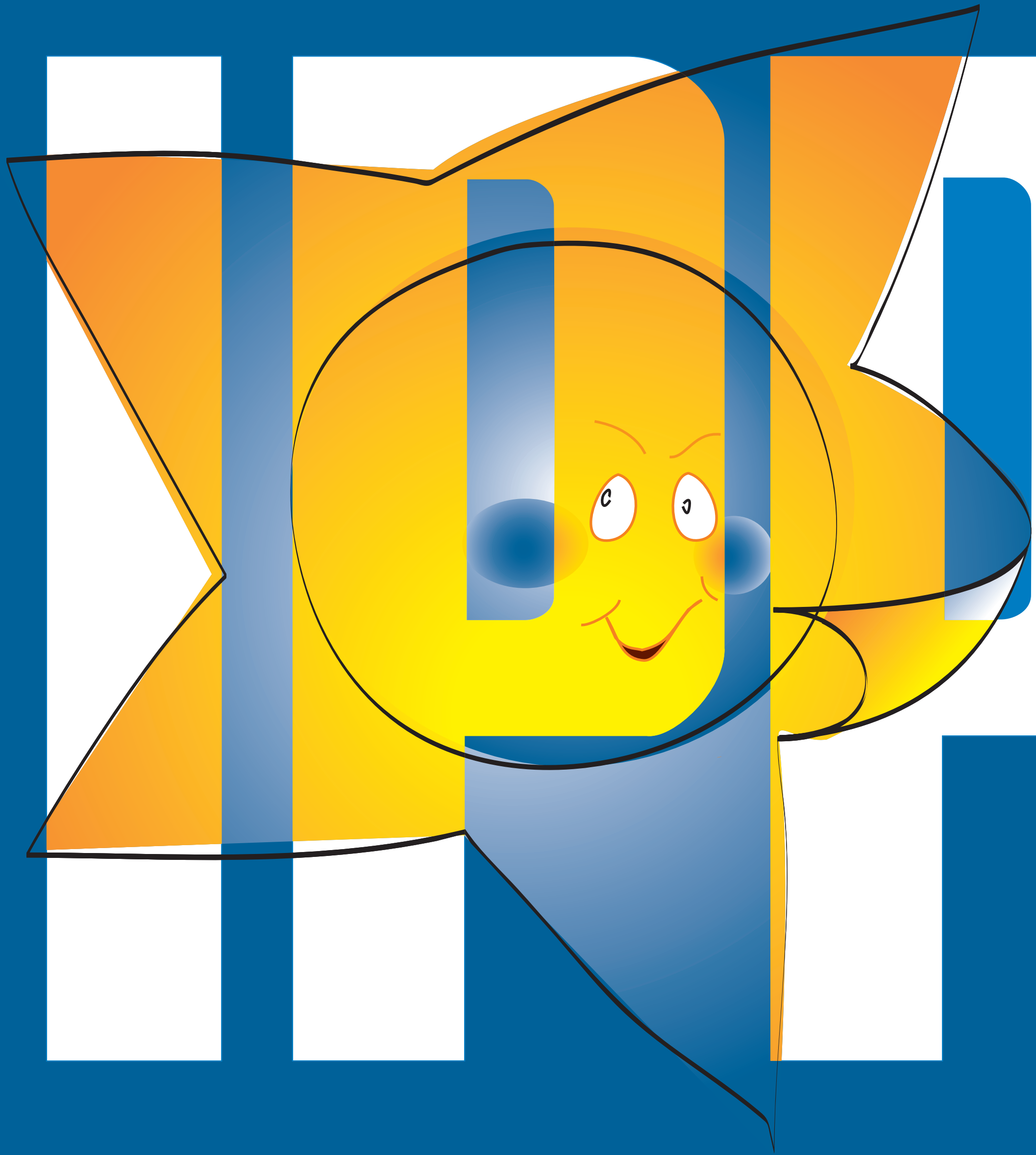
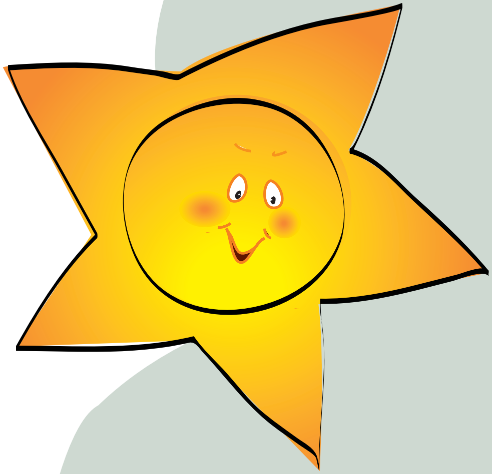


