physics in

By *L. F. Curtiss*

The author, as a 1951 Fulbright research scholar, spent several months in India where he worked in collaboration with Professor P. S. Gill of the University of Aligarh, who is also director of the recently established cosmic ray laboratory at Gulmarg.

INDIA, as is well known, has a notable record in the field of physics, the more remarkable in view of the differences between her cultural background and that of occidental countries. The major achievements in this record were made in the era preceding India's recently won independence. The people of India, having struggled so long for this independence, are making a determined effort to bring their country abreast those of other free peoples of the world. In this effort every phase of modern progress has come in for consideration. The impressions gained by an American physicist during several months in the spring and summer of 1951, while a Fulbright research scholar, may therefore be of interest to some of the readers of *Physics Today*. In presenting this discussion I should point out that I did not visit all the laboratories of this vast country, even though this statement might seem unnecessary to those familiar with India. Also this was my first visit so that I can make no firsthand comparisons with earlier conditions. My host institution was the Muslim University at Aligarh. During the six months spent in the country I visited the universities and research institutes located in Allahabad, Agra, Benares, Bombay, Delhi, Lucknow, and Madras. I also visited the University of Ceylon at Colombo and for about two months was in that part of the Himalayas situated in the province of Kashmir.

It is too much to expect that everyone who knows India will concur in all the contents of this brief survey. I will regard it fortunate if less than half the comments are considered open to question. The information on which this discussion is based results only in part from personal observation and many paraphrased comments of Indian physicists and other scientists are included. Although every conscientious effort has been made to give these views accurately it can scarcely be claimed that they have not been colored to some extent by the reporter. Little reference will be made to the accomplishments of workers in physics in India since these are described in a number of scientific journals and are undoubtedly familiar to those interested in the different branches of physics to which they belong. Because of the sketchy nature of this survey no names of individual Indian physicists will be mentioned which again can be justified on the basis that they are also known to us, at least through their publications. It seems preferable to give here some description of the conditions under which our friends in India work and related details which can scarcely be known without actually visiting the country.

Naturally to understand something of the type of work one sees in laboratories in India it is necessary to consider the period of the past in which these laboratories were created. The time since independence has been too short for radical changes and plans for improvement of conditions are just beginning to produce concrete results. During the colonial period, I am informed, promising Indian students of physics were encouraged to go to England for advanced studies where the degree of doctor of philosophy was frequently awarded by a university to these men on completion of their studies. At the same time, deliberately or accidentally, study at continental European laboratories seems to have been discouraged and American universities were scarcely considered, largely because of remoteness and expense of travel. For a variety of reasons, difficult to ascertain, little effort was made to establish graduate courses in physics in Indian universities, which, in the main, are still content to limit such activities to preparation of candidates for the degree of master of science. The natural result of such a program has been to restrict the development of research facilities, not only of those required in advanced training in physics but for all kinds of experimental physics research. This program had gained such common acceptance that there was little inclination to solicit financial support for expansion of research fa-

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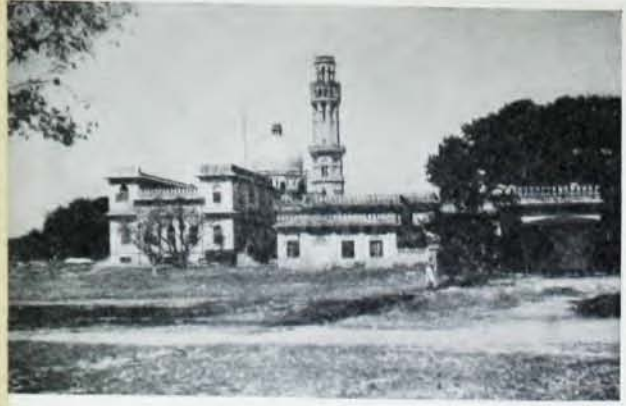
The National Physical Laboratory, New Delhi

cilities. Imposed on this tendency was the further obstacle that experimental equipment was expensive, was all imported, and that at best financial support could be enlisted only sporadically and in general on a very small scale. Regardless of any argument as to which of these influences were cause or effect, the over-all picture presented reveals what we would consider definitely inadequate facilities for physical research at the majority of the institutions. However the saving feature in this picture is that the physicists in India are well aware of this deficiency and are striving, with the means available, to correct it.

