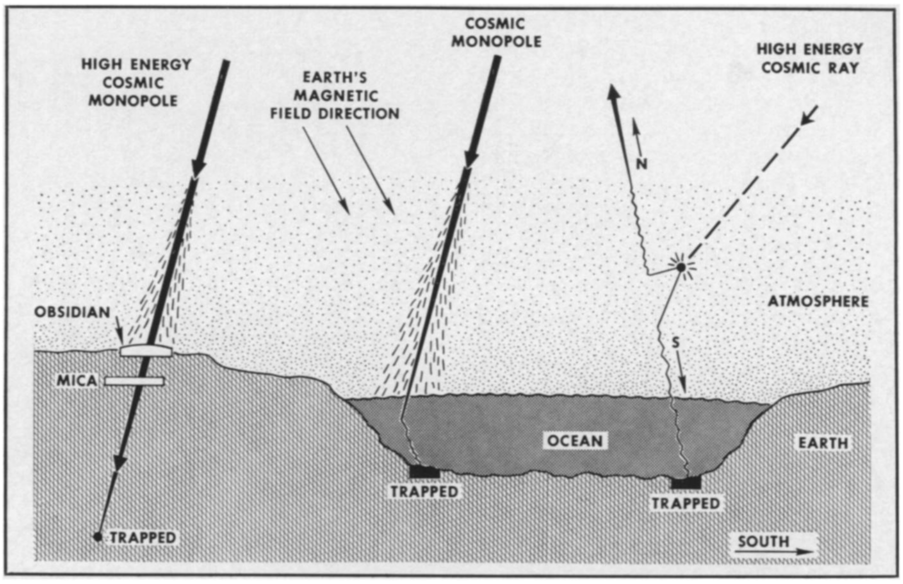
PARTICLE PHYSICS

Searching for monopoles

Theoretical neatness requires particles with one magnetic pole, but they have not been found

by Dietrick E. Thomsen



J. Appl. Phys.

Monopoles could be trapped in sea-bottom rocks or leave tracks in mica.

A magnetic monopole is a hypothetical particle that would carry a single unit of magnetic charge. It would have either one north pole or one south pole. All magnetic bodies ever seen have at least one of each kind of pole. Nevertheless, theorists of particle physics insist that magnetic monopoles should exist.

Magnetic monopoles have been sought in both of the places where physicists customarily look for unknown particles—in cosmic rays and in the collisions that occur in particle accelerators. Experimenters have searched for them from the surface of the moon to the bottom of the ocean. Within the next two years experimentation is expected to begin at the 500 billion electron volt (GeV) accelerator at the National Accelerator Laboratory in Batavia, Ill. (SN: 8/8, p. 111). This will make an entirely new range of energies available to experimenters who would like to manufacture particles that have never been seen before.

Monopoles were brought into theoretical physics in 1931 by Dr. P. A. M. Dirac of Cambridge University. His reason for doing so was a desire to make the theories of electricity and magnetism completely symmetrical with respect to each other. Every magnetic effect has an electric analogue, and every electric effect has a magnetic analogue, except for monopoles. Bodies that have either all positive or all negative electric charges are frequently encountered, but magnetic poles always come in pairs.

Dr. Dirac wished to remove this asymmetry. He worked out a theory in which single magnetic charges appear and in which they act in ways analogous to single electric charges. He says that this theory explains known electromagnetic phenomena as well as any other now current and is therefore a plausible choice.

Harvard Univ.

Schwinger: Dyons are basis of matter.

Dr. Dirac's monopoles did not necessarily carry any electrical charge in addition to the magnetic charge. In 1969 Dr. Julian Schwinger of Harvard University presented a theory in which particles carrying both a basic magnetic charge and a basic electric charge are held to be the ultimate constituents of all the elementary particles. Dr. Schwinger calls these particles dyons because of their dual character in carrying both the basic electric and magnetic charge.

Dr. Schwinger's dyons effectively combined magnetic monopoles and quarks. A quark is another sort of hypothetical particle that was introduced into theoretical physics to explain certain regularities that appear in the properties of many of the elementary particles. These regularities could be explained if all of the particles were held to be built of pairs or trios of quarks.