Science for Kids

Energy and Fusion

Contents



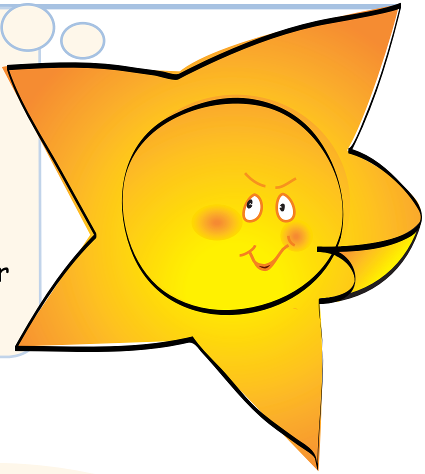
Allow me to introduce myself? My name is Solina. I'm sure my name, along with my round body, have already given me away: Yes, I am the sun, one of many stars. I am over four billions years old and I like to ask tricky questions. I know a lot about energy because I produce it myself in my hot tummy.

The scientists at the Max Planck Institute for Plasma Physics are trying to produce energy in the same way as I do. The Max Planck Institute for Plasma Physics is a very complicated name, you can just say "IPP" for short.

Energy is an extremely exciting topic. I would like to tell you all about it and about power plants as well as about the smallest particles and atoms. And what fusion is all about and … but wait! There I go again: Sorry, my fault, I am much too impatient!

If you're interested, this brochure contains a number of experiments you can have a go at. We'll have a lot of fun! I promise!

I am the most important source of energy for all of you down on planet earth! I may be 150 million kilometres away from you, but my rays put you in good spirits, help plants to grow and produce electricity in solar power plants. I am multi-talented!



Experiment:

Energy drink

What will you need?

- Beaker or jar with a screw lid
- 1/4 l milk
- 1 small banana
- 1 teaspoon of lemon juice
- Sugar, to taste
- Plate and fork

How to make it?

Peel the banana, cut it in pieces and use a fork to mash it on a plate, add lemon juice and milk.

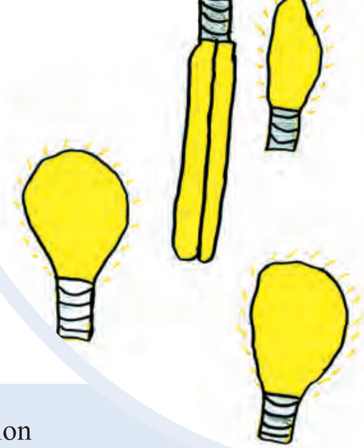
Then, pour the banana mixture into a jar or a beaker, close it tightly and shake it vigorously. You could even try singing your favourite song whilst shaking!

The energy drink should look pretty foamy. If it is not sweet enough, add a little sugar and shake it again.

Energy has many faces

What is energy actually? All day long you are absorbing and consuming energy in various different ways. Energy is available in many different forms: Drinking a fruity, sweet banana shake will give you the energy your body needs to play or to read. Feeling hungry tells you that you need to stock up on energy again. It is not possible to live without energy.

Energy does not vanish, it is just converted into another form. For example, the current that flows into an electric bulb is converted into light energy. But part of this energy is used up because the bulb is also heated, and this cannot be made into light. These conversion processes have limits, the energy in petrol can be converted to make a car move, but there is no way of converting this kinetic energy back into natural gas! It‘s actually quite simple, isn‘t it?



Our earth is inhabited by seven thousand million people. One-fifth of those still have to do without electricity. Can you imagine a life without it? Everybody needs electric light, a fridge or wants to watch TV. As the number of people on this planet is steadily increasing from year to year, it is obvious that energy requirements are also rising.

Give reasons why you think sugar is so important?

