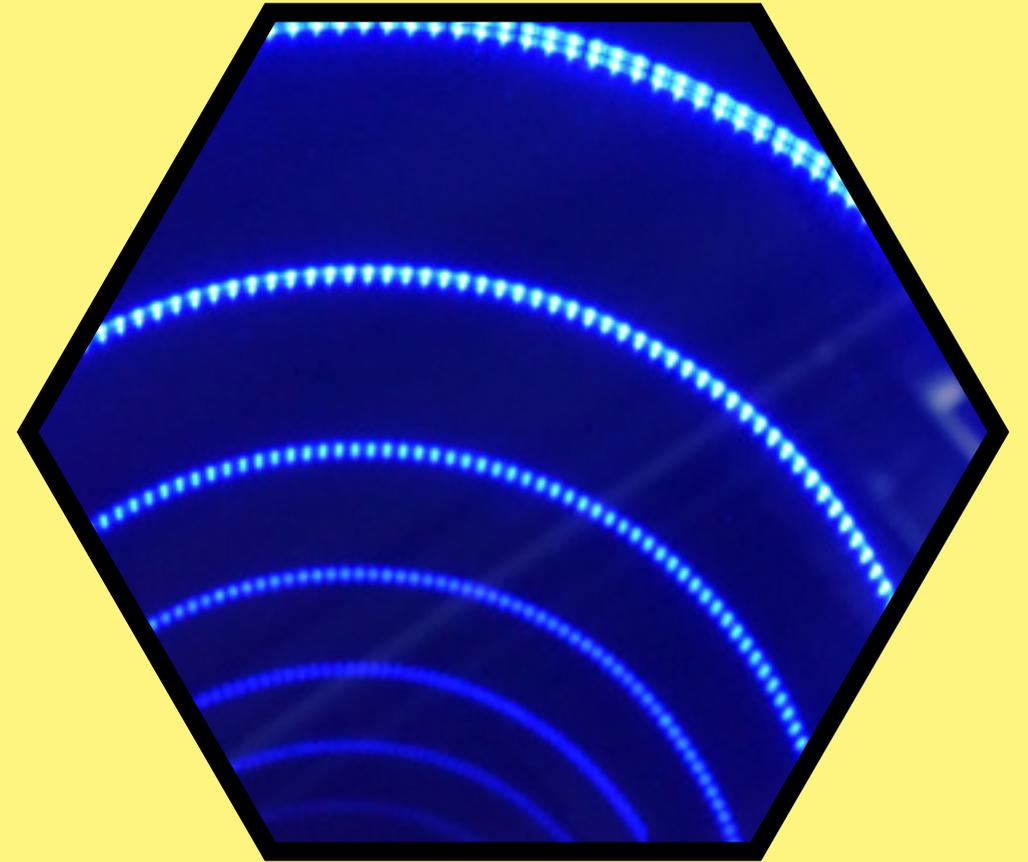
37 INFINITY WELL

Do you know that you are observing an optical illusion?

When you lean over the glass of the “well” and look inside it, you appear to be looking into deep space. However, this is an optical illusion.

How is it possible?

The exhibit consists of a set of mirrors mounted in a cylindrical metal structure. The upper mirror is made of semi-transparent glass and the lower mirror has 90% reflectivity. LED lights were used as light sources which give the impression of infinite space. You can see the optical illusion thanks to the multiple reflections of light on the mirror surfaces.



38 GHOST

Can you see the changing image of the “ghost”?

Stand in front of the exhibit and observe the interior of the installation of the black environment in the direction towards the passage without the curtain. Then go to the aperture on the opposite side of the exhibit and observe the interior from there.

What did you notice and find out?

An image of a “ghost” that is visible on one side and not on the other.

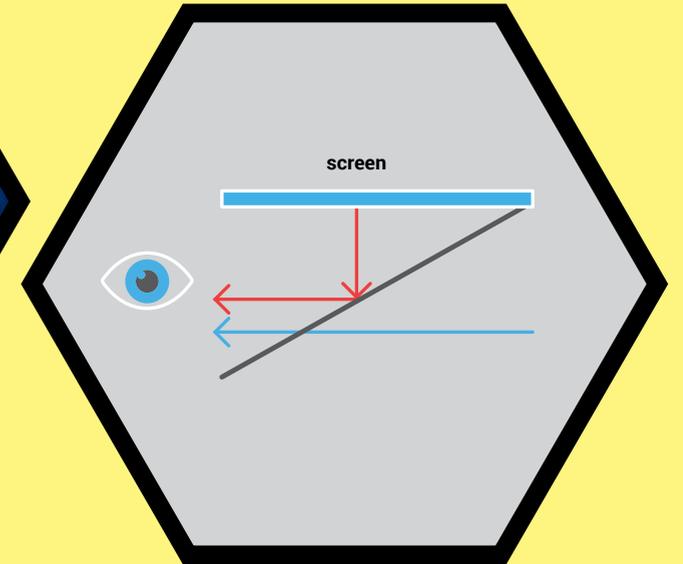
What does the exhibit demonstrate?

By the example of the optical illusion of the “ghost”, the exhibit demonstrates the optical illusion created by the semi-transmissive mirror.

What is a semi-transmissive mirror? How is it possible that it can create such an optical illusion?

It is a one-way mirror that reflects about half of the light and transmits the other half. It is a sheet of glass covered with a thin layer of metal that transmits part of the light to both sides. Since this mirror is located in a dark space, you can see through it as if through the transparent glass.

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The optical illusion in the space created by the semi-transmissive mirror is the result of the reflection of a light image of the “ghost” from the source screen at the top of the exhibit. This effect is caused by the appropriate slope of the mirror. You can only see the “ghost” effect when you look through the mirror from a certain side.

Why do you see the illusion from one side and not from the other?

To see the illusion, you must look through the semi-transmissive mirror at the right angle. In order to see the illusion from the opposite side, you would have to look through a semi-transmissive mirror in the same position as when you saw the “ghost”. This means that you can see the image only when this mirror is tilted to a certain angle relative to the source screen and relative to you.

79

39 MICROSCOPE

What is a microscope?

A microscope is an optical instrument used to optically magnify small objects to reveal details invisible to the naked eye.

What types of microscopes are in front of you?

Optical microscopes are at your disposal.

Are you familiar with other types of microscopes?

In addition to optical microscopes, there are also electron and scanning probe microscopes.

More information on electron and probe microscopes can be found in the section on Electromagnetism.



40 WIND POWER PLANT

What can be observed on the exhibit?

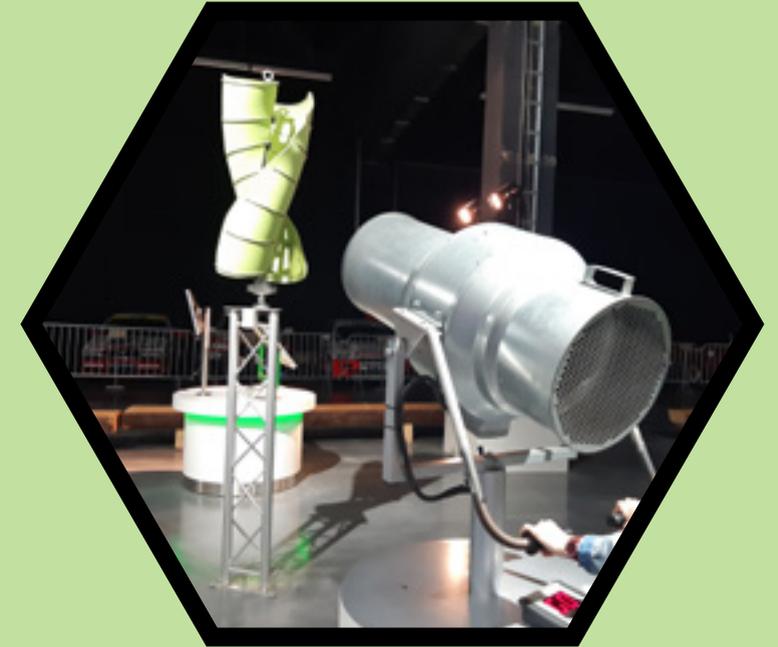
You can observe how the power of the turbine is changed depending on the direction and the intensity of the airflow from the cannon, which you can control with the control element.