Combining quarks and magnetic monopoles in this way, Dr. Schwinger contends, will provide theoretical solutions to certain problems in particle physics, especially the recently observed asymmetries between matter and antimatter called violation of CP symmetry (SN: 9/14/68, p. 265).

Monopoles of either the Dirac or the Schwinger variety should possess several times the mass of a proton—in the range of several billion electron volts of mass. For dyons Dr. Schwinger gives an estimate of 6 billion electron volts, but he adds, "I would not risk more than three groschen on the likelihood of this estimate, but at least it is an optimistic one, in relation to current accelerator plans."

A helpful property attributed to monopoles is extreme stability. A monopole can attach itself to some other matter, like a piece of rock or a water molecule, and if it does so, it can remain for millions of years without losing its identity. This property suggests that monopoles might be sought in old mineral samples that have been irradiated by cosmic rays. Cosmic rays might produce monopoles by collision with particles in the earth's atmosphere, or some of the highest energy cosmic rays might themselves be monopoles.

Several searches for monopoles from the cosmic rays have been conducted. Among the most recent is an investigation of manganese nodules from the bottom of the ocean (SN: 5/2, p. 436) by Drs. Robert L. Fleischer, H. R. Hart Jr., I. S. Jacobs, P. B. Price, W. M. Schwarz and R. T. Woods of the General Electric Research and Development Center in Schenectady, N.Y. Manganese nodules were chosen for investigation because the seawater above them would have slowed any cosmic ray monopoles to the point where they might be captured by the mineral. The technique was to put the mineral in a vacuum chamber and subject it to a strong magnetic field. Any monopoles in the sample would be pulled out by the field and eventually would have arrived at particle counters at the ends of the vacuum tube. But no monopoles were found in any of the samples subjected to the investigation.

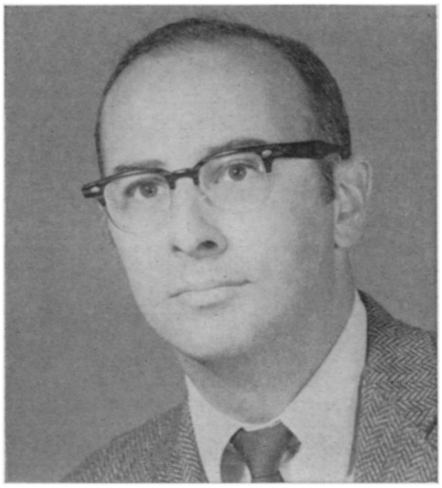
In another project, Dr. Fleischer and his co-workers spread particle counters made of Lexan plastic over a field near the General Electric Laboratory. They have had 18 square meters of this material spread out for the last year and a half. They are now about to bring it in and see if any monopole tracks can be found in it.

Failure to find monopoles trapped in terrestrial minerals led physicists to the moon. Drs. Luis W. Alvarez, Philippe H. Eberhard and Ronald R. Ross of the Lawrence Radiation Laboratory at Berkeley, Calif., and Robert A. Watt of Stanford Linear Accelerator Center in Stanford, Calif., examined 8.37 kilograms of lunar surface material. The material was conveyed through the windings of a superconducting coil in which a small electric current had been stored. If there had been any monopoles in the material, the electric field they created as they went by would have altered the current stored in the coil, and this alteration would have been sensed by recording instruments attached. No evidence of any monopoles was found.

The other likely place to look for monopoles is in particle accelerators. "A search has been done on every accelerator that has been in turn the world's largest," says Dr. Alvarez. "I'm not sure of Serpukhov, but it has been done at the Bevatron, at Brookhaven and at CERN."

Drs. Richard A. Carrigan Jr. and Frank A. Nezrick of the National Accelerator Laboratory have just completed an experiment at the 30-GeV accelerator at the CERN laboratory in Geneva, Switzerland. They were looking for monopoles that might be formed when a beam of neutrinos struck a target, but they did not find any. Now they would like to use the much higher energies that will be available at the NAL accelerator to see whether these will produce any monopoles. They have made a threefold experimental proposal to the laboratory management and are awaiting a decision.