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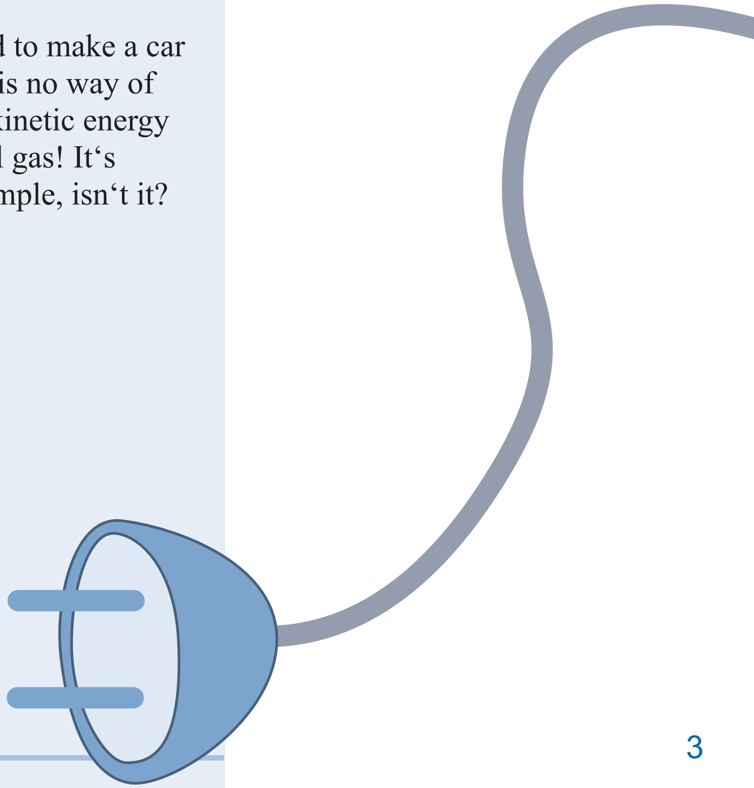
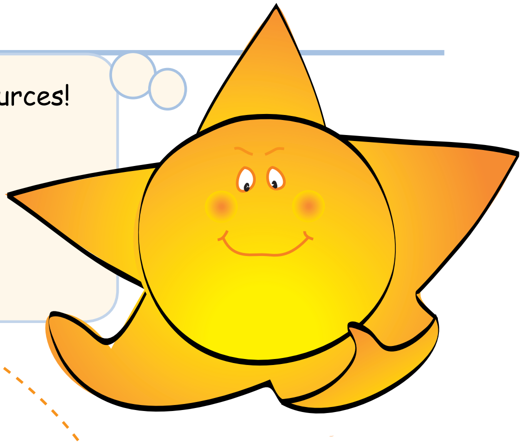
Take a look on page 12 to see what other people have found out.



Where does energy come from?

Experiment:
How to produce energy

We need to look for new energy sources! The Max Planck Institute for Plasma Physics is setting a good example and working on a new energy source for your future. Using me as their inspiration!



What do you need?

- 1 balloon
- Coloured tissue paper
- Grains of rice

How do you do it?

Blow up the balloon and tie a knot in it.

Tear the tissue paper into tiny pieces and spread them all over the table.

Rub the balloon against your head or your clothes.

Hold the balloon over the pieces of paper.

Test the experiment by rubbing against different materials – jumper, shirt, t-shirt – and watch what happens!

What did you observe?

Why do you think this happens?

Where does energy come from?

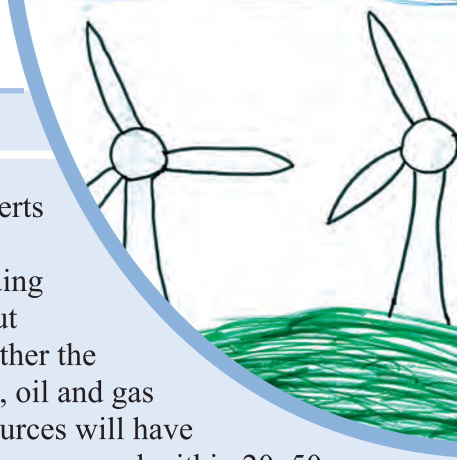
How does electricity get into the socket? Electricity is produced in power stations and transported to the cities using long power cables. It is then distributed to the houses by transformer stations and junction boxes. Next time you go for a walk, see if you can spot the junction boxes in your street!

There are many ways of producing electricity and "loading" it into the power supply network, as power plant operators say. More than half of the electricity produced in Germany, for example, is created using coal and natural gas. These high-energy materials are burned and the heat that is released is converted into electricity.

A large amount of the additional electricity required is produced from uranium in nuclear power plants.

It took millions of years to form our coal, oil and natural gas resources. If we measure this process against the length of a human lifetime, it would take too long to produce them again – and this is why we call them "non renewable" energy sources.