What does the exhibit demonstrate?

The exhibit demonstrates the operation of a wind power plant and the production of electricity from wind as one of the renewable energy sources.

What is a wind power plant?

A wind power plant is a device that converts kinetic energy of the wind into mechanical energy, which then produces electricity in a generator. In the past, people first used the energy of the wind



in windmills, which had a low efficiency. At present, a wind turbine is used to convert wind energy.

Several types of turbines have been designed, classified into two basic types. In the first type, the axis of rotation of the turbine is horizontal and in the second it is vertical. This exhibit represents a turbine with a vertical axis of rotation.

41 SOLAR ENERGY

What does this exhibit demonstrate?

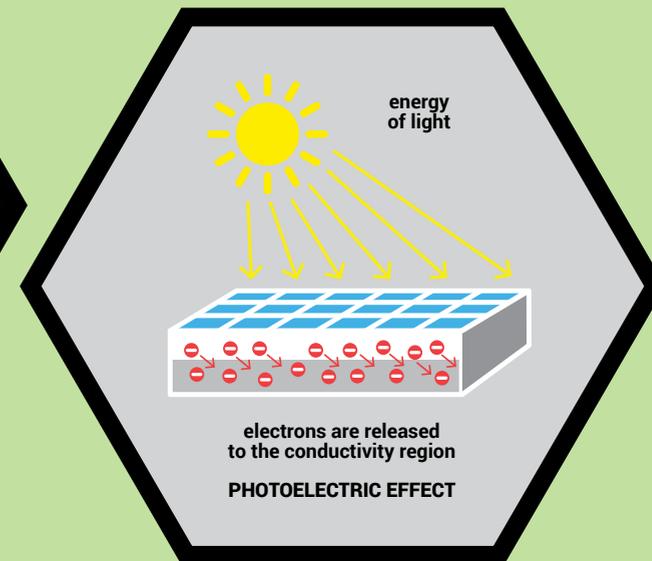
The exhibit demonstrates the operation of a photovoltaic panel (solar panel) which converts light energy directly into electric energy through a photoelectric effect.

How does the photoelectric effect work?

The principle of the photoelectric effect is that light of a certain wavelength repels electrons from atoms when it hits the semiconductor from which this solar panel is made. Subsequently, these electrons, by moving to the respective electrodes, increase the conductivity of the substance and generate an electric current.

Of interest

The Sun is our largest known natural resource. Though its distance from the Earth is about 150 million km, 1360 W/m² of energy encoun-



ters the edge of the Earth's atmosphere every second. Due to the influence of the Earth's atmosphere, solar energy of approximately 1000 W/m² per second hits the Earth's surface. This energy reduction depends on the state of the atmosphere, the latitude and the activities of the Sun. The Sun's energy has been used from time immemorial, initially for heating; later, with the help of mirrors, solar energy was focused to reach a temperature of more than 1000 °C.

42 MAN AND DYNAMO

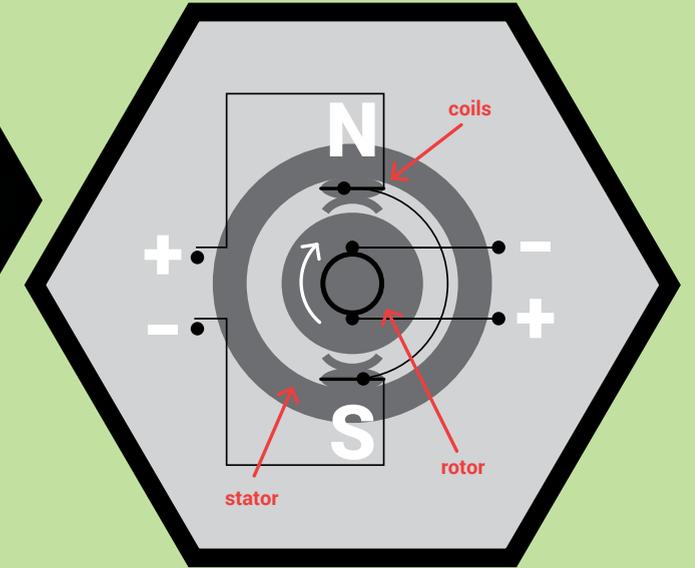
What is a dynamo? What happens when you set a dynamo to rotate?

A dynamo is a rotating electric machine – a generator that converts mechanical energy into direct current. The dynamo operates on the principle of electromagnetic induction. By the dynamo's rotation, electricity is generated that spins fans and turns the LED lights on. Everything gradually from the bottom up.

How does the exhibit work?

What happens when you stop pedalling the exhibit?

The exhibit is an elliptical trainer set in motion by pedalling. Movement is transmitted from the pedals to the dynamo by means of a V-belt to generate electricity. The electricity produced is manifested in rotating fans and illuminated LEDs. When you stop pedalling, the fans stop rotating and the LEDs are extinguished. By reducing the amount of electricity generated, the activity of these appliances gradually decreases in a top-down direction until it stops.



What does the exhibit demonstrate?

The exhibit represents a tool for electricity production and a renewable energy source.

Do you know what a renewable energy source is?

The renewable energy source is renewed in the course of its use. Energy flows that occur close to the Earth's surface are used and converted into electric energy. Sources of renewable energy can be: wind, water, sun or human locomotion.

43 BICYCLE AND ENERGY

**Can you engage the correct gear on your bike?
How important is it to engage the right gear when cycling?**

Low gear means less effort with more pedaling. And the opposite applies – a higher gear means more effort though with less pedaling. The higher the gear, the more difficult the transmission.

What does the exhibit demonstrate?

The exhibit demonstrates a vision of how sport and ecology can be combined to ecologically generate clean energy.

Do you know what bike you were riding?

This mountain bike is the twin of the exhibit which represented the Slovak Republic at EXPO 2017, an international exhibition in Kazakhstan. The theme of the exhibition was Alternative energy sources.



What types of bicycles do you know of?

For example: mountain, road, racing.