THIS BRINGS US to another aspect of the situation where again it is difficult to separate cause from effect—although there is little doubt concerning the present state of affairs. This question may be approached by observing that a relatively small percentage of physicists in India are engaged in research although the country has a considerable number of large universities. The departments of physics annually turn away numerous prospective undergraduate and graduate students of physics to avoid overloading teaching staffs and instructional facilities. Under these circumstances there is strong inducement for physicists trained abroad to accept teaching positions in the universities. As one of these commented, whereas in most other countries the recipient of a degree of doctor of philosophy accepts it as marking his entrance on a career of research, too often in India it represents the end of such a career. Undoubtedly the industrial and economic structure of the country is also responsible for the lack of opportunities for advanced training as well as for opportunities to continue research after this training is completed. In comparison with the size and population there are, for example, relatively few industrial research laboratories and practically none approaching the scale which we know in our country. Opportunities for employment in active research are therefore limited to a few government laboratories, most of which have been established recently, and to a corresponding number of private research institutes which will presumably also be dependent on the government in the not too distant future. It is understandable that there exists little incentive for training investigators who are likely to have only a slim chance of obtaining work in their specialty. Until home industries are developed for the production of highly technical equipment, the establishment of industrial research laboratories comparable to ours can scarcely be anticipated. This remark may become a little clearer when it is pointed out that all such articles of commerce as radios, television sets, electronic and X-ray tubes, and a host of others are now all imported. This situation also contributes to the problems encountered in equipping laboratories. In addition to the slow movement of shipments over considerable distances and the payment of customs duties which are usually quite high, the hurdle of obtaining an import license must be overcome. All imports are subject to rigid governmental control.

The brilliant exceptions to this somewhat negative view are sufficiently well known so that it is unnecessary to mention them. One might well inquire how Indians have been able to contribute so much to the advancement of physics if only a part of what has been said is true. It must be recalled that India has been



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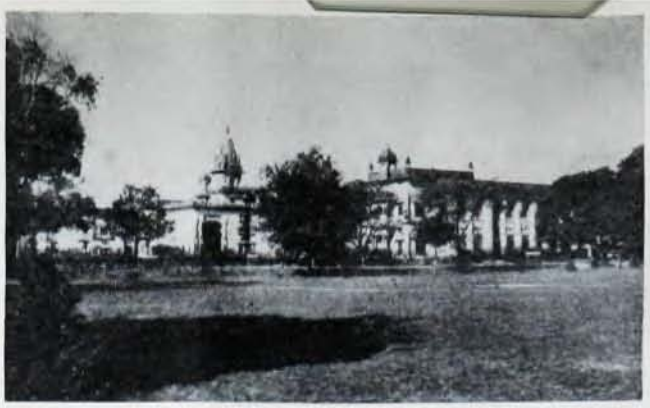
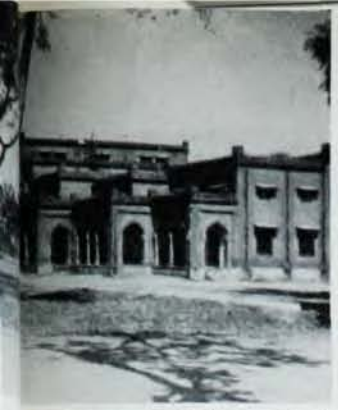


Science buildings at Benares University

noted as a country in which a few men possessed great wealth; in fact perhaps the wealthiest individuals in the world have lived there. Fortunately some of these maharajahs and nabobs have from time to time provided liberal financial support for some institution in which they became interested. As in many other countries, the ranks of these wealthy benefactors are being rapidly depleted by taxation or confiscation, a process which appears to have been accelerated under the new government. Even now the provincial and central governments are the major source of funds for educational and research institutions: again a situation that is familiar to all physicists in the United States. Therefore, those institutions originally founded and supported by private funds are rapidly joining the ranks of those relying entirely on the government for maintenance. This has not resulted in the phenomenal expansion of research facilities which we see on every side nor is it likely to at any time in the near future. The government of India has not yet explored extensively the possibilities of deficit spending. It relies chiefly on its available income which, as everyone can appreciate, must be quite small when account is taken of the limited industrial expansion compared with that in other parts of the world. Furthermore there are many more pressing problems, also perhaps a direct outcome of lack of industrial progress, for which government money must be spent. These may be suggested by recalling that the country does not produce enough food for its teeming population, which is about ninety per cent illiterate. It is almost impossible to portray, and it is left to the imagination of the reader to envisage, the obstacles which these and similar facts place in the way of creating a stable democratic government. It is small wonder that considerable confusion exists regarding which end of the general problem should receive first consideration, education or feeding the masses.

