Premier Issue

The Young Scientist

December 1980

FUSION

Bringing the star power of fusion down to Earth

Welcome to The Young Scientist

Science & mountain climbing

What will our lives be like if we can bring the power of the stars down to Earth? How can we build and harness an energy source that operates at a temperature of 100 **million** degrees?

How will a better understanding of how new forms of life developed help us to create improved medicines and better ways to grow food? What are the most important areas of science for helping the world to meet its needs in energy and food and to provide an improving life for all people? What are the unsolved problems in understanding how the universe and life continuously develop?

These are the questions we will be asking and answering with every issue of *The Young Scientist*. If you become a regular reader, you will be joining a very special group of young people who are becoming actively involved in the most important and exciting activity in the world—science!

Some people think science is formulas and facts, that it's "hard." Like any challenge, it does involve hard work. But it's like climbing a mountain—the higher you get, the broader your view.

We're beginning *The Young Scientist* with this issue because we are scientists who have seen the tremendous challenges and possibilities for science to produce the knowledge and the inventions that our planet needs in these last decades of the twentieth century. Science is like life itself: it cannot exist without progress, but progress raises new problems and challenges that must be solved with ever more advanced ideas and technology.

What are our plans? *The Young Scientist* will fill you in on the major areas of science and explain their significance with feature articles and photographic essays. The News section will bring you up to date with the latest advances in science.

We plan to take you up many mountains, so that after awhile, you can begin to see the whole picture of science, how it developed, where it is going, where it is needed. At first, we will be published every other month. As our readership grows, we will publish monthly during the school year.

But this is our most special issue, because we're meeting you, the young scientists, for the first time. Welcome!

Dr. Morris Levitt

December 1980 Vol. 1, No. 1

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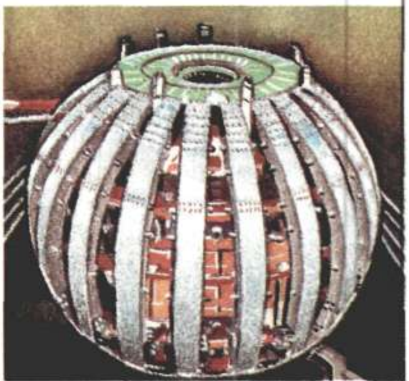
The Young Scientist



The Doublet III tokamak
—see p. 6.

About the cover

Photographer Dave Feiling used a model of the Tokamak Fusion Test Reactor at Princeton Plasma Physics Laboratory in New Jersey and a satellite photograph from NASA of newly formed stars in this collage on "star power." This month's young scientist is Elisa Henke of New York City.

news...

TECHNOLOGY

Trains without wheels!

Imagine getting on a train in New York and arriving in California 21 minutes later! It would take you five hours to fly there in an airplane today. But if the new magnetic train is developed, 20-minute cross-country trips will become commonplace.

The magnetically levitated train, which doesn't run on wheels but "floats" near the ground, is being developed by the West Germans and Japanese. It is kept completely off the train rail by magnetic fields, which lift the train—"levitate" it.

The magnetic fields in the train itself are repelled by the magnetic field in the rail, just as a horseshoe magnet "pushes" against another magnet. This lifts the train off the track and propels it forward, so no diesel or electrical engine is needed.

The train travels just a few inches above the track, but never touches it. The only thing that slows the train down is air resistance. But if the magnetically levitated train is put in a tube built underground with most of the air removed from the tube, there would be no air resistance. So the train could go thousands of miles per hour! The only limit would be the comfort of the passengers in starting and stopping.

The magnetic fields in the train and rail are produced by electricity—a moving electric charge always produces a magnetic field around it. So these trains would only need electricity for power and would save gas and diesel fuel supplies. They would also be clean and noiseless, giving passengers a fast, pleasant trip.

The Japanese now have a magnetically levitated test train running successfully at more than 300 miles per hour.

This experimental magnetic train floats on a cushion of air.

Hot off the wire... Hot off the wire... Hot off the wire...

Historic fusion bill passed: On September 23 the U.S. Congress passed a bill to spend $20 billion over 20 years for testing and developing working fusion power reactors. Nuclear fusion uses hydrogen from seawater as the fuel to produce tremendous amounts of electrical energy and heat for factories, homes, and transportation.

Mike McCormack, the Democratic Congressman from Washington who introduced the bill in the House of Representatives, compared passage of the bill to the Apollo effort that successfully put a man on the Moon in 1969: "This is the single most important event in the history of mankind. Once we develop fusion we will be in a position to produce enough energy for all time, for all mankind." The United States now has a project that may begin to solve the energy problem by the year 2000.

Hot off the wire... Hot off the wire... Hot off the wire...

BIOLOGY & MEDICINE

Recombinant DNA will help diabetics

Human insulin grown in bacteria using the biological technique called recombinant DNA has been tested in human volunteers and appears to be safe and effective. When the insulin has been tested on diabetic patients and the U.S. government approves its use, it will be produced in large volumes for doctors to prescribe to their diabetic patients.

The insulin is needed to help people who suffer from the disease called **diabetes**. People with diabetes don't produce enough insulin. Insulin controls sugar in the blood, which is the energy source for everything we do. Without insulin, there's too much sugar in the blood, but it can't be used by the cells. So diabetics have no energy and tend to get overweight. They suffer from poor circulation, and a small cut can cause gangrene and the loss of a leg or foot. They can go blind—diabetes is the leading cause of blindness.

People with milder forms of diabetes can be helped by diet alone. Doctors help other diabetic patients by giving them shots of insulin that is taken from the bodies of pigs or cattle. But many diabetic patients have allergic reactions to animal insulin, which is different from human insulin. So the new human insulin produced by bacteria offers new hope for diabetics.

The insulin is produced by the biological technique called **recombinant DNA** or "gene splicing." DNA stands for deoxyribonucleic acid, which is the genetic material in cells. DNA provides the code for the cells to make proteins, and insulin is one of the many proteins made.

In recombinant DNA, the genes that tell how to make insulin are cut off the DNA molecule and recombined with DNA from bacteria. This recombined DNA is then put into a special bacteria, which acts out the genetic instructions and starts to manufacture human insulin.

This human insulin will be much better than animal insulin because it is purer, cheaper, and can be produced in large volumes. A shortage of animal insulin is expected in 20 years. But most important, the bacteria-grown insulin is exactly like the insulin produced in our bodies and will not cause a bad reaction.

The next step will be to use genetic engineering to change human cells so that they produce insulin and then implant these cells back into the bodies of diabetics, to replace their own pancreas glands that have stopped making insulin.