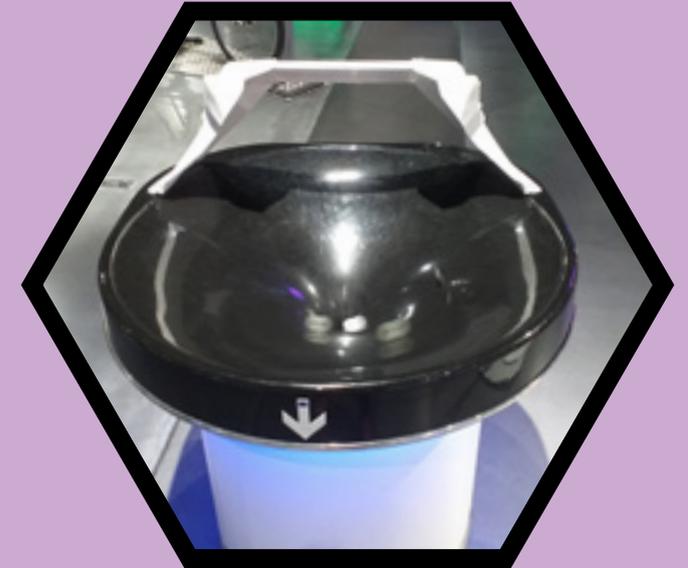
How long would it take to charge a mobile phone via a bicycle dynamo?

44 BLACK HOLE

Take the ring from the groove located at the bottom of the exhibit, insert it into the highest point of the groove ramp and release it freely. It will drop into a so-called “black hole”. Then observe what happens to the ring.

Why do you think this exhibit is called a “black hole”?

The black hole exhibit simulates the conditions under which a body falls into a black hole. There is a bridge over this black funnel – a ramp from which metal rings are released from the right or left side. A black hole is a cosmic body of such mass that its gravity prevents any particle, body, or radiation, including light, from escaping from its surface. When a body approaches a black hole from a distance, there is no return and the body spirals into the black hole.



Why does the ring move along a spiral trajectory?

From the edge of the funnel, two forces – gravitational and centrifugal – act on the released ring: the rotation of the ring is caused by centrifugal force.

Why does the movement of the ring accelerate?

The radius of the ring’s trajectory gradually decreases, and the time of the cycle also shortens, resulting in the accelerated rotation and speed of the ring increases.

45 CONES

Lifting a small metal body should not be difficult. But can you do it with just two or three fingers? Note the effect of the inclination of the cone on the degree of difficulty entailed in lifting the cone. Which of the cones were you able to lift from its housing without much difficulty?

What is happening in this exhibit?

The key element in this exhibit is four weight-matched cone-shaped metal cones. The inclination of the cone decreases as its angle increases, which is experienced as an ever-smaller gripping area. From the base of the cone downwards, the body has a cylindrical shape and a flat bottom. The surface treatment allows the cone to be relatively freely moved vertically with minimal friction, and a comfortable grip without it slipping.

Try to lift the cone out of its housing with the fingers of one hand, while only contact with its inclined part is allowed. Start with the “sharpest” cone and observe the relative ease with which you manage to lift it. The next task is more challenging, the third is at the limit of your capability and you will probably fail to lift the last cone. Note that success is directly dependent on the surface properties of your fingertips. If they are dry or are sufficiently rough, it is enough to grip the cone with light pressure. On the other hand, wet or smoother fingertips can barely lift even the most spiked cone.

How does it work?

If you want to lift a metal body, you need to overcome the gravitational force that the Earth exerts downward on the cone. When interacting with the body, you exert a force that expresses the direction of your action (here sloping upwards) and the degree of interaction. In this case, it has the character of a friction force, which further breaks down into two components. The horizontal has a pressure character and you sense it by touch. If the body were made of less solid material, this force would manifest itself in the deformation of the body. The vertical force



has a tensile or better lifting character and this is precisely what is important when lifting the body out of its housing. The apex angle of the cone top determines the magnitude of the individual components – the smaller the angle, the greater your interaction for lifting. A large angle (flatter top of the cone) causes an increase in the pressure component (at the expense of tensile). It is worth noting that, by increasing the pressure of the fingers or roughening the surface, it is possible to increase the friction force.

Where is the phenomenon applied?

Interactions by friction are used on a daily basis when lifting or moving a variety of objects. If the surfaces of the object or your skin are sufficiently rough, one can apply a relatively large effective force. That is why one often uses work gloves that meet the requirements for surface quality. If the body slides, the friction force is small and its component that can be used for movement will not be sufficient. To achieve a firmer grip, your fingers or palms will have to exert more pressure on the surface. The principle is expressed by the equation for the force of friction $F_t = f \cdot F_n$, where f is the coefficient of friction and F_n is the normal (e.g. perpendicular to the surface) force between interacting bodies.

46 CENTRE OF GRAVITY

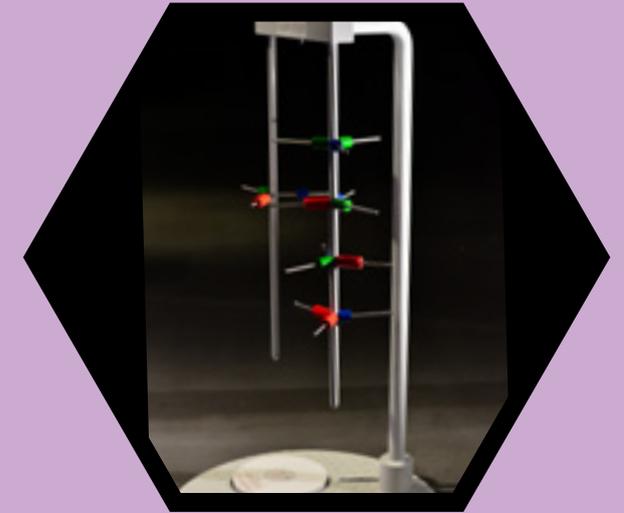
What is the centre of gravity? You may have tried to balance a long ruler or a broom on your fingertip. Can you do it with a set of the sliding cylindrical bodies in our exhibit?

What is happening in this exhibit?

The set in this exhibit consists of two independent rods, each loosely suspended at its upper end. At the bottom of the rods is a laser that points to the ground. Here is a “target” with several points. Several horizontal arms with a cylindrical body sliding along the arm are mounted on each rod. Your task is to move the cylindrical bodies to direct the vertical rod to the desired point. Note that the ability to direct or adjust the position of the rod depends on both the size (weight) and the position of the cylindrical body. Obviously, moving a larger cylinder will have a greater effect on the equilibrium of the rod, but what is the effect of its position? We will probably discover that, if the cylindrical body is close to the rod, it does not much affect the vertical position of the rod. Conversely, if we move the cylinder along the arm towards the end-stop, the effect on the position of the rod is observable. Hence, the exhibit requires concentration, careful handling and fine motor skills.

How does it work?

The exhibit demonstrates two physical phenomena – the centre of gravity of the body and the moment of force. We adjusted the centre of gravity intuitively, while the moment of force will be demonstrated practically. It is a physical quantity that characterises the rotating effects of force. What do we rotate and what is the force we exert? The horizontal arm tries to move downward, thus rotating the vertical rod. The force of gravity acts on both the arm



and the cylindrical body. This is directly dependent on the weight of the cylindrical body. The magnitude of the moment of force and hence that of the rotating effect is determined by the product of the active length of the arm (to the point to which the cylindrical body was moved) and the applied force (the mass of the cylindrical body). A valid statement is that the larger a particular cylindrical body is, and the more distant from the axis, the more inclined the rod will be. The opposing cylindrical bodies act on the rod with moments of force with opposite signs; in order to achieve an ideal equilibrium, the sum of the magnitude of the moments of force should be equal to zero – i.e. the moments of force (without signs) should be of the same magnitude.

Where does it apply?

The moment of force is encountered in simple devices like a doorhandle where, thanks to the long arm, we can turn the shaft by applying a relatively small force and thereby open the door. If we were to use the shaft alone, we would not be able to open the door. We also use the equilibrium of two forces in beam weighing scales. Once the plates are levelled, i.e. reached a horizontal position in the same plane, the weight and the object to be weighed have the same mass.

