havioral backgrounds of the great heroes of physics. Indeed, it would be considered impolite for one to note some who eagerly and successfully grasped for fame, contentedly took credit for the work of people under them, or reaped fat profits from commercial exploitation of their discoveries. I suspect that Moravcsik has actually succeeded in gauging what physicists think they should think about why they are in physics.

F. CURTIS MICHEL
Rice University
Houston, Texas

THE AUTHOR COMMENTS: Curtis Michel's critique is one that can be heard often in connection with motivational surveys, including the presumably more "sophisticated" ones in which the respondent is asked to make decisions in hypothetical situations. It is a variant of the statement that an object which looks, sounds, feels, and tastes like an apple is really something else but perfectly disguised as an apple. It is sometimes thought that the difficulty can be resolved by studying what respondents actually do rather than what they profess, but that method is shaky also because the response in an actual situation is determined by which motivation is most seriously challenged or endangered and not by which is strongest.

While such a critique is logically unanswerable (see hidden variables), it appears to me to have little functional significance. In practice, the best one can do is, a) not to be submerged in a preconceived view of what the motivations are, even if such a view is attractive on account of the simplicity or ideology of a certain model, b) to carry out as many different types of studies as possible, in the hope that they eventually point at some consensus of views which then can and must be used in practical decision making in science policy until something better comes along.

MICHAEL J. MORAVCSIK
University of Oregon
Eugene, Oregon

Spin and relativity

George Uhlenbeck in his charming reminiscences of the discovery of the electron spin (May, page 43) mentions two contexts in which special relativity played an essential role: (1) coupling between spin and orbital motion, and (2) Thomas factor.

Point (1) arises from the force resulting from Lorentz transformation to a coordinate system where the electron is at rest; point (2) is based on the fact that general Lorentz transformations with non-parallel velocities form a group only after adjoining rotations. Belated recognition of (1) caused delay in the acceptance of electron spin by Wolfgang Pauli and Niels Bohr. Belated recognition of (2) caused delay in the final acceptance of electron spin by Pauli. Both Pauli and Bohr were, of course, familiar with Lorentz transformations. However, Pauli was skeptical of the whole concept of electron spin, because of his emphasis on the "classical two-valuedness" of the fourth quantum number. Bohr, on the other hand, was prejudiced by his previous introduction of a "non-mechanical strain" to cause (1). Both Bohr and Uhlenbeck and Samuel Goudsmit learned from Einstein the basis for (1). But even the latter was surprised by (2), as Uhlenbeck notes.

Surprisingly, a survey showed that none of the great mathematicians Poincaré (who named the Lorentz group), Minkowski, Klein, Herglotz or Weyl stated explicitly the above property of the Lorentz group. Nor is it contained in Pauli's book. Equally surprisingly, however, Silberstein's *The Theory of Relativity* [MacMillan, London, 1914 (!)] does contain an explicit statement (pages 167–170), which is also contained in the second (1974) edition of his book. This fact, of course, does not the least affect the great merit of L. H. Thomas, who not only noticed the above property of the Lorentz group independently, but also showed how it led to the factor ½. A more detailed discussion, including the essentially quantum nature of the spin-orbit interaction, will be given elsewhere.

EUGENE GUTH
University of Tennessee
Knoxville, Tennessee

Lunar studies continue

George Siscoe's review of *Lunar Science: A Post-Apollo View*, by S. Ross Taylor (in your February issue) contains one possibly misleading statement: "A program of intensive lunar study started in 1964 . . . The program was completed in 1972."

Although the Apollo program itself ended with the flight of Apollo 17 in December 1972, NASA's continuing lunar-science program is alive and flourishing. Over a hundred investigators are conducting studies of the 343 kilograms of lunar rocks and soil returned by the Apollo missions. Many of the scientific instruments placed on the Moon by the astronauts are still transmitting useful data and will continue to do so for a few more years. Ground-based laser ranging to the four retroreflectors placed on the Moon is producing important results in celestial mechanics, relativity and terrestrial geodynamics. There is also a vigorous data-synthesis program in which the whole body of geophysical, geochemical and geological information about the Moon is being analyzed to produce co-

herent models for the origin and evolution of the Moon and other terrestrial planets.