Hot off the wire...

Fighting fire ants: The U.S. Environmental Protection Agency has approved use of the insecticide Amdro to fight fire ants. Especially since the insecticide Mirex was banned in 1978, fire ants have been spreading throughout the South and now infest 9 states. Their concrete-hard mounds, 3 or 4 feet high, damage farm machinery. Cattle avoid fields with fire ant mounds, making large areas unusable. Fire ants attack humans, animals, and birds, sometimes killing them.

Halley's Comet

Exploring Halley's Comet. The European Space Agency is building a spacecraft to fly by Halley's Comet, which will pass by the Sun in 1986. Comets are celestial bodies that revolve around the Sun in orbits tilted to the flat plane in which the planets orbit. The bright nucleus of the comet is surrounded by a fuzzy head of material that turns into a tail of dust, gas, and ice when the comet comes close to the Sun. The nucleus contains material that existed before the Sun was formed. The spacecraft will provide new information about comets and how they are affected by the Sun's heat. This is a rare opportunity, since Halley's Comet approaches the Sun only once every 76 years.

Hot off the wire...

Solar Polar Mission to explore Sun

This artist's depiction shows the two Solar Polar spacecraft orbiting the Sun's poles.

The Solar Polar Mission, to be launched by NASA (National Aeronautics and Space Administration) in the 1980s, will provide new information about the Earth's nearest star, the Sun. The Sun is a huge fusion machine, producing energy by the fusion of light elements in its core, and learning more about this process will help scientists build fusion machines here on Earth.

The Solar Polar Mission will also gather information about the magnetic fields produced on the Sun, which seem to play an important role in sunspots, flares, and prominences, and which have an effect on the Earth's weather and climate.

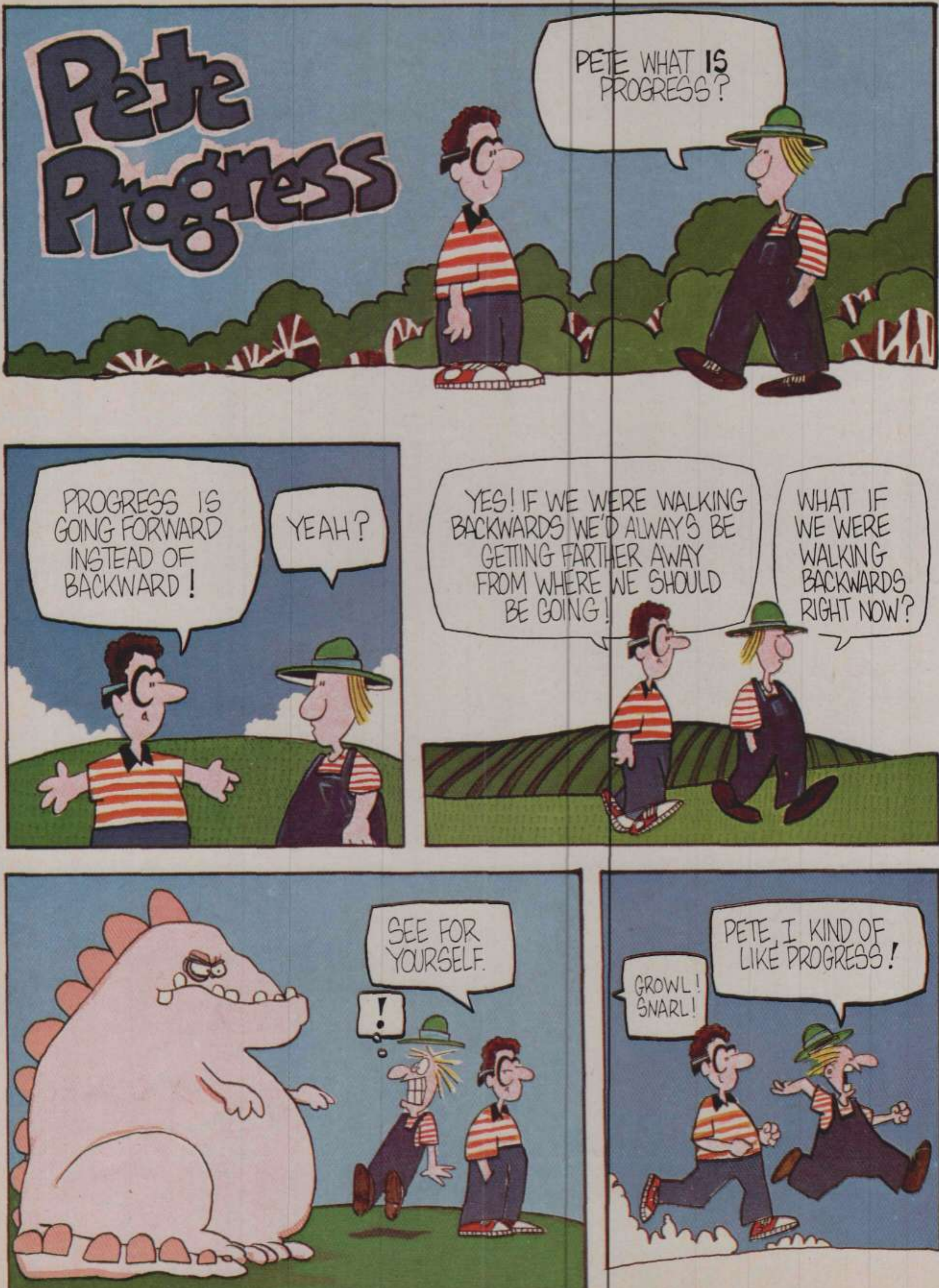
The visible sunlight that we see is energy produced by the fusion machine of the Sun. This energy is constantly radiated toward the Earth, where some of it is captured by the Earth's atmosphere and magnetic field. The Solar Polar Mission will help scientists learn more about how energy is organized on the hot surface of the Sun and how that energy eventually reaches the Earth and other planets.

The Solar Polar Mission will send up two spacecraft. They will be launched in space by the Space Shuttle and head for the giant planet Jupiter. The tremendous force of Jupiter's gravitational field will propel the spacecraft back toward the Sun with greater force, like a sling shot. They will then reach the Sun and orbit around the north and south poles.

The spacecraft will get much closer to the Sun than ever before, although not close enough to overheat. They will go around the quietest part of the Sun, the poles. (This is why the mission is called "Solar Polar.")