47 CHAOTIC PENDULUM

Rotate the handle to move the pendulum and observe its chaotic movement.

Do you know that the chaotic movement of the pendulum is apparent and not accidental?

Modern measuring technologies and evaluation tools have made it possible to carry out a study showing that the results of pendulum movements are not random. They are governed by rules that can only be confirmed by a large number of repetitions.

What does the exhibit demonstrate?

The double pendulum is a simple demonstration of chaos theory.



What is chaos theory?

Chaos theory is the part of mathematics and physics which refers to so-called mathematical chaos. It deals with systems that are complex and where their dynamics, under certain conditions, depend on the original conditions, so their long-term behaviour is not predictable.

48 SPINNING TOP

The spinning top is an interesting toy. If you try to balance it by standing it on its sharp point, you will not succeed at first. But if you spin it around its axis beforehand, you can easily make it balance. How is this possible? Does it have any practical use?

What is going on here?

The experiment set-up comprises two basic elements: an enclosed area and a rotating body. The smooth horizontal surface makes it possible to largely discount frictional forces. The spinning top has a symmetrical cylindrical, disc-shaped body and a shaft ending in a sharp point which is inserted perpendicularly to the diameter of the body. Hold the axis in your fingers and try to get it to balance on its sharp point. You find that this is almost impossible. Repeat the experiment, but set the axis (shaft) in rotation prior to establishing the equilibrium. If you manage to maintain the shaft in the vertical position while setting the axis spinning, the spinning top remains in balance when you move your fingers away and does not fall onto its side as previously. Note that the spinning top moves over the surface, its axis deviates from the perpendicular (precession) and it swings regularly (nutation). You observe that a spinning top with its mass centred around the axis is easy to spin, but it also loses its balance relatively easily. Conversely, if most of the material is further from the axis it requires more effort to spin it, but its balance is better maintained. The spinning gradually decelerates, the inclination of the spinning top increases until it falls over at a certain moment.



How does it work?

A spinning top is one form of a device known as a flywheel. It consists of a cylindrical body of a certain diameter and a symmetrically distributed mass. It rotates around the axis which is also the axis of symmetry of the body. The main feature here is the moment of inertia. The higher the moment of inertia, the more resistant is the body to a change in motion. The magnitude of the moment of inertia is influenced by the diameter of the spinning top, its mass, and the distribution of its mass around the axis. The static spinning top falls over because its individual points are subject to partial gravitational forces that are not mutually compensated for. Rotation adds the desired balance, the falling point is in a moment moved to another position. Hence, during rotation, the set of points at the spinning top behaves like a relatively symmetrical unit. There is also the centrifugal force in action which, in combination with gravity, causes the so-called precession.

Where is this used in practice?

The flywheel is deployed to stabilise motion – maintaining a certain direction of the axis or maintaining the speed of rotation of the body. It can be found in devices such as an aeronautical artificial horizon, compass or accelerometer. Kinetic energy can also be stored in the flywheel.

49 CENTRIFUGAL TURNTABLE

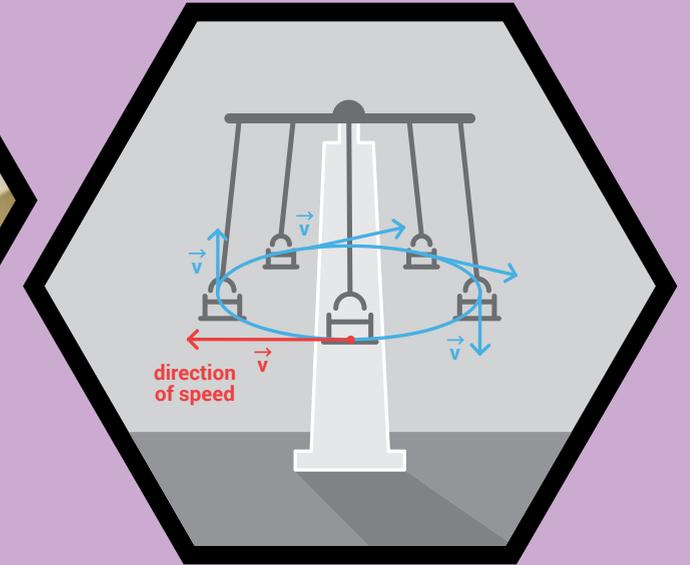
What happens when a body moves in a circle? Set the plate spinning and place a ball or disc on it. Observe the trajectory that the body describes as it travels across the plate. What conditions need to be met to keep the ball on the plate?

What is happening in this exhibit?

The basic component here is a circular plate that rotates in a horizontal plane. Place various bodies on its surface and after pressing the START button observe their rotational movement. We can move the ball or disc prior to putting it on the plate and thus demonstrate the complex motion. Note that the ability of a ball to remain on the plate depends on a variety of factors: the distance from the axis of rotation of the plate, the quality of the surface of the plate and the body, the speed of rotation of the plate. Now place a plastic ball at a suitable distance from the axis on the rotating plate, which you set in rotation, as if you wanted to roll it against the direction of rotation of the plate surface. In such a way and from your perspective, the ball remains in one place. This demonstrates the superposition of motions. To end this activity, press the STOP button.

How is it possible?

The exhibit demonstrates two basic phenomena: the origin of the frictional force and its effect on the motion, as well as the action of forces on bodies that move in a circle. As the plate rotates, it transfers its kinetic energy to the bodies on its surface. The frictional force expresses the degree of contact between two bodies. It depends on the roughness of both surfaces and also on the compressive force; in this case, this force is the weight of the body (e.g. the ball). If the frictional force is large enough, the body remains on the surface of the plate and does not slide off. The frictional force is counteracted by the centrifugal force, which originates in the non-inertial reference frame (i.e. from the perspective of the point on the plate) during the rotation and its direction is towards



the periphery of the circle. The given force depends on the distance from the axis of rotation (directly proportional) and the frequency of rotation of the plate (square). The frictional force remains constant for a given surface and body, the centrifugal force changes. That is why a body closer to the axis of rotation of the plate is easier to keep on the plate while a body further from the axis of rotation tends to fly off from the plate.

Where can this phenomenon be applied in practice?

The frictional force allows for a safe movement on various surfaces, always acting against the direction of motion. If a given surface (e.g. the floor in a vehicle) moves with acceleration (increase in speed, braking, making a turn), an inertial force (e.g. centrifugal) acts against the frictional force. If this is of greater magnitude than the constant frictional force (in this particular case), it can cause unwanted motion, such as skidding or falling. The complex movement is used in exercising on a conveyor belt, where the person runs forward and the belt moves backwards relative to the person. This results in the person remaining in a static position above a certain point of the conveyor belt. If the person runs more slowly or the speed of the belt is increased, the static situation changes to dynamic and the person might fall.

