

Objective Tests —

ALL Bad?

By Frank J. Fornoff

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I AM one of those people whose identity is hidden by the letters—ETS—which Dr. Banesh Hoffmann¹ has attacked with such determination. My responsibility, shared directly with two colleagues and indirectly with many more, is the preparation of science tests. I have a doctorate in chemistry from the Ohio State University, and I spent a postdoctoral year at the University of California. I have been on the faculties of three good universities, Lehigh, Kansas State, and Rutgers, but I must admit that there are many things that I do not know. Contrary to Dr. Hoffmann's suspicion, I believe that my colleagues and I do know a few things.

We are aware, for instance, of Einstein's relation, $E = mc^2$. I did not write the question on the burning of gasoline in an automobile cylinder that Dr. Hoffmann has been working to make famous, and I do not know who did write it. Despite Dr. Hoffmann's comments, I believe that there is a reasonable context associated with the question and that this context is normally discerned by chemistry students who understand chemical change. After all, Professor J. R. Partington, the noted British chemist, wrote for the 1950 edition of *Chambers' Encyclopaedia*, Oxford University Press, as follows: "In the great majority of changes occurring in nature there is, to a high degree of accuracy, a separate conservation of quality [chemical elements present] and quantity in the case of matter and of quantity in the case of energy, so that two—or, if the conservation of the chemical elements is taken into account, three—separate laws are recognized, the law of conservation of matter and the law of conservation of energy. In other words the total quantity of matter and the total quantity of energy remain constant in all normal physical and chemical changes. . . . For all normal chemical changes it may be safely assumed that the law of conservation of matter is true exactly." The understanding of chemical change expressed by Professor Partington underlies a number of important chemical calculations, and well-trained chemistry students are aware of these relations. I feel sure that the person who wrote this question for high-school chemistry students hoped to test for an understanding of

chemical change, and I feel sure that the teachers who reviewed the question read it in this context.

This question was never used in a test given for evaluating student performance. It has been tried out twice in what we call pretests, tests given to learn about the questions, not about the students. The second of these pretestings took place last spring when some 400 college-freshman chemistry students from 8 colleges took the pretest. A random sample of 300 of the answer sheets was studied in detail. Performances of the top quintile of the students are worth noting.²

Two of these top 60 students omitted the question. This is what Dr. Hoffmann seems to assume that superior students would do. Twenty-seven of them said that the burning of gasoline did not involve decomposition, and 11 of them said that reduction was not involved. Still, three times as many students from this group as from the bottom quintile chose the keyed response, conversion of matter to energy, as not being involved in this process.

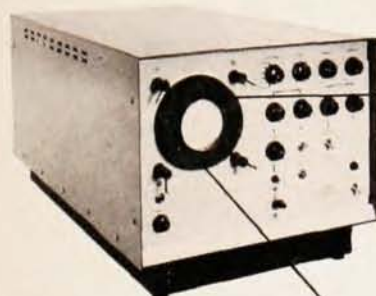
This question was written for the booklet from which Dr. Hoffmann quotes. In a communication directly to ETS back in 1955 or 1956, Dr. Hoffmann pointed out what he considered to be the weakness of the question, and the ETS staff at that time recognized that some people might miss the context in which the question was written. The question for the booklet was therefore revised and since the 1957 edition has had for its fifth option, "conversion of energy to matter." The facts do not substantiate the assertion that "ETS" does not know about $E = mc^2$, and I believe that the question as originally worded tested an important understanding of chemical change.

The question on the potassium electron and the lithium electron was also written for the booklet about the tests rather than for a test. It, too, was written for

¹ Banesh Hoffmann, *Physics Today*, October, 1961, p. 38.

² There is a technical objection to the use of the pretest score as a basis for the selecting of the superior students. If the test as a whole is faulty, those who get high scores on it are not necessarily superior. In practice few tests of achievement ever miss the mark so badly, even in preliminary form, that those who make the higher scores on it do not prove to be superior in achievement. On this particular pretest of 65 questions, getting only 37 questions right put a student in the top quintile. Even assuming that there were a number of "defective" questions in the pretest and that the superior students missed all of these "defective" questions, one must conclude that the overwhelming majority of the superior students by any criterion were in the top quintile on this test.