The renewable sources of energy include: Biomass – which is produced by using plants that grow again quickly – as well as sun, wind and water. Sunlight drives solar power plants, the wind powers windmills and the movement of water can also be used to produce electricity.



Experts are arguing about whether the coal, oil and gas resources will have been consumed within 20, 50 or 100 years. But the actual moment is not really that important. Scientists need to find new sources of energy before the ones we use today run out completely.

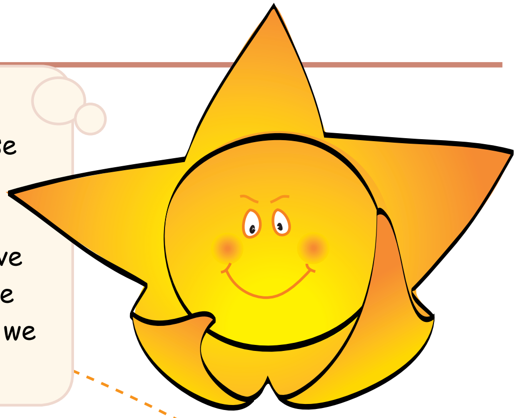
Take a look on page 12 to see what other people have found out.

Experiment:
Building a model atom

What do you need?

• 50 cm stiff wire
• 1 piece modelling clay
• 1 plate
• 1 fork or a stick
• 6 tablespoons of soap bubble solution or mix 3 tablespoons of thick washing-up liquid with 3 tablespoons of water

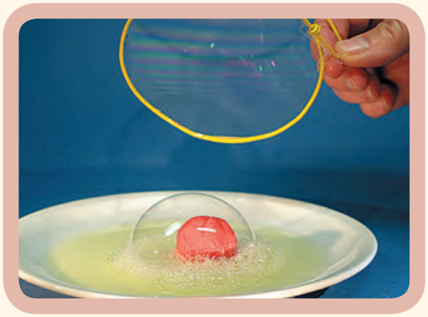
You cannot see an individual atom with the naked eye. These tiny things I have in my tummy could be used to provide energy for the next five billion years. And because I use atom nuclei to produce energy we call it "nuclear energy".

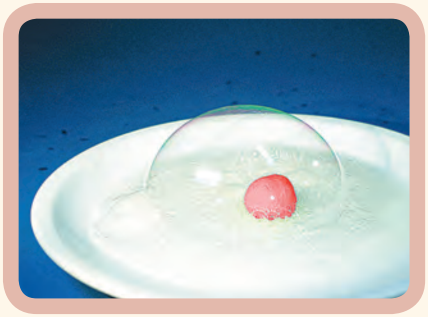


What do you have to do?

Bend the wire and make a lasso shape. The diameter of the lasso should be smaller than the plate you are using.
Make a small ball using the modelling clay. This will represent the "atomic nucleus".
Pour the soap bubble solution onto the plate and stir it with the fork.
Then place the "atomic nucleus" in the middle of the plate.

Place the wire lasso around the "atomic nucleus" and dip it into the soap bubble solution, agitate it and lift the wire.
A soap bubble will appear over the "atomic nucleus".





Atoms – Unknown and yet everywhere

For a long period of time, people believed that our entire surroundings were made of the elements earth, fire, water and air.

Nowadays, we know that tiny building blocks known as atoms, form everything that is around us: The soil and the stones, animals, plants and human beings, planets and stars. You can imagine an atom by thinking of a peach: It has a stone, a nucleus – the atomic nucleus. And the peel represents the surface on which the electrons move.

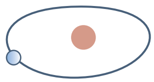
The sun is also made up of atoms. Inside the sun, an incredible heat of 15 million degrees can be found; that is the number 15 plus six zeros! A kitchen oven only manages 300 degrees!
At that temperature, the atoms in the sun take off their “peach mantle” made of electrons. When this happens, scientists call it a “plasma”.

Atomic nuclei move very quickly within a plasma and in doing so, collide at random. Sometimes they melt and create a new and bigger nucleus. During this melting process – or fusion – an enormous amount of energy is released. This is the way the sun has been producing energy for 4.5 billion years.

Atoms consist, above all, of a lot of emptiness. If an atom nucleus were the size of a tennis ball, the electrons would be moving about two kilometres away! And in-between the two – there is nothing!

IPP wants to imitate the sun and produce energy using certain atoms. A sun power plant on earth!

What can you see here?
Use your imagination!