50 GYROSCOPE

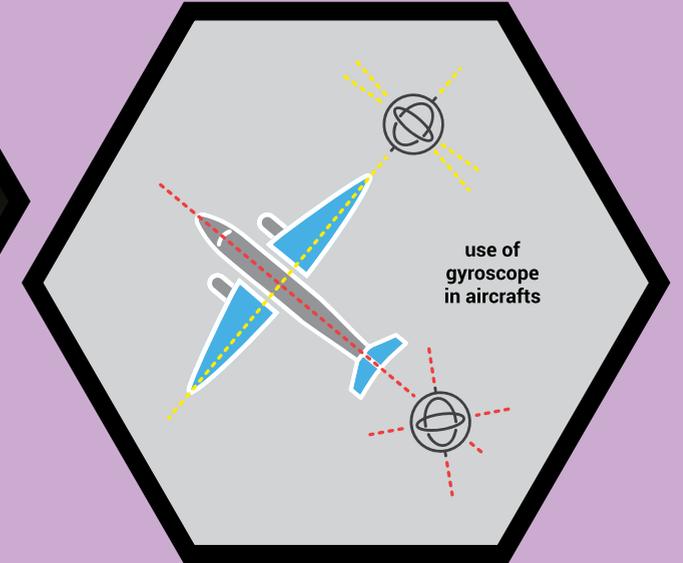
How does a rotating disc affect a structure you control? Stand on the marked place on the base of the exhibit and hold the handlebars firmly. Then spin the gyroscope disc, turn the handlebars to the right or left and watch the change in the motion of the structure.

What does this exhibit demonstrate?

What is the exhibit made of and how does it work?

The exhibit demonstrates the operation of a gyroscope, the fundamental part of which is a flywheel. The flywheel is a body rotating around its spin axis. Most often it is disc-shaped so as to have the greatest possible moment of inertia. The axis of the rotating flywheel retains the same direction as when the flywheel was set in the rotation unless external forces act on it.

The gyroscope consists of two gimbals, inner and outer, which are connected via pivots. A flywheel is mounted in the inner gimbal, also via pivot pins. The flywheel retains its spin axis position regardless of the orientation of the gimbals.



Where is the gyroscope used in practice?

The gyroscope is very important in piloting aircraft and is used under the term "artificial horizon". This makes it possible to keep the aircraft in the correct position, even in situations where the pilot cannot see the Earth due to clouds or darkness. Nowadays, gyroscopes are used in ships, satellites, smart cars, smartphones and tablets.

51 GALTON'S BOARD

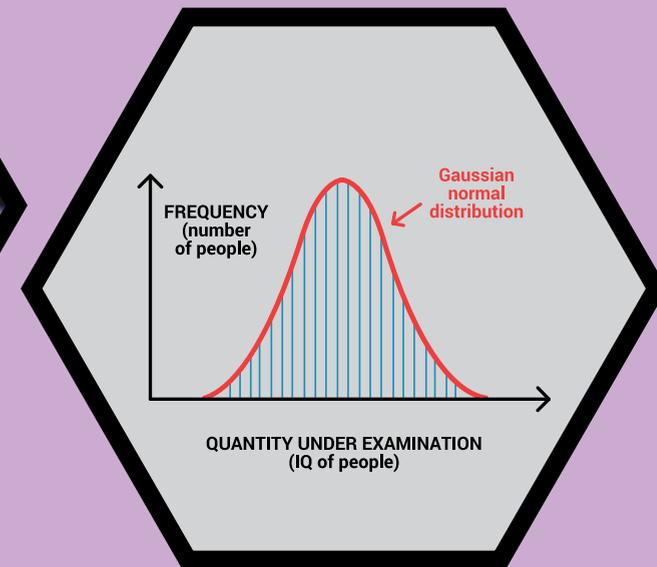
Perform a simple statistical experiment in a playful way and clarify the mathematical concept. Rotate the frame to pour the sand into the 2D funnel section. The sand drops through the obstacles to the collection bins at the bottom. Observe what pattern is created.

What pattern was created?

A Gaussian statistical distribution pattern, represented by a Gaussian curve, was created.

What is a Gaussian curve?

The Gaussian curve shows the probability density and has the shape of an inverted parabola (bell-shape).



What does the resulting pattern of the exhibit demonstrate?

The exhibit demonstrates the probability density of the quantity investigated. In practice, the figure can show, for example, the population of a certain IQ value. The number of people with the highest and lowest IQ values is the lowest, and for the average value of IQ, the number of people is the highest.

52 PYTHAGORAS THEOREM

Implement and clarify the mathematical concept in a playful way. Rotate the frame of the exhibit and observe how the sand inside regroups from two smaller squares to one large one, or vice versa.

What does the exhibit demonstrate?

Filling the volume of one large square with sand from two smaller squares clearly demonstrates and proves the validity of Pythagoras theorem.

What does Pythagoras theorem state?

Pythagoras theorem states:

"The sum of the areas of the two squares on the legs (a and b) equals the area of the square on the hypotenuse (c)."

$$c^2 = a^2 + b^2$$



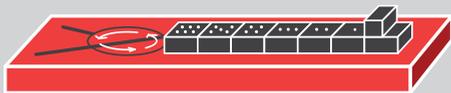
Do you understand the visualisation of Pythagoras theorem?

Calculate and compare the area of the squares using small grid squares and verify the validity of Pythagoras theorem.

53 BRAIN-TEASERS

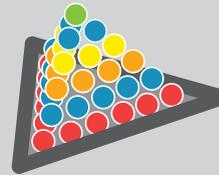
Apply and clarify mathematical concepts in a playful way.
Can you solve the individual brain-teasers?

TURNTABLE TRAIN



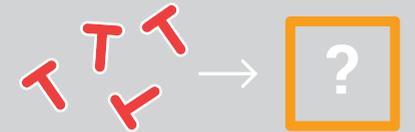
Move the carriages by turning the turntable and arrange them by the number of dots from lowest to highest or vice versa. At any one time, three carriages can be accommodated on the turntable. Did you succeed?

THREE-SIDED BALL PYRAMID



Form a regular triangular pyramid in a triangular base to maintain colour symmetry. Use non-detachable coloured ball parts. Is it possible?

T PUZZLE



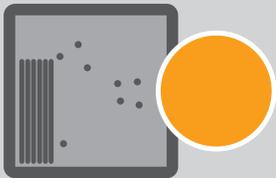
Assemble the pattern from four identical "T"-shaped components in such a way that the components fit into a confined space and must not overlap. There are four possible solutions.

WHEEL



Assemble the wheel-shaped body. Use five different components so that they fit into a confined space. Can this task be completed?

BALANCE TABLE



How do you place the pegs in the holes to keep the board balanced?

RINGS



Assemble a symmetrical pattern out of three intersecting circles. The components must remain within the confined space in one plane. Is it possible to complete this task?

INFINITY EIGHT

Guide the bead in the groove so that it travels along the entire circumference of the figure of eight. Note the colours at the sides. What did you notice?

TOWER OF HANOI



Stack all the discs from the original rod onto another. Only one disc can be moved at a time and stacked onto one of the rods so that the smaller disc is always on top of the larger one. Use as few moves as possible. Maintain the original "A" - shape assembly.

How many moves did you take to complete the task?

If you want to know the minimum number of moves required, here is an equation:

$2^n - 1$, where n = number of discs.

