INSTITUTE
OF
NUCLEAR PHYSICS

UNIVERSITY OF CALCUTTA

1955

PREFACE

The Institute of Nuclear Physics has grown out of the research laboratory of the Palit Professor of Physics of the Calcutta University. The foundation stone of the building was laid on April 21, 1948, by the Hon'ble Dr. Syamaprasad Mukherjee, the then Minister of Supplies and Industry in the Central Government. The Institute was formally opened on January 11, 1950 by Prof. Madame Irene Joliot-Curie, Nobel Laureate and daughter of the discoverers of Radium. The function was attended by many eminent scientists of the world *viz.*, Prof. Frederick Joliot-Curie, Lady and Sir Robert Robinson, Prof. J. D. Bernal, besides local scientists.

The Institute is at present housed in a three-storied building, having a total floor area of 30,000 sq. ft., located within the compound of the University Colleges of Science and Technology, at 92, Upper Circular Road, Calcutta-9, and was built at a cost of Rs. 6 70 lakhs. By mutual agreement between the Calcutta University and the Government of India, the Institute is managed by an autonomous Governing Body, composed of representatives of the Calcutta University, of various departments of the Government of India, of the Inter-University Board, and is presided over by the Vice-Chancellor of the Calcutta University.

The Institute of Nuclear Physics is devoted to teaching and research in nuclear science. The Institute offers courses of instruction in nuclear physics to students appearing for the M.Sc. degree in pure physics of the Calcutta University. It offers one year Post M.Sc. Associateship Course, which imparts advanced training in theoretical and experimental nuclear sciences, and also enrolls students for research degrees, D. Phil (Science) and D.Sc., of the Calcutta University. The Institute is engaged in extensive research work in the various branches of nuclear science, *viz.*, particle accelerators, beta and gamma ray spectroscopy, nuclear magnetic induction, neutron physics, mass spectroscopy, nuclear chemistry, instrumentation, theoretical nuclear physics, etc.

This pamphlet gives a short account of the history of the Institute, the programme of work undertaken during 1950-54 by the different divisions of the Institute, the difficulties that hampered the progress of work, and the achievements of the various divisions during the first five year period. The pamphlet also describes the plan of work of the Institute for the second five year, 1955-60, the expansion schemes of the different divisions and the need for creation of new divisions within the next five year period on the lines approved by the Governing Body of the Institute.

When the Institute was founded, it consisted of the Cyclotron division, small sections carrying out researches on the various branches of nuclear science and the Biophysics division. The work of the Biophysics division has expanded greatly in recent years and a separate Institute of Medical Physics has been proposed to be set up with the Biophysics division as the nucleus. The plans and programme of the Institute of Medical Physics have already been published in the form of a brochure and therefore are entirely excluded from this pamphlet.

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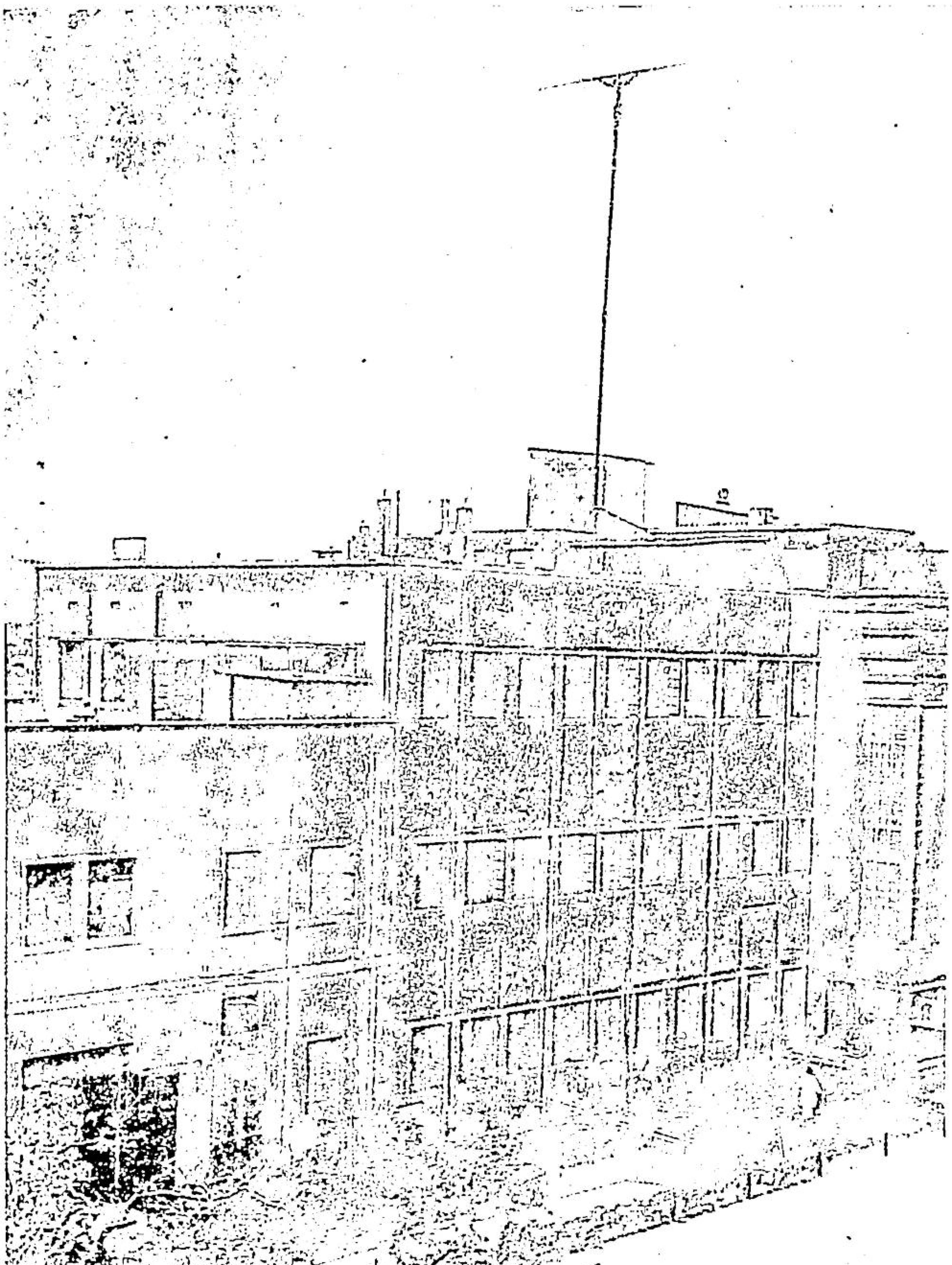