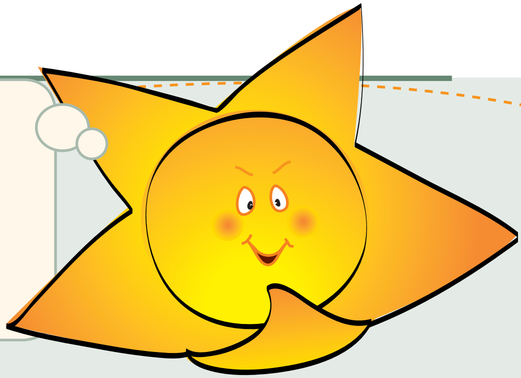
A hydrogen atom

Take a look on page 12 to see what other people have found out.

Magnetism – A mysterious force

Experiment:
How to make a magnet

Imagine a life belt made of invisible magnetic field lines. The hot atomic nuclei and electrons move inside this life belt and cannot escape!



What do you need?

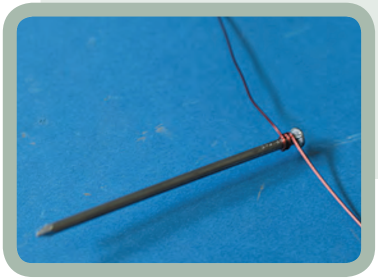
- 1.5 Volt battery
- 1 metre of copper wire, about 1 mm in diameter
- 1 steel nail, about 10 centimetres long and 2 mm thick
- Sandpaper
- A few paper clips or drawing pins

What do you do?

Wind the wire tightly and evenly around the nail 60 or 70 times, leaving a 10 cm length of wire free at both ends.

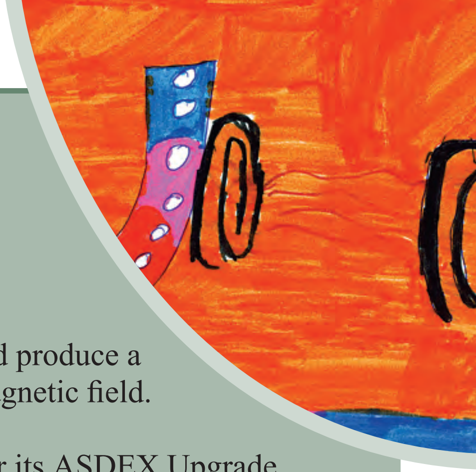
Sandpaper the ends of the wire until about 1 cm is shiny all round.

Touch the two polished ends to the „poles“ of the battery and allow the current to flow through the coil. Now dip the end of the nail into the paper clips or pins.



Important:
Never do any experiments using electricity from the wall socket! Use batteries with low voltage only – up to about 4.5 Volts.

Magnetism – A mysterious force



What did you see?

Why do you think this happens?

Take a look at page 12 and see what other people have discovered.

Magnetic forces are mysterious. You cannot feel, hear, smell, or taste them, nor can you see them directly. You can, however, make their effects visible using iron filings. Within a magnetic field iron filings line up in so-called magnetic field lines.

A magnet always has two ends, the north and the south pole, and the magnetic field lines radiate from these. Metals such as iron, cobalt or nickel have magnetic properties and can be made into permanent magnets.

Magnetism can also be produced using electricity. The most important component of an electromagnet is a coil. It basically consists of a solid centre with a metal wire wrapped around it. Connecting both ends of the wire to a battery allows electric current to flow through the wire and produce a magnetic field.

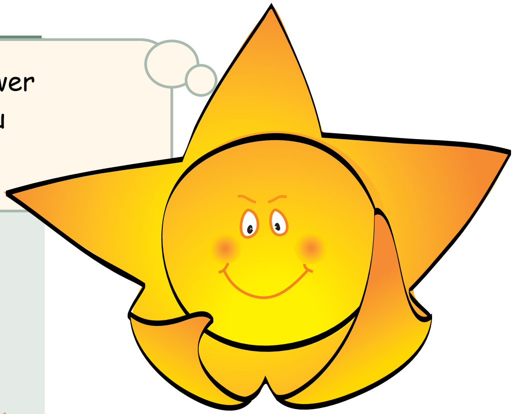
For its ASDEX Upgrade fusion experiment, IPP needs 16 coils weighing as much as 112 cars! The coils are arranged in such a way that the magnetic field lines build a closed, ring-like cage.

It is not just filings that line themselves up in a magnetic field. Atom nuclei and electrons within plasma do the same. This is simply a law of nature!