In this case, the equation is as follows: $2^6 - 1 = 63$

54 AN INVISIBLE CLOAK

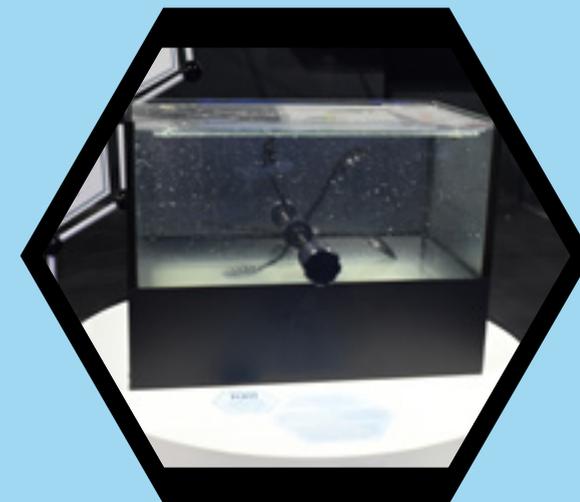
How to become invisible? All you have to do is blend in perfectly with the environment. Take a look at the aquarium. **What is in there? Water - and what else?** Turn the paddle wheel to transfer part of the container volume above the surface. **What did you find out?**

What is happening in this exhibit?

The aquarium is filled with an aqueous solution, which can be stirred using a partially submerged paddle wheel. A small aliquot of the solution can be displaced above the surface in the container and observed against the surrounding environment - the air. A closer look at the aquarium reveals small spherical objects. These are small beads on the paddle above the surface of the solution. Since they consist almost wholly of water, they are very difficult to distinguish within the container. However, in the air, they can be observed without any problems.

How is it possible?

The basic component of the exhibit is an advanced "SMART" polymer-based material, so-called polyelectrolyte hydrogel. In the dry state, it has a relatively small volume and a high degree of porosity. Upon contact with water, this results in high liquid absorption and a significant increase in bead volume, up to 90% of which can be water. Hence, the density of the material is very similar to that of pure water, and the beads float in the vessel. The (in)visibility lies in the optical properties of the beads and their surroundings, more precisely in their refractive indices. You will learn more in the part



of the exhibition dedicated to optics. The important thing is that the refraction of light by water and by the hydrogel is practically the same, hence we cannot distinguish them with the naked eye. However, the refractive indices of hydrogel and air are different and the two substances also form a significant boundary which makes the bead visible above the surface.

What is the practical use of this phenomenon?

Gel beads have a decorative-functional use in supplying indoor plants with water. A vase filled with gel beads loses moisture more slowly than a vase just filled with water. The water does not evaporate into the surroundings and flowers stay fresh and aesthetically pleasing for longer. The beads can also be used in potted house plants, which then do not need to be watered so often. The beads also refract and reflect light, so they can serve as an interesting interior feature. A small difference in the refractive indices of the gel and water serves some aquatic animals (e.g. jelly-fish) as an evolutionary advantage. Due to their poor visibility, these animals are less prominent to their prey and better protected from predators.

55 MYSTERIOUS TERRARIUM

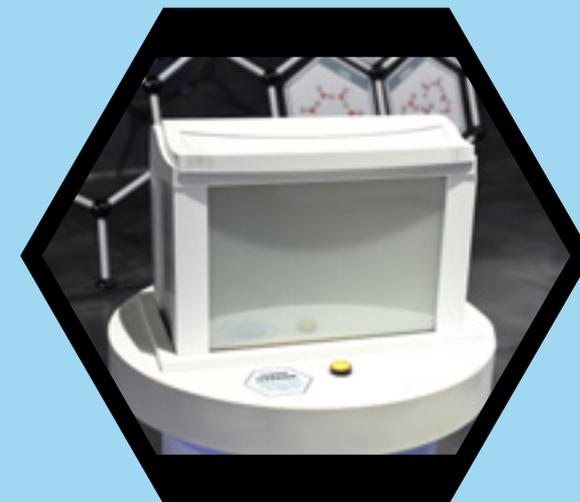
Is it possible for non-transparent plastics to turn transparent? Press the button and watch what happens to the terrarium. **What did you see before and after pressing the button?**

What does the exhibit demonstrate?

The mysterious terrarium before you consists of a covered container with walls made of polymer (plastic) material. It is possible to change its optical transmittance; in this case, by passing an electric current through it. By pressing a button, an electrical voltage is applied to the material sufficient to change its phase. Originally randomly arranged particles now form a crystal lattice with the optical properties of the terrarium walls similar to those of glass or transparent plastics. Inside the container, you will see a model of a rook which was previously invisible. If you release the button, the walls of the terrarium turn opaque again. You can repeat this procedure over and over again. The exhibit has another button for changing the light inside the terrarium to white or blue, or you can switch the light off.

How does the exhibit work?

The key to the mystery is the advanced “SMART” material, the polymer forming the walls of the terrarium. This special plastic material alters its properties (e.g. phase, transparency or colour) under different external conditions. In this exhibit, an electric current is applied. But the external factors can also be a change in temperature (heating)



or lighting of the plastic surface by radiation of a suitable wavelength (e.g. UV radiation). In most cases, the effect is lost once the external factor is removed (e.g. the power is turned off). Some, however, can be designed to have a hysteresis (a memory effect that ensures that the material does not immediately return to its original state).

What is the practical use of the material presented here?

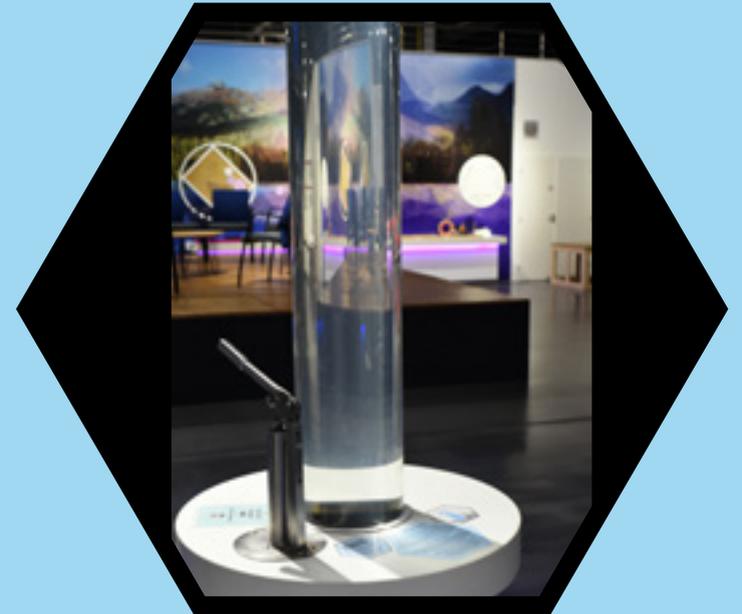
Use of the same building component with different optical properties has applications in interior design and architecture. The wall of an apartment unit can be made of a polymer which can be transparent or not according to the requirements of the residents, thus increasing the variability of the space. It would also be possible to regulate the amount of sunlight in the interior. In the case of a polymer sensitive to alterations in temperature, one encounters the so-called eraser pen, where the plastic is a component of the ink. The pen is used for writing text in the usual way. If one wants to remove the text, an eraser is applied which, due to friction, increases the ink temperature above a certain value at which a phase change occurs. The visible manifestation is the “disappearance” of the written text, without any mechanical damage to the paper.

56 CARTESIAN DIVER

Can you move the bottle from the surface to the bottom of the cylinder and, conversely, from the bottom to the surface? Move the lever down or up to move the bottle in the cylinder. **What happens to the bottle when you press the lever down? What happens to the bottle when you push the lever up?**

When does the bottle move down and when up? How is this possible? What does the exhibit demonstrate?