For many years, scientists have noticed dark spots on the Sun, called sunspots. These are regions of great energy activity. The polar caps of the Sun seem less active and have a weaker magnetic field, although there is a wind of particles blowing from the poles out into space. Scientists hope to learn why the poles behave the way they do.

The mission will also provide the first three-dimensional look at the Sun by taking pictures of it from two different places at the same time. All other pictures have been taken from Earth or Earth orbit. Solar Polar will thus be looking at the Sun with two eyes at once, instead of just one eye.


Pete Progress
PETE WHAT IS PROGRESS?
PROGRESS IS GOING FORWARD INSTEAD OF BACKWARD!
YEAH?
YES! IF WE WERE WALKING BACKWARDS WE'D ALWAYS BE GETTING FARTHER AWAY FROM WHERE WE SHOULD BE GOING!
WHAT IF WE WERE WALKING BACKWARDS RIGHT NOW?
SEE FOR YOURSELF.
!
GROWL! SNARL!
PETE, I KIND OF LIKE PROGRESS!

The tokamak

Bringing the star power of fusion down to Earth

by Charles B. Stevens

Can you imagine a world with an unlimited supply of cheap energy? Just think of how many things that seem impractical today would become possible. Such a world is not just a dream; it can happen in your lifetime with the development of fusion energy.

By the end of 1981, scientists at Princeton Plasma Physics Laboratory in New Jersey will have built a machine for making man-made stars—a fusion machine. Like the Sun, these man-made stars will generate large amounts of energy from the fusion of hydrogen atoms to form helium atoms.

Once this has been done, we can start developing the technology for harnessing fusion energy to produce electric power before the year 2000. This will be a great moment in history, because all of mankind can then use fusion energy to heat their homes and run their factories for millions of years.

The fuel for fusion energy production is a special kind of hydrogen called **heavy hydrogen**. This heavy hydrogen is found in ordinary seawater. It is easy to get and very cheap. When "burned" in a fusion power plant, the heavy hydrogen in 1 gallon of seawater is equal to the energy in 300 gallons of gasoline. A few pounds of the pure heavy hydrogen will provide enough energy to run a large city for several weeks. And there is enough fusion fuel in the oceans to meet the energy needs of the entire world for millions of years!

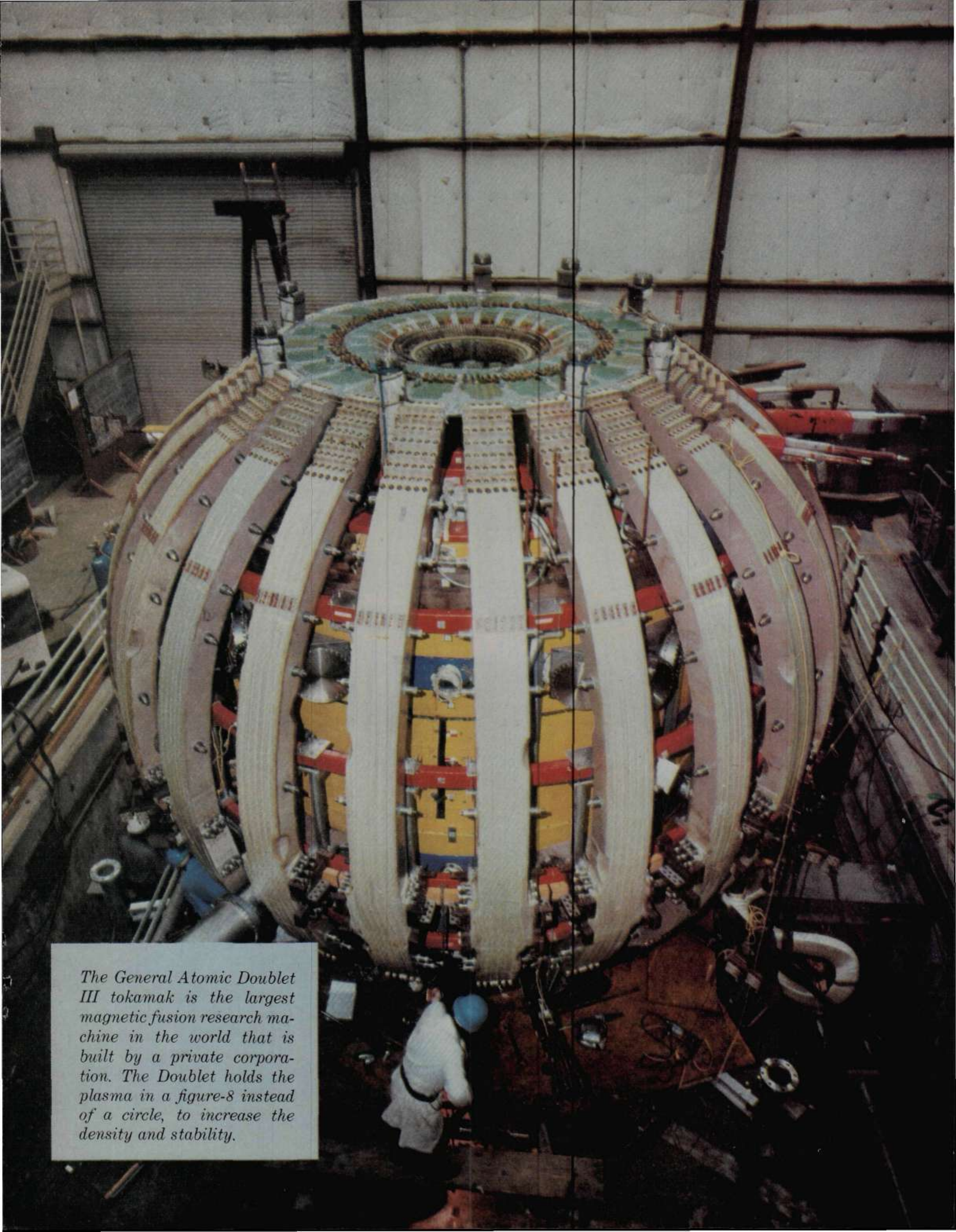
How fusion works

Most of the atoms out of which the Earth is made were at one time created by the fusion of hydrogen atoms. This process is called **nuclear fusion**. Until recently, nuclear fusion only took place in the very hot and dense centers of stars. At very high temperatures, measured in tens of millions of degrees, atoms of lighter elements like hydrogen can be fused to form atoms of heavier elements.

The huge mass of a star generates an intense gravity force field. This gravity force field produces the high temperatures needed to spark nuclear fusion. And it also holds the fusion fuel together while the star "burns."