The atoms in the huge sun are held together by their own weight. To create a power plant on earth operating like the sun, physicists have come up with a very clever idea. They use magnetic forces to keep the atoms together.

Fusion power – How does it work?

I think there will be fusion power plants one day. How old will you be in 2050?

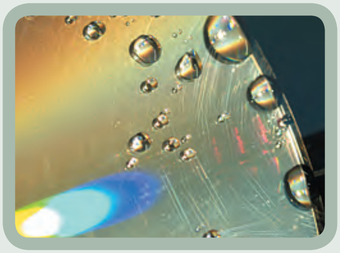


Experiment:

Fusing water droplets

What do you need?

- A CD cover or a CD that is no longer needed
- A pump spray bottle to be filled with water
- Pencil or tooth pick



How do you do it?

Pour a little water into the pump spray bottle.

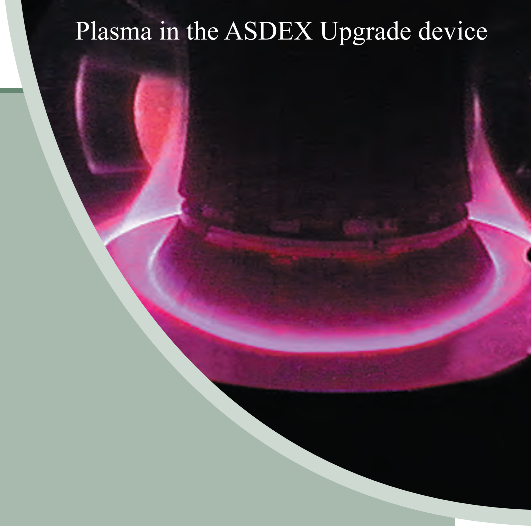
Put the CD, with the shiny side facing up, onto a waterproof surface and spray some water on it.

Hold the CD at an angle, dip the tip of your pencil into one of the droplets and pull it across the CD surface to the next droplet. Continue to the next drop, and the next …

What did you see?

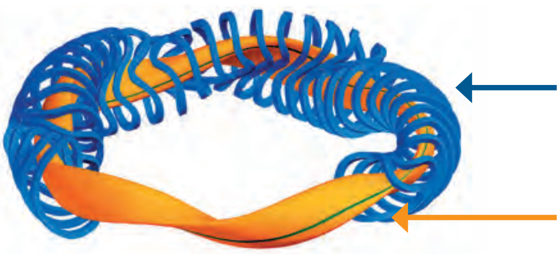
Take a look at page 12 to see what other people have discovered.

Fusion power – How does it work?


Plasma in the ASDEX Upgrade device

This is how physicists imagine a fusion power plant: Electromagnets are lined up in a vessel and are switched on. The magnetic field cage forms inside the vessel. The vessel is filled with atoms which are heated to hundred millions degrees: A plasma is generated.

The atom nuclei and electrons now move very quickly, they collide, some nuclei fuse and produce thermal energy which is converted into electricity.



Wendelstein 7-X

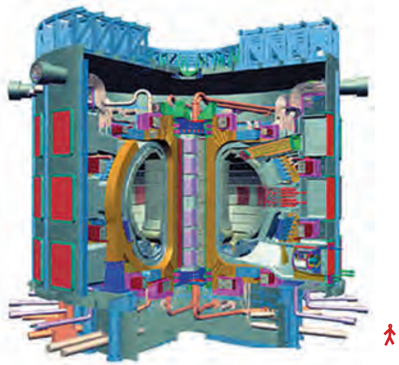
Fusion power is amazing! The energy content of a single gram of fusion fuel is the same as an entire freight waggon full of coal!

The JET experiment belonging to a research institute in England succeeded in producing fusion power – what a great achievement!

But for a real power plant, the amount of energy won must be higher. This is why researchers across the world are working on lots of experiments in order to find out more about atoms, plasma and fusion.

Physicists at IPP are working on their ASDEX Upgrade experiment in Garching and just have built a new one in Greifswald, the Wendelstein 7-X.

By 2050 we should have learned enough from these experiments to help us to build a power plant capable of using fusion energy to provide big cities with power.



They have already started work on ITER, the world‘s largest fusion experiment, in the South of France. Can you find the little man on this picture? Look how small he is compared to the machine itself! Now, you can imagine how big a fusion power plant will need to be.

Check your findings

Here you will find explanations for your experiments

Page 2

Energy drink
Why is sugar important?