The exhibit is a system consisting of two cylinders. One is large and transparent and the other is small and metallic with a piston. The system is closed and filled with water. The piston is operated by a lever. Moving the lever downward or upward changes the pressure in the large cylinder. A change in pressure in the large cylinder causes the plastic bottle to deform (a change in its volume), thus making the pressures in the cylinder and in the bottle equal. If you move the lever down, the pressure in the large cylinder will increase. The plastic bottle will deform (reduce its volume). If you move the lever upwards, the pressure in the large cylinder will reduce and the plastic bottle will regain its original shape (increase its volume). This will increase its buoyant force and the bottle will rise.



Archimedes' principle:

A body immersed in a liquid is pushed upward by the hydrostatic buoyant force, the magnitude of which is equal to the weight of the liquid displaced by the immersed part of the body. Hence, the bottle, which has reduced its volume, is subject to a lower buoyant force, which can no longer keep the bottle on the surface of the large cylinder, hence it descends.

Can you compress the liquid? Can you compress the air?

No, you cannot compress the liquid because the liquid is non-compressible. Yes, you can compress the air. This can be proved by the increase and decrease in air volume in the bottle due to the higher or lower pressure in the large cylinder.

57 HYDRAULIC EQUIPMENT – PASCAL'S LAW

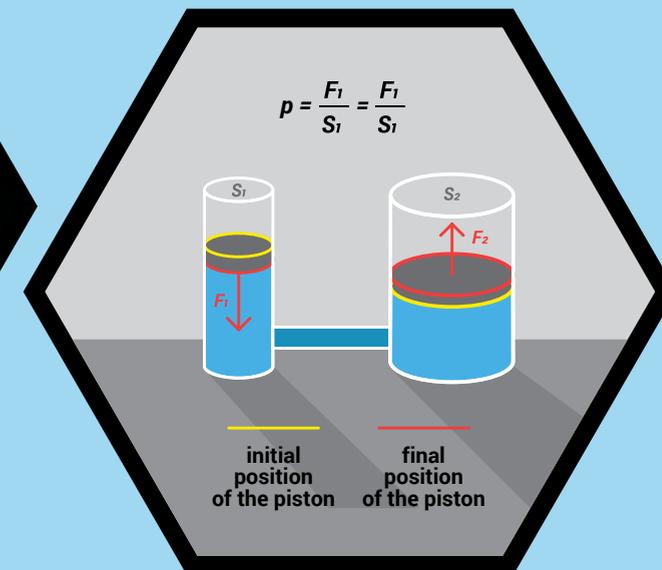
How to render manual operation easier? One option is to use a force multiplier, a typical representative of which is hydraulic press or jack. Pull the lever and observe how the movement of the smaller piston makes the significantly greater piston move, while the force you exert is relatively small.

What is happening in this exhibit?

Before you is a simplified model of hydraulic equipment, which usually consists of two cylinders of different cross-sections that are connected via a tube. The whole system is filled with a hydraulic fluid, such as oil. The liquid serves as a transmission medium – by the action of force F_1 you push the piston of a smaller cross-sectional area S_1 and thus the pressure in the whole volume of the system increases ($p_1 = F_1 / S_1$). The same pressure acts on the piston of a larger cross-sectional area S_2 by the force F_2 , where $p_2 = F_2 / S_2$. Note that the displacement of the larger piston is smaller than the displacement of the smaller piston. If work is a product of force and displacement, then the hydraulic system does not save work, it only transmits energy. It is used in hydraulic drive systems.

How does the exhibit work?

The model works on the basis of Pascal's law. The pressure exerted by an external force on a liquid in the closed container is constant in all parts of the container. If a certain force is applied to a smaller piston, pressure in the hydraulic system is increased by the value of p . Pressure is the ratio of force and cross-sectional area (of a piston). If this ratio is to be



maintained, the force must also change when the cross-sectional area is changed. Hence, if a force of a certain magnitude is attributed to a small area, a force of a greater magnitude will be attributed to a larger area. The force depends on the ratio of the piston's cross-sectional areas and not on their diameters. For example, for a larger piston of a diameter twice that of the smaller piston, the area is four-fold the area of the smaller piston and so is the force that acts on the larger piston and also the force that the piston can exert on its surroundings. The law described was formulated by the French scientist Blaise Pascal. His experiments and findings in the field of pressure in liquids and gases were so significant that the basic unit of the physical quantity of pressure - Pa (pascal) - was named after him.

Where is this principle applied?

In technical practice, the force multiplier is encountered in devices such as the hydraulic press and the same principle is deployed in the hydraulic jack. The hydraulic drive has its application in construction machines (loaders, cranes), in the control of remote mechanisms (wing flaps on aircraft) and, for example, in the transmission of mechanical energy between otherwise difficult-to-connect devices.

58 BUBBLE SUBMARINE

How can a submarine be made to dive from the surface to the bottom of the cylinder and then re-surface? Turn the crank and observe how the properties of the fluid in the cylinder are demonstrated.

What is happening in this exhibit?

The submarine floats on the surface. On turning the crank, the air is blown into the cylinder with water thus altering the density of the water. As a result, the upward buoyant force of the water decreases and the submarine descends to the bottom.

What physical law is the exhibit based on?

The exhibit is based on Archimedes' principle.



If a body is submerged in a liquid, three possibilities pertain:
1. the buoyant force of the liquid is greater than the gravitational force of the body – the body floats;
2. the buoyant force of the fluid is equal to the gravitational force of the body – the body floats freely in the fluid;
3. the buoyant force of the fluid is lower than the gravitational force of the body – the body descends to the bottom.

59 ARCHIMEDES SCREW

What is Archimedes screw and what is its origin?

One of the oldest machines used for irrigation and drainage is known as the Archimedes screw. It was first described by the well-known ancient scholar Archimedes around 200 BC. He was born in the Greek colony of Syracuse on the island of Sicily and became famous as a physicist, mathematician and inventor. He saw the screw during his stay in Egypt, where poor farmers used it to irrigate fields and move water from a lower to a higher level. It was a huge spiral enclosed in a wooden cylinder. As it turned, the screw moved the water along its thread without advancing.

What is the use of the Archimedes screw?

Water pump – the Archimedes screw is one of the oldest known pumps. It is a helical mechanism mounted in a trough or it can be a tube wrapped around a mounted shaft, both in an inclined position. The transported liquid is held in the Archimedes screw by gravity and the pumping is performed by rotating the spiral or shaft.

Conveyor – it is also important for the transportation of granular substances such as sand, cement, coal, cork, feed or flour. Conveyors are one of the oldest and simplest mechanisms for transporting bulk materials. They are used for mixing dry or liquid substances, and they can serve as a dryer or cooler.

Fish transport – it is also used to safely transport fish from ponds to another location.



Sewage treatment – use of an Archimedes screw prevents some parts of the pipe from becoming clogged with bulkier material.

Snow removal – snow removal from driveways with snow blowers.

Drills – it is a part of drills in various devices, such as drilling machines or motorised earth drills.

Fastening – it was not until the 16th century that threaded nails began to be produced that held more securely. Screws did not come into general use for fastening until the end of the 18th century.

Electricity generation – it is also used in electricity generation. The mass of water that descends through the screw rotates the generator turbine, which converts the mechanical energy into electrical energy.