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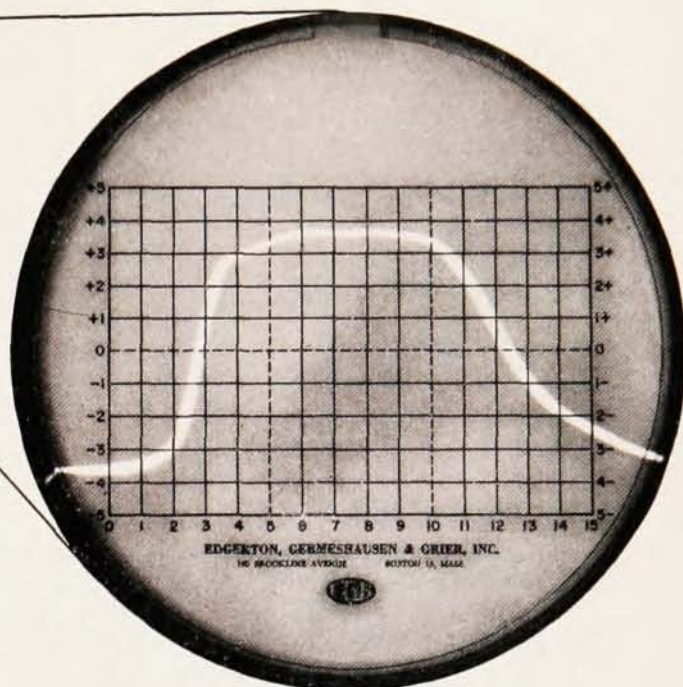
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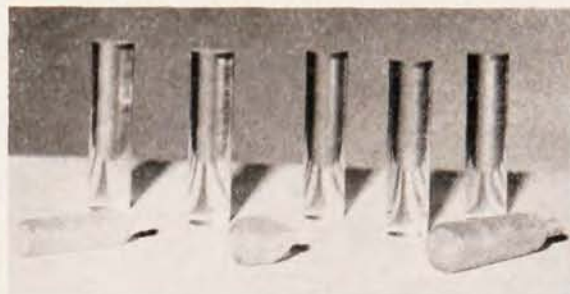
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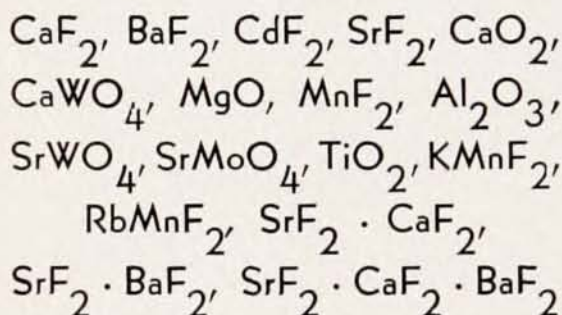
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high-school chemistry students. Again I know nothing of the writing of the question, but I believe that the wording was devised in the hope of asking something about ionization potential and energy levels of atoms in a context where students would not be able to respond from memory but would have to do a little thinking. The question was reviewed by a group of competent college and school chemistry teachers, and, in the context for which it was intended (high-school chemistry), they were satisfied that it had merit.

Dr. Hoffmann has expressed his opinion that four of the options listed for this question are satisfactory answers. In a communication² to the editor of *Physics Today*, Dr. Robert Hart has pointed out that the question, referring as it does to the photoelectric effect, must relate to the solid state but that the responses are applicable only to gaseous atoms. He concludes that none of the suggested responses are appropriate for the question that is asked.

The comments of Dr. Hoffmann and Dr. Hart can be used to illustrate the way in which the committee system for test review operates. Suppose that a committee member had written the question and that Dr. Hoffmann, but not Dr. Hart, had been on the committee. During the review session, Dr. Hoffmann would have commented as he did in his *Harper's* and *Physics Today* articles. After some discussion another committee member might have said, "As I see it, Dr. Hoffmann, if we agree with your viewpoint, we must be saying that we accept all of the following statements as true: The valence electron of potassium is farther from the nucleus than is the valence electron of lithium because the potassium atom contains more electrons than does that of lithium. The valence electron of potassium is farther from the nucleus than is the valence electron of lithium because the potassium atom contains more protons than does that of lithium. The valence electron of potassium is farther from the nucleus than is the valence electron of lithium because the potassium nucleus is larger than is that of lithium."

For myself, I do not consider these satisfactory statements of cause and effect, but suppose that the committee had decided to modify the question to meet Dr. Hoffmann's objections. Without Dr. Hart on the committee, his objections to the question would still not have been raised and he would not have been satisfied with it. If he had been on the committee, he no doubt would have asserted that the trouble with the question was not that there were four answers but that there was no answer. The committee might have decided that reference to the photoelectric effect would have to be removed from the question and the test because the effect was not understood by a large majority of present-day high-school chemistry students since they had not been taught about it and did not have adequate background to understand it.

This situation is not unusual in fields of dynamic change like the sciences. A test committee, after

² *Physics Today*, February 1962, p. 62.

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debating the implications of a question, may decide that the value of the question is great enough to merit its use in a test for high-school students even though the committee knows very well that a research scientist in the field covered by the question would consider the question incomplete or unsatisfactory. In such cases, the committee is acting on the belief that the rare high-school student who has pushed his knowledge of the field involved far beyond his textbook will be sophisticated enough to recognize the context associated with the question and will answer it correctly. Such a decision does not reveal professional incompetence on the part of the committee but rather shows that they recognize that education proceeds by steps and that, at the moment, questions are being prepared for beginners.

The question about the potassium and the lithium electrons was included in the recent pretest referred to previously. Only five of 60 students from the top quintile missed the question, and about three times as many students from the top quintile as from the bottom quintile chose the expected answer.

