tion equilibrium was found to occur at an $N_2H_4$ concentration of about $10^{-4}$. However, similar experiments with liquid ammonia but with fission recoil particles gave $G_{N_2H_4}$ values of 1.2 to 2. The work (*11*) with fission particles has proceeded to the loop-operation stage, which involves the use of enriched uranium oxide in liquid ammonia as a slurry. Results of the work at this stage have not been officially reported. Chemonuclear designs have indicated that the process would be economically practical if a hydrazine concentration of a few percent with a $G_{N_2H_4}$ of about 1.5 could be obtained.

Finally, a cursory glance should be given to a few present uses of ionizing radiation in industry and a few novel concepts concerning radiation chemistry that are in early stages of investigation. The industrial processes include irradiation of polyethylene coating on wires and irradiation of ethylene and hydrogen bromide with gamma rays to form ethylbromide, by the Dow Chemical Company. The novel concepts under investigation concern the production of ozone in liquid oxygen and the formation of carbon suboxide in the irradiation of CO. Ozone is a cheap oxidant, and carbon suboxide is a starting material in the manufacture of some organic chemicals or pharmaceuticals.

Although no "demonstration" nuclear plants for nitrogen fixation exist at present, the radiation chemistry of the fixation of nitrogen points to the probability that nuclear energy will eventually be directly used for chemical synthesis.

### References and Notes

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# Academic Organization in Physical Science

## Universities should organize a unified approach to all pure and applied physical science.

Henry G. Booker

What constitutes the physical science area of a university? Of what should it consist in the future? How should the various facets fit together? Where does a subject like geophysics fit into the overall operation? What kind of academic structure should house all these activities?

By the physical science area of a university I mean all those activities on the campus for which physics is the basis. Besides the physics department, the physical science area includes departments such as geophysics, earth sciences, meteorology, and astronomy. It also includes those areas of the campus where students who ultimately hope to follow the profession of engineering are engaged in study and research in physical science. These are departments with such names as aerospace engineering and electrical engineering. However, I would not include in the physical science area of a university any engineering department that still regarded its prime function as the professional training of students in empirical design; frankly, I would not include such an engineering department in a university at all! By the physical science area of a university I mean, therefore, the departments dealing with theoretical physics, experimental physics, observational physics, and applied physics; with present university organization this area includes the dynamic part of the Engineering College.

An awkward feature of the physical science area of a typical American university is that it is illogically bisected by a major administrative division of the university. Part of the physical science area is usually located in the college of humanities and sciences, while part is located in the college of engineering. In an Ivy League university with which I am familiar, plasma physics is studied in its laboratory form in the department of aerospace engineering, in its upper-atmospheric form in the department of electrical engineering, in its cosmic form in the department of astronomy, and in its solid-state form in the department of physics. Of these four departments, two are responsible to the dean of engineering and two to the dean of arts and sciences. Thus, the coordination of even one facet of physics involves not only four department heads but two deans, not counting the dean of the graduate school. And yet it only takes one dean, the dean of arts and sciences, to handle such diverse subjects as quantum theory and Greek literature. Universities are well organized to do many things that do not need doing, but in physical science they are often poorly organized

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for providing even normal working contact between people concerned with the same facet of the same subject. The physical science area of almost every university suffers from the disease of dichotomy in the deanery.

The division of a university into a college of humanities and sciences on the one hand and a college of engineering on the other is an academic structure that belongs to an era that is passing. This was an era in which scientists were scholars who lived next door to the humanists. It was an era in which the engineers dealt with mundane design problems by largely empirical methods. It was an era in which, from the scientists' point of view, the engineers lived on the wrong side of the railroad tracks in a scientifically underprivileged area of the campus. This class distinction between the ignorant engineering masses and the scientific aristocracy is dying. It is time for university administrations to begin thinking about a formal interment. It is time for the physical science area of a university to be organized as a coherent operation free from dichotomy in the deanery.