The lunar programs have conclusively proven the value of continuing scientific research after the cessation of a major flight program such as Apollo. Most of our understanding of the Moon has been achieved since the last Apollo flight. I will be glad to supply further information to readers interested in participating in any of these programs.

EDWARD A. FLINN
Deputy Director, Lunar and Planetary Programs
National Aeronautics and Space Administration
Washington, D.C.

Engineering physicists

I would like to add to the discussion of the relevance of physics to training for the engineering profession. (See the letters of T. G. Stinchcomb and C. E. Riedel, January, pages 95 and 96).

At the University of Oklahoma we have trained engineers with a major in physics for over 50 years. The degree is called "Engineering Physics" and granted by the College of Engineering. The major department faculty is Physics and Astronomy which, incidentally, is a part of the Arts and Sciences College. Physics course requirements are comparable to those of the non-engineering physics major.

Employment is in a wide range of industries, which include the chemical, petroleum production, refining, electronic, nuclear, computer, electric machinery, automotive, aerospace, energy services, optical, steel manufacturing and processing industries.

The fundamental motivation of engineering physicists is problem solving. As engineers they work more directly with physics as a basic tool than any other kind of engineer and because of this are

- pioneers—they often work in areas not widely developed,
- versatile—they work on a variety of problems that span all engineering fields,
- communicators—they speak the language of other engineers and scientists and assist engineering group efforts.

The engineering physicist with a broad training in the fundamentals of physics can choose a specialized area of work after a broad exposure to several problem areas. He or she can change the area as the needs of society change.

ROBERT M. ST JOHN
University of Oklahoma
Norman, Oklahoma

THE AUTHOR REPLIES: Robert St John refers to the letter of Charles Riedel and myself as discussing "the relevance of physics to the training of persons entering the *engineering* profession." Riedel's letter talks about physicists obtaining jobs by describing themselves as engineers rather than physicists. To me it seems that he almost proposed their disguising themselves as engineers. St John's letter discusses the employment of *engineers* who have as their speciality "Engineering Physics" rather than one of the other specialities. His main point appears to be that these graduates are "*bona fide*" engineers and need no disguises. My letter, on the other hand, discussed the employment of baccalaureate physicists from physics departments in colleges of arts and sciences. Most of these departments are not related to colleges of engineering. My main point was that if the physics community in the United States is interested in the survival of these physics departments, it should increase by orders of magnitude its concern and its efforts to match the training of these baccalaureate physicists with jobs available in the *physics* profession. The physics community needs to identify and develop a large group of baccalaureate positions that are fully recognized, not only by the physics community, but also by society at large, as an essential part of the physics profession. It may well be that engineering physics should be a significant member of this group, but many other equally significant members are needed also.

St John states further in his letter, "Physics course requirements are comparable to those of the non-engineering physics major." This implies an equivalency between the two curricula, which I would like to question in two ways: Do graduates of both curricula who seek employment at the baccalaureate-degree level have the same degree of success as measured by the number of job offers, starting salary, and so on? (St John may be able to provide us with such statistics from the placement service of the University of Oklahoma.)

Do graduates of both curricula who seek to enter graduate study in physics, both at the University of Oklahoma and elsewhere, have the same degree of success as measured by the absence of make-up courses, by the percentage obtaining teaching and research assistantships and the percentage obtaining fellowships, and so on? If the answer to both questions is a definitive affirmative, then the equivalency must be more than an implication. It must be a fact, which could benefit all baccalaureate physics graduates to the extent that their major is similar to that at the University of Oklahoma. The physics community should then make sufficient effort and publicity to convince engineering personnel managers that it is very much to their company's advantage to consider

continued on page 88