60 WORLD OF TESLA

Nikola Tesla

- born on 10 July 1856 in Smiljane, Austrian Empire, today's Croatia
- he was of Serbian nationality
- most of his life he lived in the USA but spent the part of his professional career on the old continent – he worked in Budapest as well as in Germany, Prague and Paris
- the biggest discoveries and inventions: alternating current, X-ray, economic light bulb, radio signal, wireless power transfer and 300 other patents

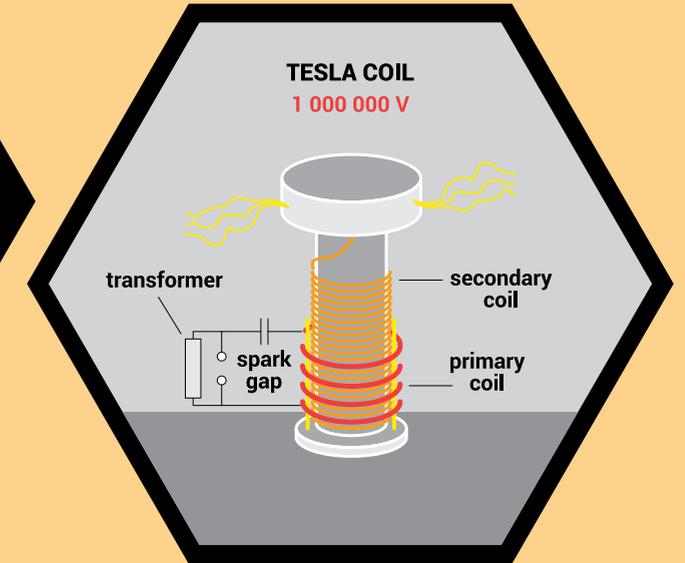
Alternating current (AC)

- motors, radio signal, electric appliances
- flows through electric circuit alternatively – reverses the direction
- the graph showing the change of AC with respect to time is sinusoid
- suitable for the long distance transfer

Direct current (DC)

- galvanic cells (batteries), fuel and solar cells, LED
- flows through electric circuit in one direction – from positive to negative pole of the source
- graph showing the intensity of DC with respect to time is constant, it doesn't change over time
- long distance transfer is complicated

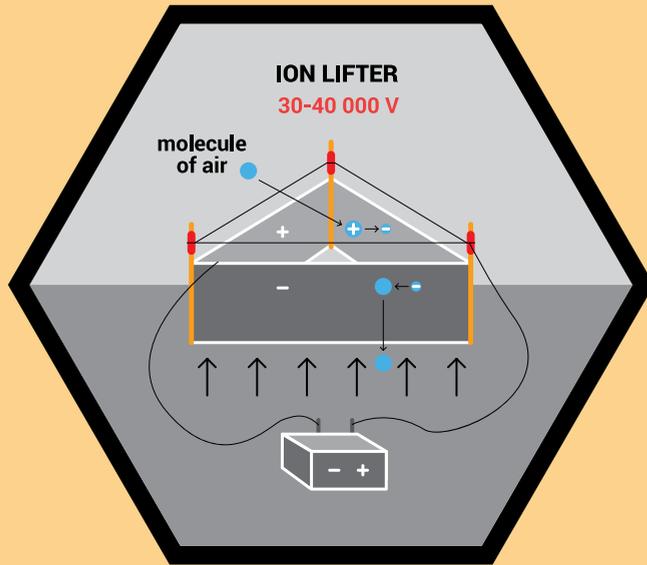
The concept of alternating current was met with great reluctance of another famous inventor **Thomas Alva Edison** and the list of Tesla's adversaries was even longer. So called **'The War of Currents'** was the source of long lasting rivalry between these two genial inventors but finally Tesla, Edison's former employee and underrated assistant, won. Edison was forced to admit his fail.



Tesla coil

Tesla coil is a resonant air-core transformer made of primary and secondary coil which serves as a generator of very high voltage with high frequency. The primary aim of Nikola Tesla was to use the coil for wireless transmission of energy, but it was never used for this purpose. Our constructed coil is of DRSSTC type (Dual Resonant Solid State Tesla Coil) with both winding tuned on the same frequency. The windings are excited by power semiconductor switching devices – transistors. High-voltage transformer charges the capacitor of the primary coil through its winding. After receiving the particular amount of a voltage a spark leaps in the spark gap and collaterally reverts charged capacitor with primary coil. A resonant circuit starts to oscillate and makes a particular amount of oscillations. Meanwhile in the secondary coil an alternating voltage is induced. When the capacitor is out of charge a spark in the spark gap perishes and the capacitor disables itself of the primary coil. Then the whole process is repeated. The secondary coil has a loaded capacitor from which the sparkles shoot.

Consequences of exposure for man: Thanks to high frequency in Tesla coil as well as in Ion Lifter there is so called skin effect (surface electric phenomenon) causing the concentration of an electric current being higher on the surface of the conductor than in any other parts. The higher frequency of the passing current, the stronger effect. That's why it would probably cause only surface burn but for weaker person (e.g. with heart disease) it could be even deadly dangerous.



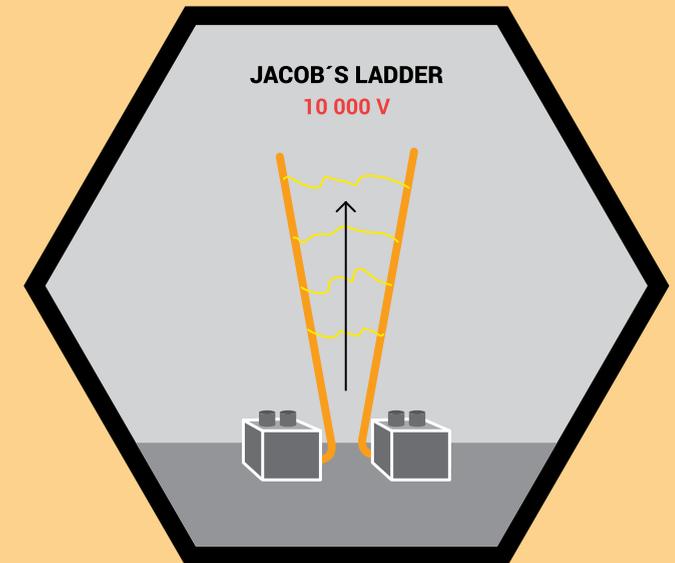
Ion filter

Ion filter carries the basis of the physical phenomenon displayed by the disequilibrium of the forces in an asymmetric capacitor which is charged by high voltage. This physical phenomenon is also known as **Biefeld-Brown effect**. It is an electric effect in which the ion wind is generated – **electro-hydrodynamic** phenomenon. The ion winter arises when air molecules get close enough to positively charged wire (an electrode of the capacitor). Molecules lose an electron so they gain a positive charge. Then they bounce off the wire and are attracted to negatively charged foil (an electrode of the capacitor) where they gain the neutral charge again. Considering the acceleration, molecules moves quickly downwards and cause the triangle capacitor fly up.

Jacob's ladder

Jacob's ladder is the name of the device that represents the physical phenomenon in which an electric arc moves freely between two electrodes. Electrodes are closer to each other at the bottom and farther at the top so they are in the V-shape. The arc is created at the bottom, where the electrodes are closest and finishes at the top where they are furthestmost. An electric arc heats the air around and this ionized air subsequently rises, whereby, the stability relates closely to the temperature and humidity of surrounding air.

Consequences of exposure for man: For the man an electric current with the frequency of 50 Hz is deadly dangerous because it affects the nerves endpoints in the heart muscle, that operate the heart' frequency (1Hz) – fibrillation occurs. The risk of fibrillation decreases at 1000 Hz and it's very small at the couple of kHz and more.



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