Some may question whether a contemporary graduate physics department, with its legitimate emphasis on research in areas of physical science where the laws of physics are imperfectly understood, is ready to enter into genuine partnership with those sections of the physical science area that are more concerned with observational and applied physics. This is a question to which the answer is unclear at present. The theoretical and experimental physicists frequently feel that second-rate physics is done in the name of observational and applied physics, and unfortunately they are too often right. On the other hand those concerned with observational and applied physics frequently feel that the theoretical and experimental physicists, far from taking an overall view of physics, in reality take a restricted view, to the detriment of the entire physical science area. Perhaps we can derive encouragement from a recent statement made by Hans Bethe in a lecture on the social responsibility of scientists and engineers. He said:

> In physics we have an obligation to give training in such subjects as atomic physics, which is by now an almost forgotten field. Research in physics has moved to high energy problems and field theory, but for practical applications atomic physics is still the most important field, and the larger fraction of our students will be concerned with practical application. It is a difficult task for the university professor to dissociate his direct research interest from the subjects which are socially useful. There is especially the question of establishing a sense of values in the student. It is very likely that the students will value most the things their professors do. As a consequence, there are many frustrated scientists working in industry who think that they are not really doing first class work because they are not doing the same things that their professors did in the university. At the same time they are doing extremely useful work and they would do it better if they felt in their bones that this was important. So I think that it is one of our social responsibilities to instill the right sense of values in our students. [*Cornell Engineer*, Dec. 1963]

Bethe's statement of the social responsibility of educators in physical science is not restricted to atomic physics; it can and should be extended to the whole of observational and applied physics.

Some universities have taken steps toward unification of theoretical, experimental, observational, and applied physics. However, I fear that many universities have scarcely become aware that unification of the physical science area is now a subject for serious thought and action. In my own university a unique opportunity for reorganization in physics and engineering recently occurred. The university acquired a new president, a new provost, a new vice president for academic affairs, and a new vice president for research and advanced studies. Because of the promotions involved, this team faced an unusual situation in which vacancies existed simultaneously for a dean of arts and sciences and for a dean of engineering. Moreover, the new university administration was quite aware of the effect on the physical science area of dichotomy in the deanery. The provost had previously been the dean of engineering and, before that, the chairman of the physics department. What new academic organization in physical science emerged from this unique situation? None! Even serious discussion was not feasible.

For the introduction of a more reasonable academic organization in science and engineering perhaps we should look to some of the new campuses that are coming into existence, especially in California, with its flare for the novel in public education. What kind of academic organization in physical science should a newly established campus seek to achieve?

## Suggested Organization

I suggest that the physical science area of a university should be organized as an integrated operation, with research activities in a number of interesting fields, the character of which should change in a major way from one decade to the next. Research activities that might constitute the physical science area at present are listed in Table 1.

Notice that the activities listed range from research work carried out in contemporary graduate physics departments to research work carried out in those engineering departments that have become emancipated from empirical design. Notice also that geophysics is incorporated as part of the broader concept of solar system physics, which is listed separately from the distant astronomy studied in most astronomy departments. Organization according to contemporary research areas should replace the usual departmental structure in physics and engineering. The terminology and arrangements should be such as to imply and facilitate academic evolution on the time scale of our developing knowledge of physical science, rather than on a time scale set by the lifetime of a faculty member.

It is clear that, with such an organization in the physical science area of a university, graduate courses could easily be offered by faculty members engaged in the various research activities. But how would undergraduate education in physical science be organized? Undergraduate education in the entire physical science area should be organized as a unified operation. Even the students bound ultimately for the engineering profession should receive an undergraduate education based on physics, mathematics, and the humanities, and not on engineering in the classical sense. But the undergraduate curriculum (exclusive of the humanities) should not be taught solely by pure mathematicians and by those physicists who are searching for undiscovered laws of physics. The undergraduate faculty in physical science should be drawn from all the research activities in the entire physical science area of the university. Overall policy should be such that reasonably comparable numbers of research workers from the various graduate areas in theoretical, experimental, observational, and applied physics would be engaged in undergraduate teaching in physics.

Students seriously interested in physical science should become aware, during their undergraduate careers, of the full range of activities that constitute theoretical, experimental, observational, and applied physics. This should be achieved, however, without forcing students to take a continuous and uniform interest in all aspects of physical science. What is required is an arrangement in which undergraduates majoring in physics come into specific contact with faculty members in observational and applied physics as well as with faculty members in theoretical and experimental physics.