Scientists are trying to harness this tremendous

It is estimated that our supplies of coal, oil, and nuclear fuel will run out in about 100 years. But the fusion fuel in our oceans will last for a billion years.



The General Atomic Doublet III tokamak is the largest magnetic fusion research machine in the world that is built by a private corporation. The Doublet holds the plasma in a figure-8 instead of a circle, to increase the density and stability.

"star power" on Earth in a fusion power machine. Because this process has to be controlled, it is known as controlled nuclear fusion, compared to the uncontrolled fusion energy of the stars.

For man-made stars here in the laboratory, fusion researchers have designed magnetic force fields to control the fusion fuel and keep it from losing heat. In this way, once the hydrogen fuel is heated to the fusion temperature, it can be kept at this temperature and held together. Scientists call the magnetic system they use to capture a star on Earth a **magnetic bottle**.

The most successful type of magnetic bottle for controlling burning fusion fuel is the **tokamak**. In Russian, tokamak means "donut carrying an electric current," a good description of a fusion machine.

The tokamak was originally developed by Soviet scientists. Once the Soviets began to reach temperatures that were almost hot enough for fusion in their magnetic bottle, scientists from other countries became interested in the tokamak. In the early 1970s, several tokamak machines were built in the United States and in other countries.

How tokamaks work

If you examine a donut-shaped fluorescent light like those found in kitchens, you will be able to see many things that are similar to the tokamak. When you turn on the switch, an electrical current flows through the gas in the donut-shaped glass light tube, which gives off ultraviolet light. When this ultraviolet light strikes the **fluorescent** coating on the inside of the light tube, much white light is produced.

In a sense, the fluorescent light is a kind of tokamak—a donut carrying an electric current. But in a real tokamak, a much larger electrical current is made to flow around the donut. This heats the gas to several million degrees. And instead of fluorescent gas, the tokamak uses heavy hydrogen fusion fuel.

Hydrogen is a gas, and it also shines light

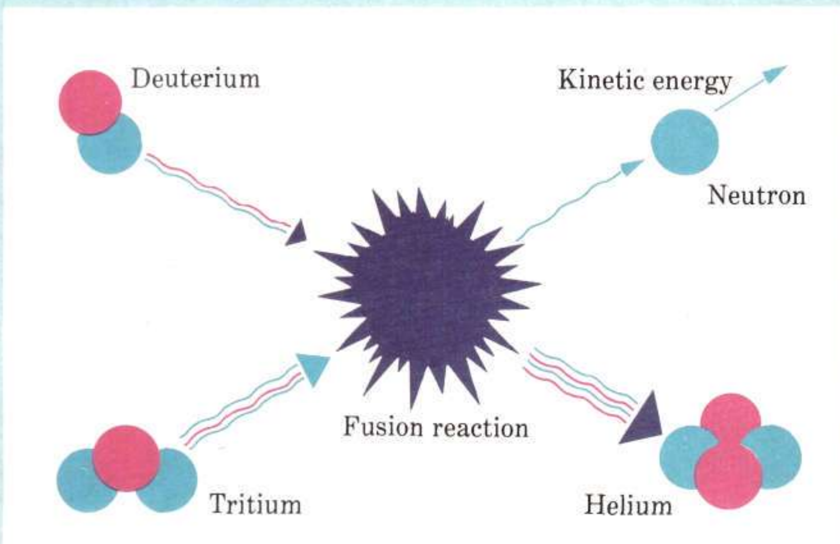
How fusion turns water into energy

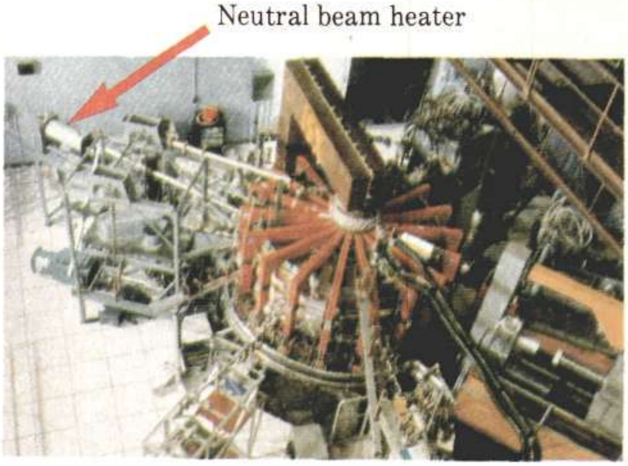
All material is made up of atoms, joined together as molecules. For example, water is called H_2O because it has two atoms of hydrogen (H) and one atom of oxygen (O) in each molecule of water. In the center of each atom is the **nucleus** (plural **nuclei**), which has smaller pieces called **protons** and **neutrons.** The number of protons tells you what kind of atom it is—hydrogen always has one proton, for example. But the number of neutrons can change, without changing the identity of the atom.

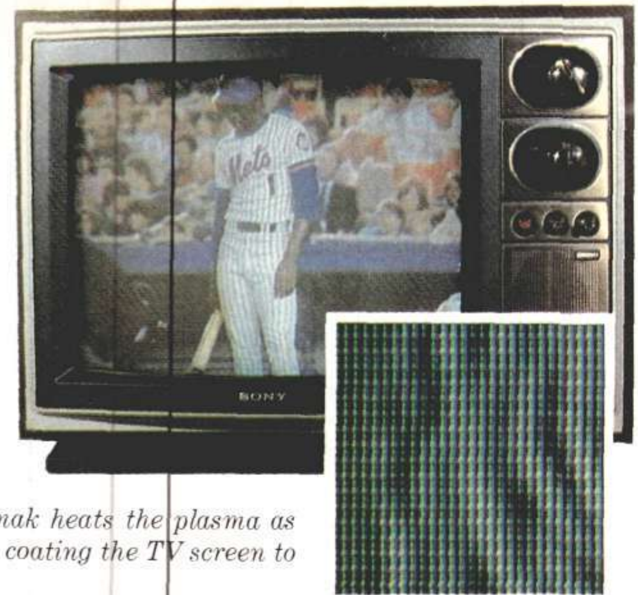
Most of the water in the oceans has hydrogen atoms with just one proton and no neutrons at all. But some of the water is called **heavy water** because it also has a neutron in the hydrogen atom's nucleus—it is heavier than the other hydrogen, but it's still an atom of hydrogen, and the molecule it's in is still H_2O, water.