The instructions to students who take the ETS multiple choice tests direct that the "best" answer of those offered be selected. Question writers occasionally try to require students to make decisions among choices none of which contains an error of fact but only one of which is a best response when the situation described in the question is evaluated. The question on the prism forming a spectrum from white light is such a question. Dr. Hoffmann is, of course, clearly right in asserting that a prism could not form a complete spectrum from white light if this light did not contain light of all the colors of the spectrum. This is surely a necessary condition for the prism to work but not a sufficient one. A plane mirror may receive the same white light and yet produce no spectrum. The desired response—the amount of refraction differs for light of different wave lengths—is more nearly, though not perfectly, both a necessary and a sufficient condition. To eliminate judgments such as that required in this question and that asked for in the potassium-electron question, tends to reduce a test to questions which can be answered by rote memory and so to lead to a test favoring students with photographic memories. Is this desirable? I join with most teachers in thinking not.

In addition to the knowledge which I have in common with Dr. Hoffmann, I believe that I know some things of which Dr. Hoffmann seems not to be aware or which he ignores. Questions for the physics tests prepared by ETS are written, almost without exception, by physics teachers in colleges and secondary schools and without exception are reviewed several times by these teachers before the questions are used to evaluate the knowledge of students. In recent years committees of examiners for our physics tests for high-school students have included professors in the following institutions: Bryn Mawr College, California Institute of Technology, Colgate University, DePauw University,

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Members of the committees for the comparable chemistry tests have come from Amherst College, Hamline College, Kenyon College, Michigan State University, Pennsylvania State University, Tufts University, the University of Kansas, Wabash College, Lawrenceville School, Lewis and Clark High School of Spokane, Lincoln School, New Trier (Ill.) Township High School, and South High School of Denver.

In the second place, I know that in the times in which we live some method of selecting students to be admitted to a certain college must be used. Everybody cannot go to Harvard—or to Queens. Surely methods better than drawing names from a hat should be employed to decide which students shall be admitted. I agree that secondary-school grades, letters of recommendation, interviews, and lists of interests and activities should be used, and all these factors are being used. Beyond these, however, I believe that the selection is improved by including performances on a set of tasks which all candidates have undertaken under approximately the same conditions. College Board tests, prepared by committees with ETS technical assistance, are such a set of tasks.

Perhaps Dr. Hoffmann thinks that essay examinations should be used to avoid the "tyranny of the multiple choice question". Though essay tests have important values, they do have some faults. Essay questions, too, must be written and they can be as misleading as objective questions. Furthermore, many fewer essay questions than objective questions can be asked in the same testing time, and the chance is much greater that a superior student will not even be asked the questions for which he is particularly prepared when he takes an essay test than when he takes an objective test. Even more important, essay tests must be read when they are graded. This grading is subject to large uncertainties due to differences among the readers. The grading is very expensive, and it takes many man-hours. There is still one further problem. Dr. Hoffmann believes that our committees of examiners miss some of the meanings of the questions they review; yet this review is performed by at least five teachers and is done a number of times. Reading each essay answer and scoring it accurately requires the same looking for meanings, and each essay answer could not possibly receive the attention that each question in one of the multiple choice tests does receive. Yet the future of a student would rest on the scoring of the essay papers just as much as it rests on his score on a multiple choice test.

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Another factor that Dr. Hoffmann prefers to ignore, it seems to me, is that the value of the entire test is not determined by one or even several of its questions. An objective test score is the summation of the performances on an appreciable number of tasks even as a scientific law, on a different level of generalization, emerges as the summation of many laboratory experiences. I happen to have run some low-temperature heat-capacity determinations. The fact that a few points do not quite lie on the smoothed curve of heat capacities plotted against temperature is not an adequate reason for throwing out all the data nor for convening a committee to look at the method. One may hope that all the points will lie on the curve when the next determination is run, and one may work very hard to this end, but he is really not surprised if this goal is not reached.

If I am not willing that multiple choice tests be condemned on the basis of judgments on a few questions, what criterion would I use for judging them? I would ask, "Do the test scores correlate well with teacher-given grades in the appropriate courses? And if used in admission procedures, do the scores have value in predicting college performance?" Studies have shown that scores on a carefully prepared test, even though planned for a national sample of students, correlate 0.60 and more with the course grades assigned by the science teacher to his students in a single school. In a number of colleges and universities, though not in all, College Board test scores correlate as well with grades obtained during the college freshman year as do the grades from the entire high-school course of study. These results do not suggest that objective tests are perfect predictors, but neither do they indicate that the scores on the tests are valueless or dangerous.

These comments are not to be taken as evidence that I as an individual—or ETS as an organization—condones the use of defective questions or that I am not concerned about the superior student. Far too much of my day-to-day effort goes into the arduous process of trying to prepare good and fair questions to make such a charge justifiable.

I shall continue to be concerned that the committees charged with the preparation of ETS science tests be composed of the best people who will accept the appointments and will spend the necessary time at their tasks. I shall regrettably expect that a few of the questions included in the tests will be subject to interpretations which the committees will miss. But I shall continue to believe that, despite the limitations imposed by these "defective" questions, superior students will get superior scores on multiple-choice tests, that the complicated admission practices will guarantee college admission to the superior students who apply for admission, and that both the colleges who do the selection and the students who are considered by these colleges benefit from careful selection based, in part, on multiple-choice tests.