### Undergraduate Program

In the observational areas of physical science, such as geophysics and astronomy, it is sometimes said that the activity should be primarily at the graduate level, and that undergraduates interested in observational physics should take the regular undergraduate program of a physics major. True; but this should not mean that the observational physicists should wash their hands of undergraduate education in physics or be excluded from undergraduate education in physics by the theoretical and experimental physicists. The absence of observational physicists from undergraduate physics education results in observational physicists having either a dearth of good graduate students or a supply of graduate students in need of reorientation. This leads to unfortunate pressure for specialized undergraduate curricula in observational science, such as exist in meteorology, for example, in a number of universities. What is needed is not a specialized undergraduate curriculum in observational physics but an arrangement in which the attitude and ideas of observational physicists have influence in the regular undergraduate program for physics majors.

The introduction of observational physicists into the undergraduate teaching force in physics is not without its difficulties. While many senior observational physicists know a good deal of physics, many of them have operated for years only at the graduate level or in specialized curricula; they have forgotten how to take part in undergraduate education in physics, or in some cases they have never had the experience. It would not be good policy to force such people to take part in the undergraduate educational program. But it would be even worse policy to bring up young faculty members in observational physics to think of the undergraduate educational program in physics as other people's business.

What has been said about the relation of observational physics to undergraduate education is also true of applied physics. The professionally oriented undergraduate programs in engineering that are a feature of most well-established universities are a mistake. The pace of engineering development is such that tomorrow's leaders in engineering need to understand today's physics, whether or not the details of its applicability are currently clear. The undergraduate education of potential leaders in engineering should not differ, so far as subject matter is concerned, from the undergraduate education of potential physicists. However, undergraduates in physical science should become conscious of the spectrum of mental attitudes that exist in physical science, from the intellectual approach at one extreme to the materialistic approach at the other.

How is it possible for undergraduates in physical science simply to major in physics and yet, at the same time, become conscious of the mental attitudes of people interested in theoretical physics, experimental physics, observational physics, and applied physics? The answer lies in operating an undergraduate program which, in subject matter, is fairly close to that usually considered appropriate for a physics major but which is taught by a faculty drawn from all the research areas in theoretical, experimental, observational, and applied physics. Large classes should be divided into parallel sections taught by professors from different research areas in physical science who are consciously illustrating the general principles involved in the undergraduate physics curriculum from their own experience and interests. Thus, a junior year course in electromagnetic theory might be taught in three parallel sections, one by a professor engaged in field-theory research, another by an ionospheric physicist, and another by a professor interested in electromagnetic radiating devices. Students in all three sections should acquire a thorough understanding of Maxwell's equations and should be eligible to enroll in a subsequent course in electromagnetic theory, whatever its flavor or orientation.

With this plan not all students would be directly exposed to all points of view. However, the student grapevine is effective, and an individual student would stand a reasonably good chance of acquiring some awareness of the range of interests involved and of the correction, if any, that he should apply to his own heading. In this way it should be possible to proceed from a common curriculum in the lower division, through a unified curriculum in the junior year, to an elective curriculum in the last semester of the undergraduate program.

Even in the lower division of the undergraduate school the teaching faculty in physics should be drawn from the full range of physical science. A cut-rate lower-division educational operation in physical science, dependent on the use of a large number of graduate-student teaching assistants, should not be allowed to take root in new universities and should be eradicated from well-established universities. Instead, reliance should be placed on a largely professorial staff drawn from all the research areas in theoretical, experimental, observational, and applied physics.

Table 1. Interesting areas of research in physical science.

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|---|
| High-energy physics (natural and man-made) |
| Physics of materials |
| Biophysics |
| Thermodynamics, energy conversion, and fusion. |
| Fluid mechanics, electromagnetic theory, and plasma physics (natural and man-made) |
| Quantum electronics, optics, and microwaves |
| Systems (electrical, mechanical, and human) |
| Solar-system physics (including geophysics) |
| Galactic and extragalactic astronomy |
| Applied mathematics |

### Conclusion

This discussion of an integrated academic approach to physical science has not included pure and applied chemistry, the future of which is as important to biological science as to physical science.

With the kind of reorganization in physical science that has been described, together with a similar reorganization in biological science, it should ultimately be possible to combine the two into a reasonably coherent university approach to science as a whole, with pure and applied chemistry as the cement.