When an atom splits and its nucleus breaks into smaller pieces, we call this **nuclear fission.** Nuclear fission is what supplies the energy in our modern nuclear power plants. But when the nuclei of two different atoms join together or "fuse," we call this **nuclear fusion.** Fusion is what goes on all the time in stars and in the Sun, making all their light and heat energy.

The fusion energy that scientists are working to produce







The neutral-beam heater on the Oak Ridge ISX tokamak heats the plasma as an electron beam heats the millions of fluorescent dots coating the TV screen to produce an image.

when it is heated. But when we heat hydrogen to a temperature high enough—above 50 million degrees Celsius—the hydrogen atoms undergo nuclear fusion and energy is generated. As in the Sun, this fusion energy will come out of the hydrogen gas in the form of light and heat. We can then use the fusion energy either to make electricity or run a factory.

By itself, the tokamak is unable to reach the temperatures needed to generate fusion. That is, the electrical-current heating is not hot enough. Therefore, we must add additional heaters to raise the temperature further. One way scientists have done this is to use **microwaves**. In the same way that microwaves cook our dinners in a microwave oven, when microwaves are directed onto the tokamak they "cook" the hydrogen gas to higher temperatures.

Another additional heating method is to use **neutral beam heaters**. (You can see the neutral beam heaters in the photograph of the ISX tokamak.) This works very much like a TV set. In a TV set a very hot beam of electrons is generated. These electrons are directed onto the TV screen, which has a fluorescent coating that lights up when it is heated by the

on Earth comes from making two nuclei of hydrogen join together and form an atom of helium. Helium has two protons and two neutrons in its nucleus. So scientists use an atom of heavy hydrogen, which has one neutron in its nucleus. This atom of hydrogen is called **deuterium.** They also use another atom of hydrogen that they make in a nuclear-fission process, which has two neutrons with its one proton. This special atom is called **tritium.**

When the two hydrogen atoms are "squeezed" together at very high temperatures in the fusion plasma, the neutrons and protons get all mixed together and turn into an atom of helium. We started out with two protons, one from each hydrogen atom, and we end up with two protons, because an atom of helium always has two protons in its nucleus.

But what about the neutrons? Remember that we had three neutrons altogether: one neutron in the deuterium atom and two neutrons in the tritium atom. Helium is most comfortable with just two neutrons, however. So one of the neutrons is left over, and gets thrown away with tremendous speed.

That's where most of the energy from the fusion process is: The kinetic or moving energy of the neutron can be changed into heat energy and then into electricity, just like in a power plant that burns coal or oil. The main difference is that we get so much more energy from fusion than we get from burning oil. If we use 10 units of energy to heat and squeeze the fuel, we get 18,000 units of energy from the fast neutrons. Fusion energy is the cleanest, most efficient power source known—and it runs on water.

hot electron beam. In this way the TV picture is produced.

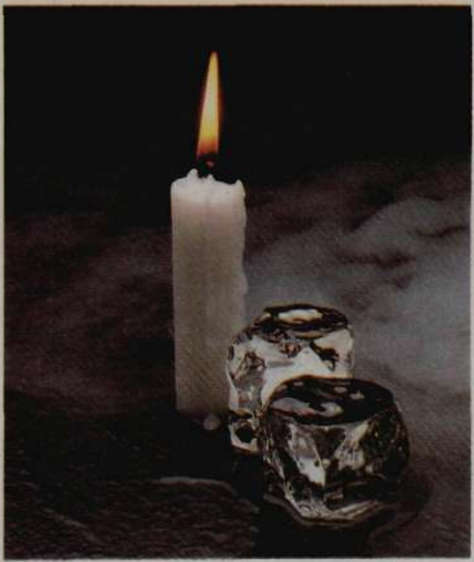
For heating tokamaks, a beam of "hot," electrically neutral atoms is used instead of electrons. Only electrically neutral atoms can get inside the magnetic force field that makes up the tokamak bottle.

How magnetic bottles work

So far we have found how to make a tokamak—a donut of gas carrying an electrical current. Second, by using either microwaves or "hot" neutral beams, we also have a way to heat the tokamak gas up to fusion temperatures.

But if we tried to get fusion in this way, it still would never work. The heat that we put into the hydrogen gas would simply escape long before we had cooked enough to reach fusion temperatures. To solve this problem, we must come up with a bottle that will trap the heat in the donut of hydrogen gas.

An ordinary gas bottle could not withstand the 50 million degree fusion temperatures without melting, even if we made the bottle out of steel.



The fascinating thing about fusion is that the solution to trapping the hot hydrogen gas in the tokamak long enough to keep the fusion reaction going is right in the hydrogen gas. The superhot hydrogen can make its own "wall" to contain the fusion reaction. The reason that the hydrogen gas shines light and carries an electrical current when it is heated to high temperatures is that it becomes "electrified." When matter is electrified it is called **plasma.**

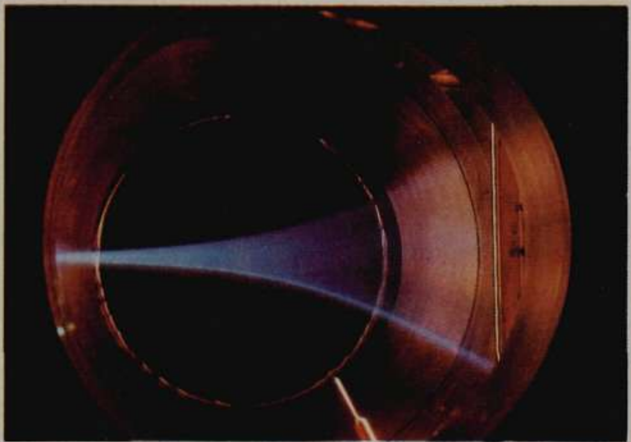
Plasma is very different from the ordinary forms in which we find matter. Usually matter on Earth is in a solid, liquid, or gas form. Plasma is a fourth kind of matter with new qualities. In fact, most of the matter in the universe—99 percent—is in the form of plasma, because it is contained in very hot stars.

One of the very special qualities of the plasma form of matter is that the plasma is **electrified** and will therefore be affected by an electrical force field.

Every time we have an electrical current, an invisible "electrical" force field is created, called a **magnetic field**. And this magnetic force field can withstand any temperature without melting since it is not made out of matter. But to a plasma, the magnetic force field acts just like a wall. So we can make a bottle out of magnetic force fields to prevent heat from escaping from the fusion fuel while we heat it to fusion temperatures.

In the tokamak, a donut-shaped magnetic bottle is created by placing magnet coils around the outside of the donut-shaped tokamak container. Electrical current is passed through these metal coils, generating a donut-shaped magnetic bottle. The electrical current flowing in the hydrogen gas within the tokamak also helps form the magnetic bottle.