The sugar you added, along with the banana fructose, quickly provides your body with new energy so that you will feel alert and strong enough to carry out the next experiments.

Page 4

Producing energy
What did you notice?

An invisible force allows the balloon to attract the pieces of tissue paper and the grains of rice. If the weather is particularly dry, you may even see the grains of rice dance!

Why does this happen?

You rubbed electrons away from the outer shells of the atoms. This creates a charge separation and the balloon attracts the shreds of paper as a result. The harder or longer you rub, the better the paper sticks to the balloon and the grains of rice dance for you!

Further experiments ...

Try rubbing a plastic ruler or an empty, dry plastic bottle instead of a balloon.

Page 6

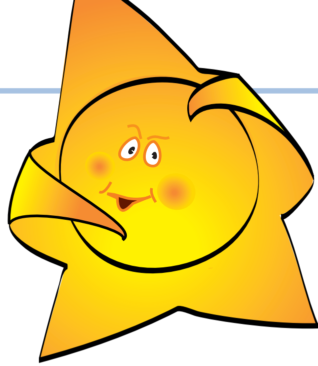
Building a model atom
What did you see?
Use your imagination!

The soap bubble is a half-sphere shape gleaming over your hand-made “atom nucleus”. Squint your eyes and imagine how the electron “rushes” over the surface of the ball.

Page 8

Building a magnet
What did you see?

The paper clips or drawing pins are attracted as long as the current flows. Cut off electricity and the effect decreases.



Why does this happen?

The coiled wire allows electricity to flow and creates a magnetic field within the nail. The more the wire is coiled, the stronger the magnetic field becomes.

Page 10

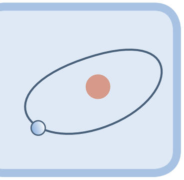
Fusion of water drops
What did you see?

The round drops fuse to create a larger drop. You can no longer identify the two original drops, or however many drops you started with.

Further experiments ...

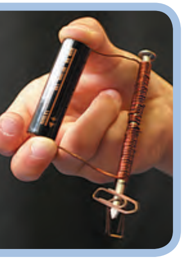
“Oil drop” fusion: Oil drops found on the surface of a soup or in a salad dressing can be fused by using a spoon to connect them.

Definitions – in a nutshell



Atom and
Atom nucleus

Everything around us – plants and animals, stones, planets, sand, people – consist of tiny elements known as atoms. An atom is made of a nucleus and one or many electrons.

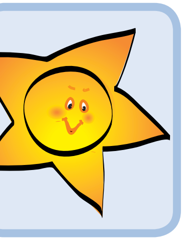


Electromagnets

We can produce magnetism with electricity. A coil plays the most important part of an electromagnet. A basic coil consists of a body and a metal wire which is coiled around it. If both ends of the wire are then connected to a battery, the current flows through the wire and creates a magnetic field.

Electrons

Very tiny particles called electrons circle around the atom nuclei. A similar pattern, although much larger, can be seen in the universe: the planets circling around the sun.



Energy

There are many forms of energy. Your body takes its energy from the food you eat and transforms it into movement and warmth. Energy does not just disappear, but is transformed into something else. For example, electricity flowing through a bulb is converted into light energy and heat.

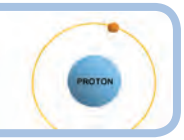
(Non) renewable energy

Sun, wind and water cannot be used up. Biomass can be produced quickly. This is why these are referred to as renewable energy sources. Gas, coal and oil reserves which are formed over the course of millions of years are non-renewable energy sources and are also called “fossil fuels”.

Experiment

Latin *experimentum* “trial, proof, checking, test”. Whenever you are testing something in order to find out how it works, you are conducting an experiment.

Definitions – in a nutshell



Fusion

An enormous amount of energy is released when atom nuclei melt, this process is called fusion. This is how the sun has been producing energy for 4.5 billion of years.

IPP

IPP is actually the Max Planck Institute for Plasma Physics and is working on plasma physics and fusion research.

ITER

The largest international fusion experiment in the world, ITER, is currently being built in the South of France.

Nuclear energy

We talk about “nuclear energy” when we refer to energy that originates from the fission or fusion of atom nuclei.

Power plant

In a power plant, substances like coal are burned in order to generate heat and electricity.