The desirability of large-scale government support for science has often been questioned in the United States. Even today, it is frequently the subject of lively debate, although most universities in this country have largely given up any hesitancy in accepting such support when available. The voices of the opposition have been muffled considerably by the great increase in the output of physical laboratories which receive such support and by the fact that very substantial amounts of money have been forthcoming. This eliminates any possible accusation of favoritism or negative control by the refusal of funds. This happy situation does not prevail in India. What we would now regard as a mere trickle of money can be supplied by the government and many requests must be refused and even occasionally obligations cancelled. Under such circumstances there seems to be a temptation for those responsible for the distribution of funds to favor friends or projects in which they may have a personal interest. At any rate dissatisfaction in the system seems to be growing whether suspicions are justified or not. Conversely, considerable time and effort must be spent by those in charge of research programs to justify their projects or win the favor of government officials. In an economy such as exists in India today, where in different ways every level of society is struggling for existence, any means by which even a momentary advantage may be gained is eagerly seized upon. Official and personal conflicts often break out into open hostilities which do additional damage to the support of science.

After visiting a few laboratories in India, I believe the average American physicist would be most strongly impressed by the absence of any kind of accelerators for experimental investigations in nuclear physics and the production of radioisotopes. When we recall that the prodigious developments in our country have resulted from the possible military by-products of such machines, we can understand quite readily why much of this difference exists. All equipment of this kind is far too expensive to build and to operate for the budgets of laboratories in India. The physicists there have until the present been forced to make use of much more modest equipment. This explains, in a large measure, why they have been chiefly concerned with investigations of cosmic radiation and the development of mathematical theories. These activities require a minimum of apparatus and can be pursued at relatively small cost. Cosmic rays also offer an especially attractive field as a result of the geographical location and general topography of the country. Geomagnetic latitudes extending roughly from 24° N to a few degrees south lie within its boundaries. Elevations up to 18,000 feet and higher are reasonably accessible during several months of each year in the Himalayas. Since these mountains rise quite abruptly from the plains, ob-



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Gulmarg, where a new cosmic ray laboratory has been established

servations from near sea level to the higher altitudes can be made in the same geomagnetic region.

The availability of locations for high altitude research, in other fields of science as well as physics, has stimulated efforts to establish research laboratories at some of these sites. At the present time the University of Aligarh, in cooperation with the University of Jammu and Kashmir, has begun to equip a laboratory for cosmic ray and high altitude studies at Gulmarg in Kashmir about thirty miles from the capital, Srinagar. Although this laboratory is now located in a building at an altitude of only 9,000 feet, comparatively low for the Himalayas, there are other convenient nearby sites at significantly higher altitudes where permanent observation stations could be established. Gulmarg enjoys a remarkably pleasant climate in summer, gaining the title of "queen of the hill stations," during the period of British occupancy of the country. The laboratory will include living quarters for visiting scientists and their families which should provide ideal surroundings for pursuing investigations which must be made at high altitudes. The unsettled political situation in which Kashmir now finds itself may hamper the future growth of this laboratory. Otherwise it may well become one of the important centers of the world for high altitude research, a possibility favored by the liberal attitude of the sponsors in inviting investigators from all nations and in any field of science to make use of whatever facilities can be provided.

THE RESEARCH INVESTIGATOR in India enjoys some advantages not generally available in our country. The chief of these is that he may have a considerable number of skilled workmen to assist in constructing and assembling equipment and to take care of its maintenance and operation. This statement must not be interpreted in the light of procedures here at home and requires a little explanation. India is famous for its craftsmen who produce intricate and elaborate objects from metal, wood, glass, ivory, and other materials by the simplest manual operations. This native skill has found useful applications in the laboratories so that much of the equipment required in the kind of experimental work undertaken can be made in the laboratory. Using elemental hand processes, these craftsmen often can produce metal parts that compare favorably with products of machine tools. Glass blowers are also recruited from these artisans and become quite proficient after short training periods. The wage scales are so low that an American at least would scarcely believe them. Many of these craftsmen work for less than the equivalent, at present exchange rates, of twenty dollars per month. The physicist usually will have a metal worker, a glass blower, or woodworker, depending on his needs, always ready to help with construction of equipment, as well as laboratory assistants to assemble, maintain, and operate his equipment. This tends to compensate for many of the handicaps which confront him. After designing and superintending the assembly of the apparatus he proceeds with the observations with a helper at hand to undertake many of the manipulative operations. This marked division of labor, characteristic of India over many centuries, also involves some disadvantages. In this situation the investigator may not gain a familiarity with his materials and therefore may find it difficult to develop new methods and procedures. He comes to rely on his assistants for information regarding possible modifications of design. He even may find himself so dependent on these helpers that he cannot proceed with his work in their absence. There is evidence that the limitations of this regimen are beginning to be appreciated and of conscious efforts to train the experimenter to bring himself in close contact with the details of his experiments.