The details of how this magnetic bottle is formed are quite important. Even a small "leak" will prevent the tokamak from reaching temperatures hot enough for fusion. Also, once the tokamak reaches



Top picture: Matter can exist in four different states: solid—the ice; liquid—the water; gas—the cloud of water vapor; and plasma—the charged ions in the flame of the candle. Bottom picture: In this picture of the fusion plasma inside a vacuum chamber, you can see how the magnetic fields bend and shape the plasma ions.

fusion temperatures, enough heat must be trapped in the bottle to keep the fusion fuel at the needed temperature.

On our way

Scientists working together from almost every country in the world have shown that the tokamak magnetic bottle is very good for fusion. It is leak-proof enough to produce fusion temperatures. At the Princeton Plasma Physics Laboratory, fusion scientists working on the PLT tokamak machine have been able to heat hydrogen gas to 80 million degrees Celsius by using neutral beam heaters. This is well above the temperatures needed for fusion.

Scientists all over the world, using various types of fusion machines, are working to fulfill the conditions needed for a commercial, economical fusion power reactor. The conditions required are:

Temperature: 44 million degrees Celsius is needed to ignite the fuel.

Density: The density of the fuel must be high enough to make sure that every nucleus hits another nucleus before leaving the plasma.

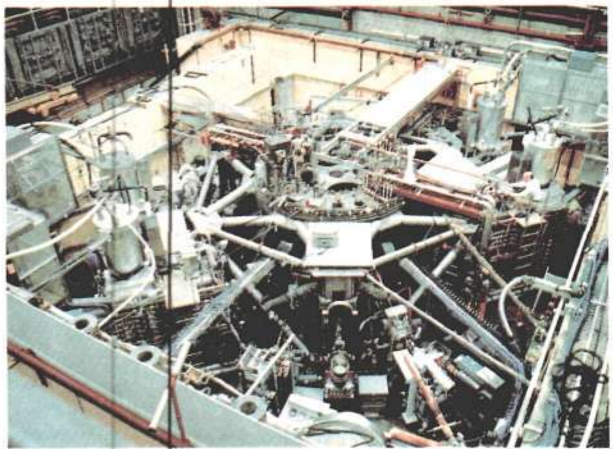
Stability: The fuel must be contained long enough for energy to be produced in an amount greater than the energy that is put in.

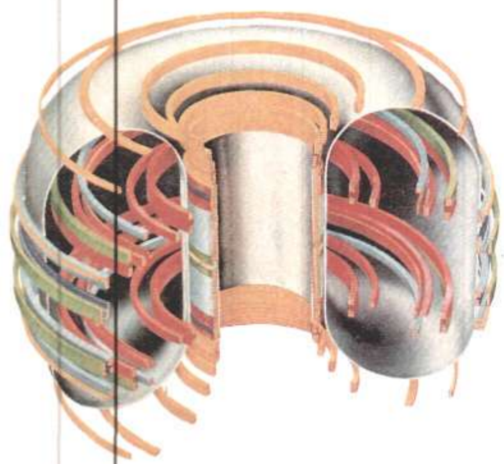
Energy loss: The plasma must be very pure to avoid loss of heat by impurities from the walls of the tokamak.

Power density: The amount of energy per area and time must be very high.

Magnetic fields: The entire technology of superconducting magnets must be highly developed because commercial power plants will require gigantic magnets. Ordinary magnets would overheat from the huge power flowing through them. But superconducting magnets are made of material so cold that it has no resistance to electricity and can handle huge power loads.

A Tokamak Fusion Test Reactor being built at Princeton University will begin working in 1981. This machine will be the first magnetic bottle actually to create fusion on a large scale. Scientists agree that it is almost certain to be a success. After this model, electric power plants using fusion energy can be designed. And by the year 2000, tokamak fusion reactors should begin to supply some of the energy that we consume. Later in the 21st century, all of the world's energy needs can be met by fusion reactors.





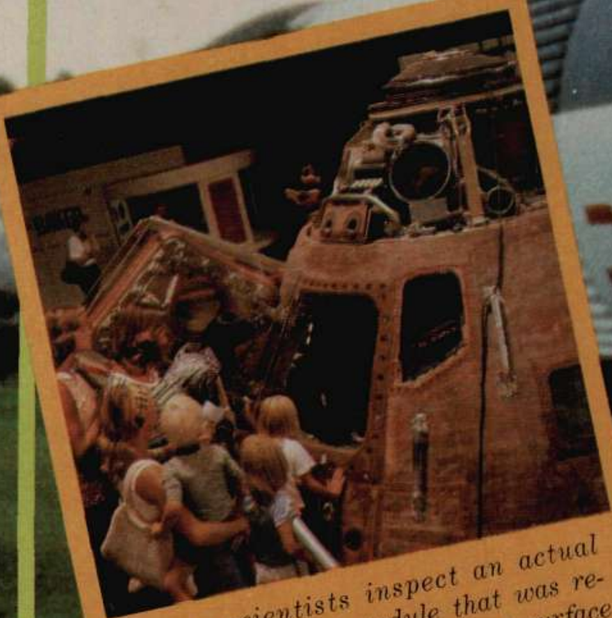
Top: The PLT tokamak at Princeton Plasma Physics Laboratory was the first fusion machine to reach fusion ignition temperatures (80 million degrees Celsius). Middle: Workmen are shown laying the base magnets for the PDX fusion machine at Princeton, the world's largest tokamak. Bottom: This drawing shows how the magnetic force fields passing around and through the PDX contain and shape the fusion plasma.

Science on tour

The biggest space museum in the world

by Paul Everitt

Would you like to fire a live rocket engine? Guide a spacecraft by computer? Or command your own missile defense squadron? Visitors to the Alabama Space and Rocket Center can do all this and more, at the largest space museum in the world. Located in Huntsville, Alabama, the museum has more than 60 exhibits for visitors to take part in, as well as $35 million of hardware actually used in the U.S. space program. The museum also provides bus tours of Marshall Space Flight Center, where the Space Shuttle, Spacelab, and other NASA projects are being developed. There you can watch astronauts training in the neutral buoyancy simulator, a gigantic water tank that imitates the conditions of zero gravity. The museum was dedicated by the citizens of Alabama to "those Americans who made it possible for man to walk on the Moon and to the youth of America who will use the technology of space for the benefit of mankind."