One part of the proposal is to try to make monopoles by driving the accelerator's beam of protons against metal plates immersed in a water tank. The second part would be to make a beam of neutrinos with the proton beam and then strike the neutrinos against water molecules in a water tank.



General Electric Co.

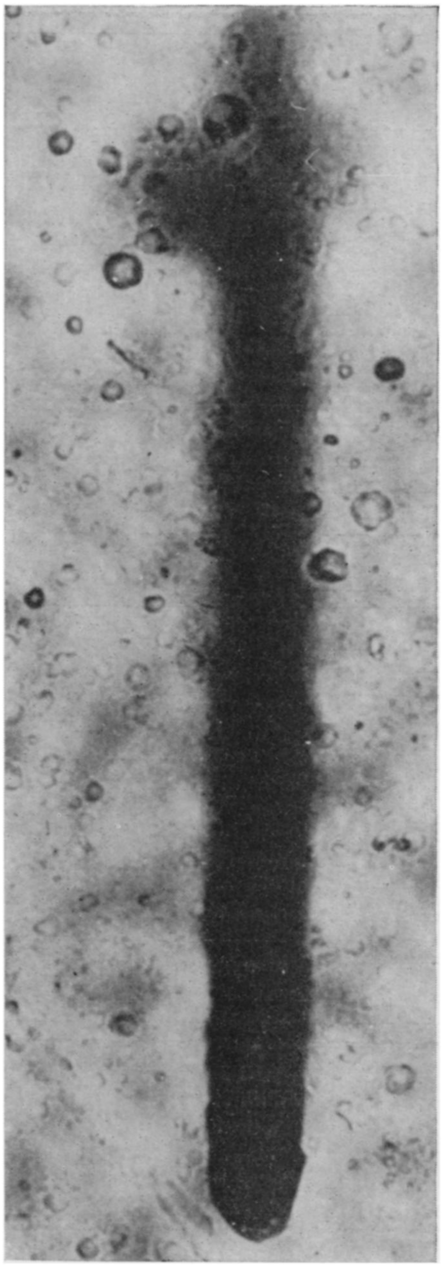
Fleischer looked on the sea bottom.

A third part of the proposal is an attempt to produce pairs of monopoles. According to theory monopoles can be made only in pairs of opposite polarity, and to free them from each other, energy must be supplied to overcome the strong force that is supposed to bind them to each other. There may not be enough energy in the NAL proton beam, says Dr. Nezrick, to produce free monopoles, but there could be enough to produce bound pairs. Theorists have speculated that such a bound monopole pair would form a system with many similarities to a deuterium atom and, says Dr. Nezrick, the name monopolium has been applied to this system. As the two poles gradually came together, they would give off gamma rays. The experiment proposes to watch for the gamma rays.

Drs. Fleischer and Hart, with Drs. George Comstock of General Electric and Edward Hubbard of NAL, have another proposal for a monopole search at Batavia. They would place particle detectors above and below the path of the accelerator's beam. If monopoles were produced when the beam struck the target, the fields of the accelerator's own magnets would pull them above and below the beam path and bring them to the detectors.

A third proposal to the NAL management comes from Drs. Alvarez, Eberhard, Ross and Watt. They would like to take targets that have been irradiated for some time in the NAL accelerator and run them through the same apparatus that they used on the moon soil to see if they can detect any monopoles stored in the targets.

Success in any of these efforts depends on whether there is enough energy available in the NAL beam. Dr. Nezrick thinks it unlikely that free monopoles will be found at accelerator energies below 1,000 GeV, but, he says, there are so many uncertainties in the estimates entering such a calculation, that he would like to make the attempt even at lower energies, just to be sure. If the particles have a fractional electric charge, as they should according to Dr. Schwinger's theory, then there is more likelihood of finding them at lower accelerator energies. Dr. Fleischer says, "If the monopole mass is 12 proton masses (about 11 GeV), at 200 GeV we're not going to produce them." This limit does give some leeway above the 6-GeV guess of Dr. Schwinger, but no one knows for certain until a monopole is found. □



J. Appl. Phys.

How a monopole track would appear.