WITHOUT INTENDING to make comparisons with other laboratories of the country which I was unable to visit, I would like to mention two laboratories which have adequate, if not outstanding, equipment for their work. There may be others as fortunately situated. At the University of Ceylon the department of physics has one of the several large Wilson chambers with a powerful electromagnet designed by P. M. S. Blackett for cosmic ray studies and constructed in England under his supervision. This chamber is well equipped with practically every desirable accessory of the highest quality. It has only recently been put into operation at Colombo. In a few years, after the particle spectrum at sea-level has been thoroughly studied, it will be moved to the new site of the University at Kandy where this work can be repeated

at the same geomagnetic latitude and at an altitude of several thousand feet. Ceylon seems to enjoy a comparatively high degree of prosperity and the government has been quite liberal in its support of research in physics. The staff there would welcome visiting physicists who may wish to come for an extended stay and make use of facilities suited to their work. The other laboratory attracting my attention with respect to quality of equipment is at the Tata Institute for Fundamental Research at Bombay. This institute was started with private funds but now enjoys what is apparently generous support by the government. It has succeeded in bringing together a number of enthusiastic investigators who have acquired and assembled up-to-date equipment, particularly electronic devices, needed in the study of cosmic rays. Their specialty at present is the exploration of cosmic ray intensities at the high altitudes reached by balloons and the study of the variation of these intensities with geomagnetic latitude. The existence of these rather exceptional laboratories emphasizes that more adequate financial support on a much wider base is what is chiefly needed to increase greatly the productivity of physics in India. Although those responsible for such a program are striving to do what they can along this line it would seem that financial assistance from other countries not only would be welcome but would pay richer dividends for modest investment than perhaps anywhere else in the world. This conclusion assumes, of course, that a corresponding increase in opportunities for advanced training, in the universities and elsewhere, would accompany such a program. At present it is apparent that there are shortages of trained personnel to carry on expansions already under way.

Perhaps the most notable example of the efforts to improve the position of physics in India which came to my attention is the new National Physical Laboratory at Delhi. The whole institution is to be housed in a truly enormous modern laboratory building that is as yet less than half completed although construction has been proceeding several years and is in continuous progress. Careful study of laboratory buildings in other countries, particularly the more modern examples in the United States, preceded the planning of this building. Consequently it incorporates many of the best features of advanced laboratory design. The expense has been so great that as yet only a small amount of equipment has been acquired to equip the laboratories already completed. The small staff is nevertheless enthusiastically at work in an effort to fill this void. It is easy to predict that this laboratory will, when in full operation, contribute handsomely to the progress of physics not only for the benefit of India but the rest of the world as well. Even in its present incompleted state the building in size and attention to detail represents a structure that would form a prized acquisition by any government. In addition it seems to stand as a symbol of the kind of progress to be expected in a country which has already made valuable contributions to the advancement of physics.

Books

Photosynthesis and Related Processes (Volume II, Part 1). By E. I. Rabinowitch. 1208 pp. Interscience Publishers, Inc., New York, 1951. $15.00.

Photosynthesis, the utilization of light energy by green plants to convert carbon dioxide to organic compounds of high energy content, has been investigated experimentally for a century and a half by hundreds of biologists, chemists, and physicists. The mechanism of the natural process is not known, nor can it yet be reproduced outside of living material. The great diversity in objectives, in methods of attack, in language, and even in the experimental results of various workers with nearly the same objectives makes it a most difficult field to summarize thoroughly and critically. This, Rabinowitch has done with lucidity, elegance, and precision, both in Volume I, and in the present book. It is no longer possible for one who is primarily an experimental investigator to completely understand and appraise any large fraction of the publications in botany, biochemistry, chemical physics, photochemistry, and applied optics that are of relevance to this subject. Therefore the penetrating understanding, the completeness of coverage, and the author's good judgment in the handling of the subject make it seem likely that this book will be of value for a generation, as was true of the 1926 book on the subject by Spoehr.

Volume II, Part 1 begins with the absorption spectroscopy of purified pigments, goes on to consider the absorption by these substances in living cells, and then takes up their fluorescence in extracts as well as in the cells. The fluorescence spectra and the variation of fluorescence intensity of the pigments are discussed in relation to their photochemical activity.

To quote from the introduction to the second half of the book dealing with kinetics of photosynthesis: "What one measures as the 'yield of photosynthesis' is the net result of the operation of a complex mechanism. No simple kinetic equation can account for all the factors that influence this yield. It is comparatively easy, after having made a series of kinetic measurements on a selected system, to invent a model that would interpret these particular observations, or even to write down equations fitting the experimental results more or less closely. The literature on photosynthesis abounds in such formulations. Their limited significance is illustrated by the fact that practically nobody ever uses equations derived by somebody else; instead, every investigator starts anew, often without as much as re-