Young scientists inspect an actual Apollo command module that was recovered from space. Its burnt surface reflects the 5,000-degree temperatures caused by friction as it re-entered Earth's atmosphere at 25,000 miles per hour, bringing its astronaut safely home.

The Space Shuttle will be launched in 1983 to c and supplies into space and back. Visitors here l it will feel aboard the Shuttle Spaceliner blasti Earth orbit.

Alabama Space and Rocket Center

The Apollo Saturn V Moon rocket at left was used as a test model for the family of Saturn V rockets that carried man to the Moon and put the Skylab space station in orbit. The smaller rockets on the right were military forerunners of America's space program.

The Lunar Odyssey, a spinning theater with movies and sound effects, lets you feel the gravity forces of an actual trip to the Moon.

Miss Baker, America's "first lady in space," was just two years old when she made her historic suborbital journey aboard a Jupiter rocket on May 28, 1959. To show that the 10,000-mile/hour trip didn't faze her, the monkeynaut bit the hand of a rescuer upon landing, and then retired to a well-deserved life of plenty of bananas and admiring visitors at the museum.

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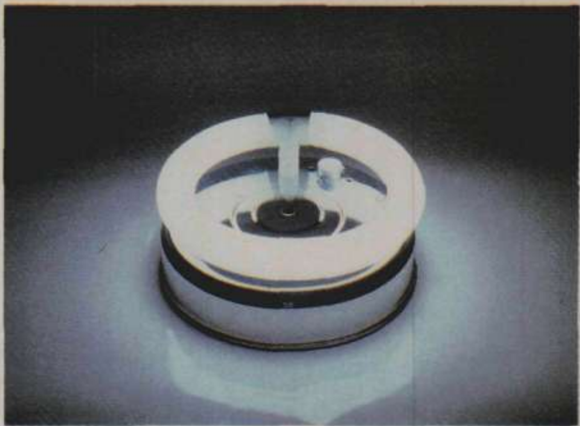
For more information, call (800) 633-7280.

Magnetic Fields



A fluorescent light illustrates the principle of magnetic confinement of charged ions, like those in a fusion plasma.

Magnetic fields are very important for fusion because they are used to confine the hot plasma and keep it from losing heat to the environment. Fusion power reactors will need huge magnetic fields, probably made with superconducting magnets that can handle large amounts of electricity (matter loses its resistance to electricity at extremely cold temperatures).

You can't see magnetic fields, but they exert strong forces on moving particles that have an electrical charge and also on other magnets. The experiments on this page will show you the shape of the magnetic field and how a magnetic field can trap charged particles.

Every bit of space around a magnet is filled with its presence, which can be felt by a magnetic material like iron. The field is stronger close to the magnet than it is farther away. You can actually map the magnetic field by seeing its effects on iron filings.

You will need a few simple materials:

- a permanent magnet, a bar magnet or a horseshoe, or any other kind
- a piece of cardboard about the size of this magazine page
- a piece of white paper about the same size
- a steel wool pad (preferably without any soap in it)

Place the magnet on a table and put the cardboard on top of it. Rest the sheet of white paper on top of the cardboard.

Hold the steel wool over the paper and crush it in your hands so that small pieces of steel fall onto the paper. These filings will arrange themselves in lines linking the north and south poles of the magnet.

Notice that the lines are closer together near the poles and are spread farther apart away from the poles. These lines are the magnetic field lines and show you the shape of the magnetic field.

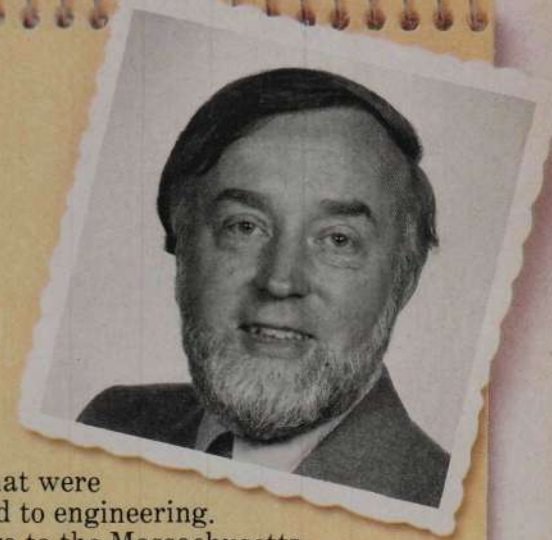
If you have more than one magnet, compare the shapes of the field lines for each type and arrange different combinations of magnets to see how the field of one magnet interacts with the field of another. You might want to sketch the lines on different sheets of paper to compare them.

Now try another experiment. For this one you'll need a fluorescent lamp, the kind found in many kitchens and schools. Inside a fluorescent light tube are atoms of a gas that become ionized when the electricity is turned on—they lose electrons and become positively charged. Charged atoms and electrons can be forced to move in circular paths by a magnet, because they are affected by the magnetic field. If the magnet is strong enough, the atoms and electrons will be confined to a region of space that is defined by the magnet. So your experiment is to place a strong magnet close to the fluorescent lamp while it is turned on.

You will see the confinement of some of the gas atoms, if you look carefully at the lamp near where you place the magnet. There should be a brighter spot, which means that more of the atoms are being trapped there by the magnetic field. Move the magnet back and forth to see if the bright spot moves with it. This is exactly the way magnets help confine hydrogen plasma ions in a tokamak fusion reactor.

Interview

with Dr. Stephen Dean



Dr. Stephen Dean is the president of Fusion Power Associates. For 17 years, all through the early years of fusion research, he was a leading government scientist supervising the overall fusion program.

Question: Were you interested in science when you were very young?
Dean: When I was a child I always liked solving mathematical problems and puzzles. I always thought discovering new things was fun, and as time went on I found that I was pretty good at finding solutions to problems. This encouraged me even more. One of my proudest experiences was when I was the only one in my class to solve all the trigonometry problems we had for homework.

Question: How did you become interested in fusion?
Dean: When I went to college I majored in physics. I always read a lot, and one of the books was *Project Sherwood*, about the fusion program in the United States. Fusion sounded very exciting and challenging, a whole new area of physics that had lots of problems to be solved. It was a new frontier. I wanted to help make some of the new discoveries that would help mankind in the future.

Question: This was in 1960, when the fusion program was very small and new. How did you find courses to study fusion?
Dean: I knew that many of the problems in fusion were problems in technology. So I went to summer school trying to pick up courses that were more oriented to engineering. I decided to go to the Massachusetts Institute of Technology for graduate work, because there were only a couple of schools that had a fusion course at that time. After college, I went to work at the Atomic Energy Commission in their fusion office. The fusion program was very small, with only about 2,000 scientists around the country. We had five people in the Atomic Energy Commission supervising it, with a budget of about $25 million a year.