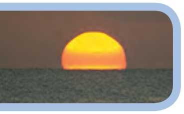
Magnet, Magnetic field, Magnetic field lines

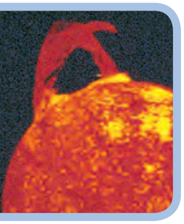
A thing that attracts or repels something is called a magnet. Magnetic forces can be found in nature. All forms of magnetism come from electric charges. Magnetic forces are to be found along so-called magnetic field lines when fine iron filings line up in magnetic fields.

Million and Billion

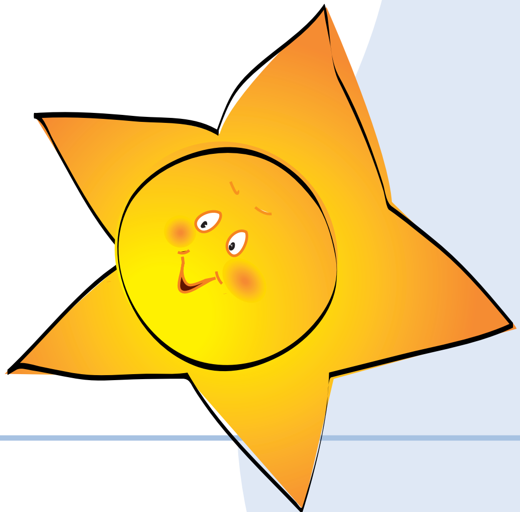
One million, as a number, is a 1 with 6 zeros behind it, so it is written 1,000,000. A billion is thousand times more, so it is a 1 with nine zeros: 1,000,000,000.

Definitions – in a nutshell





Plasma and Plasma physics	Plasma is a gaseous medium. Atom nuclei and electrons move separately. You can see plasma in nature, as a bolt of lightning, at home in a fluorescent light tube or in energy-saving light bulbs. Plasma physics investigates the behaviour of that gas.
Solar collectors	Solar collectors use sunlight to produce electricity and warmth.
Sun	As an energy supplier, the sun is very important for the earth. It is the sun which makes it possible for the planet to have a weather system and a climate. And without the sun there would be no life. A lot of energy is required to do all this and this energy is produced inside the sun by nuclear fusion.
Transformer station and Junction box	They are part of power plants and ensure the distribution of electricity in the cities, to homes and to the power socket.
Scientists	… work in many fields, for example in biology, history, medical science, astronomy (science of the stars), or physics. Physicists analyse natural activities and laws.



For parents and teachers

Are your children interested in science? The Max Planck Institute's "kids-bits" programme in Garching is offering "Living Science" for children of different ages. Several activities are designed especially for children aged 3 to 13.

All of the programs have one thing in common, they make a point of getting the children to join in and ask questions.

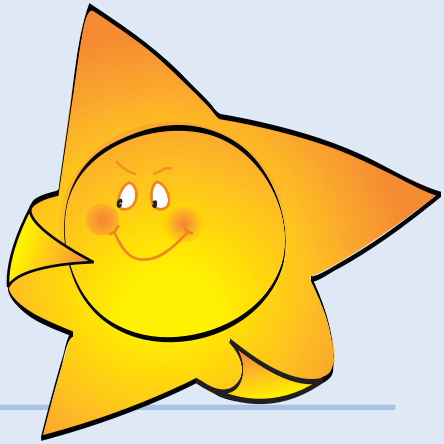
From January to July, experienced colleagues from our institute are available at IPP to host nursery schools, preschools and primary schools.

You will need to set aside about two hours for the activity session. This will involve talking to the children and carrying out experiments which will give them an exciting and interesting insight into fusion research.

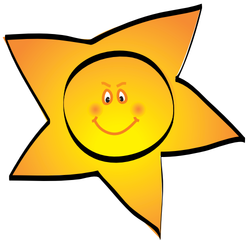
If you would like to register your class or a group of children, please take a look at

www.kontakt.kidsbits.info

to find out all you need to know. Above web sites are only available in German and visits to the IPP are conducted in German too.



The “kidsbits” programme in 2005 received financial support from Pallas Athene, the European “Ambassadors for Women and Science” project. Max Planck Institute for Plasma Physics regard this as recognition of their activities in promoting the young generation. This funding also served to produce the very brochure you are now reading.



Thank you very much to all of the small and large scientists for their tireless proofreading efforts, their suggestions and patient photo sessions!

Come and visit IPP – at Garching or Greifswald:

We invite all interested adults, as individuals or groups, to come and visit our institute. Fusion research will be introduced in a comprehensible way and you will be able to find out about the achievements and possibilities. Visit Garching and Greifswald to discover what fusion experiments are all about!

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