Question: How do you think a young scientist today can find new areas to specialize in?
Dean: For me personally, the frontiers of science were always the most important. I think the real excitement of life lies in solving the puzzle of the universe. That's why I went into fusion research. Today it's still fairly easy to read science books and talk to people to find out what the new and exciting fields of science are. There are rapid developments in almost every area of science that require new ideas and open up exciting career opportunities.

The fusion bill just passed by Congress will mean money for jobs and education programs in fusion as well as the advanced equipment needed to push forward the advanced fields in science. This kind of growth is needed across the board in science today.

I think that in addition to the thrill of making discoveries about the universe that no one has known before, a scientist needs to have a sense of moral purpose. Fusion will mean a new era of unlimited energy to solve the problems of mankind.

TALES OF SCIENCE

Samuel Morse

I'm not sure where America would be today without my code, my telegraph, and my Atlantic Cable. But I owe a debt to the great Americans and Europeans who helped me in my efforts. I was born in 1791, just after George Washington became the first president of our new republic. Men like Oliver Evans and Robert Fulton were making new discoveries and inventions, and the entire United States was mobilized to support scientific and industrial development.

Samuel Morse

Actually, I started out as a painter. I painted men like the Marquis de Lafayette, who had helped America so much during the Revolution. In 1826 I helped found the National Academy of Design in New York City, which still exists.

In 1829, on my way back from a painting trip to Europe, I became fascinated with something that changed my life. In Europe I had seen scientists pioneering various kinds of electromagnetic systems—like wired circuits—through which they could transmit electric current. They were using the work on electricity done by Benjamin Franklin.

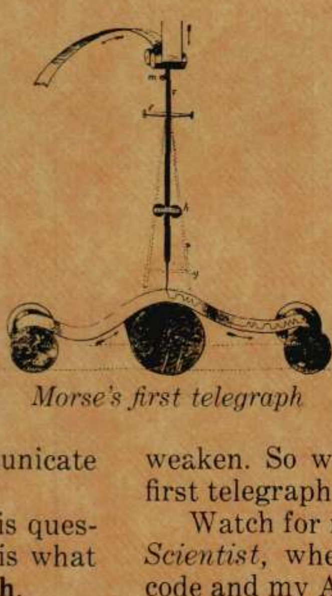
All the way back across the Atlantic on the ship Sully, I tried to imagine how these systems could be used to communicate over long distances. It seemed obvious to me that this electromagnetic current could travel very long distances. My question was, "How can I use this current to communicate information?"

I spent the rest of my life on this question. The system I had in mind is what you know today as the **telegraph**.

In trying to design a telegraph system I was handicapped because I didn't have enough laboratory experience. I had imagined that you could just string miles and miles of wire on poles from village to village. Then you could send impulses over the wire, and by interrupting the current you would get little "bleeps" of energy over the wire. If you had a decoder or deciphering machine at the receiving end of the wire, you could then read the message.

But how could I keep the current *strong* over miles and miles of wire? And how could I design some simple way to code messages that would use the features of the current; namely, interrupting and resuming the current in a regular way?

To solve these problems, I went to experts who knew more about electricity than I did, and I followed their advice. Now you may have heard that I was an irascible old fellow, who got into one patent fight after another over my inventions. That's true. I was kind of cantankerous in my old age.

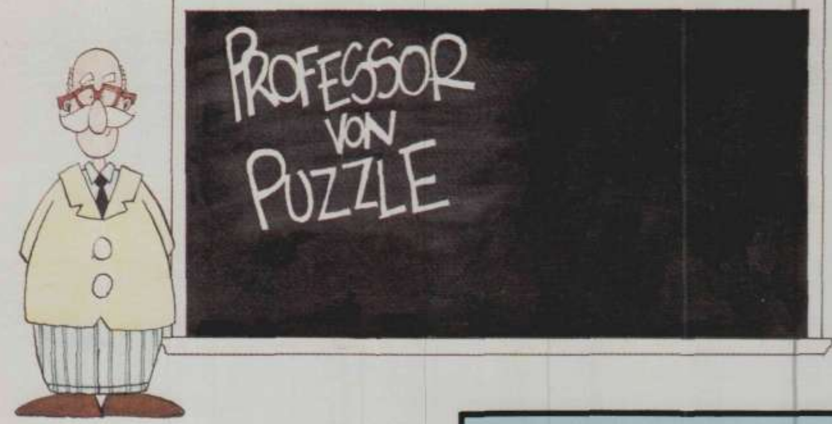


Morse's first telegraph

But I also had the good sense to listen when experts like Joseph Henry told me how to solve my technical problems. Henry had developed a set of relays for transmitting current. Instead of sending a current over a long wire, you sent it over a shorter wire, at the end of which it hit a coiled wire that reinforced the current just as it was starting to weaken. So with Henry's help, I built my first telegraph.

Watch for my next column in *The Young Scientist*, where I'll tell you about my code and my Atlantic Cable.

(To be continued)

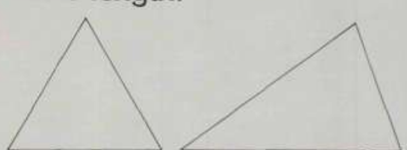


Welcome to the puzzle page. Next month I'll give the answers to these puzzles and explain some of the mathematical principles behind them.

If you have puzzles that you think other young scientists would enjoy, send them in with your answers. Send them to me, Professor Von Puzzle, Fusion Energy Foundation, 888 Seventh Ave., New York, N.Y. 10019.

PUZZLE ONE

An equilateral triangle is a triangle with all sides the same length:



Equilateral triangle   Nonequilateral triangle

You have 6 toothpicks all the same length. Can you arrange these 6 toothpicks to make 4 equilateral triangles with each side equal to the length of a toothpick? (You cannot break the toothpicks.)

PUZZLE TWO

You wake up very early in the morning when it's still dark and find your bedroom light is broken. You have to get dressed and need a pair of matching socks. There are 22 white socks and 16 black socks in your drawer. How many single socks must you take out to make sure you have a matching pair of socks, either two black socks or two white socks?

PUZZLE THREE

Take a compass and draw a circle.

Now, using only a compass and a ruler, try to figure out how to draw an equilateral triangle that fits just inside the circle.

The equilateral triangle that fits inside the circle like this is called **inscribed** in the circle.