The Institutte of Nuclear Physics, 1955.

HISTORICAL INTRODUCTION

As early as 1940, immediately after the discovery of fission by Otto Hahn, Professor Meghnad Saha, the then Palit Professor of Physics, Calcutta University, realised the great importance of atomic research. Through several articles in the leading scientific journals he drew the attention of the Indian public to the fact that this great discovery might bring about a greater technological revolution than any previous scientific discovery like the discovery of fire or of the steam engine. At Prof. Saha's instance, Nuclear Physics was introduced as the subject of a Special Paper in M.Sc. Syllabus for Pure Physics. The Palit Research Laboratory was reorganised for teaching and research in Nuclear Science. Through the patronage of Pt. Jawaharlal Nehru, the then Chairman, National Planning Commission of the Indian National Congress, the Calcutta University received a gift of Rs. 60,000/- from Dorabji Tata Trusts to purchase parts of a Cyclotron machine and the University supplemented the gift by an equal amount.

At this time, Dr. B. D. Nag Chaudhuri, at present Palit Professor of Physics, was working as a research assistant to Prof. E. O. Lawrence, inventor of the Cyclotron, at the Radiation Laboratory, Berkeley, California. He was provisionally appointed Cyclotron Officer and an amount of money was sent to him to purchase the necessary components. He was greatly helped in this task of purchase by Prof. Lawrence and the staff of the Radiation Laboratory.

Dr. Nag joined the Calcutta University in 1941, and goods began to arrive from the beginning of 1942. But due to the outbreak of hostilities with Japan, a substantial part of the components including the all important high vacuum mechanical pumps were lost in transit. The cyclotron was housed in a small two storied building of covered area of 4,000 sq. ft., built at a cost of Rs. 30,000/- After the completion of the Cyclotron building in 1942, the work of installing the Cyclotron magnet, the power supply and other parts was undertaken in right earnest. These presented engineering problems of great difficulty, but were successfully overcome, thanks to facilities available at a great industrial city like Calcutta. But the want of high capacity mechanical pumps was a great handicap. Attempts to procure such pumps (Cenco Hypervac 100, or Kinney 8 CVD 8810) were unsuccessful due to war conditions. Attempts were made to manufacture pumps in our own workshop with the aid of a grant from the C.S.I.R., but though we succeeded in making pumps up to the standard of Cenco Megavac Type, these did not give us the desired pumping speed.

In 1944-45, Prof. M. N. Saha, as a member of the Indian Scientific Mission, travelled widely in England and U.S.A. and gathered much information about the developments in the construction of Cyclotrons and other particle accelerators.

Immediately after the National Government was formed, the late Dr. S. S. Bhatnagar and Prof. Saha waited upon the Prime Minister for a grant to enable the Calcutta University to buy the pumps and other accessories. The Prime

Minister was kind enough to sanction a capital grant of Rs. 70,000/- and a recurring grant of Rs. 40,000/- for two years on 6th September, 1946. He only remarked that the amount asked for was too small. The recurring grant was raised to Rs. 60,000/- in 1948.

Dr. B. D. Nag was again sent to U.S.A. in 1947, to make the necessary purchases. He stayed for about 6 months in the Radiation Laboratory, Berkeley, California and was able to secure through the good offices of Prof. E. O. Lawrence and the Radiation Laboratory staff, the Kinney high vacuum pump and other necessary components.

The materials began to arrive by the end of 1948, and the reinstallation work was undertaken in right earnest. By the middle of 1950, the reconstruction had been completed, and the machine was put into operation.

However, during all this period a programme of research and development had been under way and worthwhile contributions have been made by the Palit Laboratory of Physics. Though the Cyclotron could not be completed at that

Dr. S. P. Mookerjee laying the foundation stone of the Institute of Nuclear Physics.

time, work in other directions were in progress. The workers of the laboratory were mastering the techniques of measuring nuclear energies. Dr. N. N. Das Gupta had installed the electron microscope, the first one in India. Dr. S. C. Sircar, Dr. N. N. Das Gupta, Dr. P. C. Bhattacharyya were already well-known in the field of cosmic rays. Dr. A. K. Saha had made original contributions to beta-ray spectroscopy. The workers of the laboratory were specialising in the various uses of electronic devices under the guidance of Sri B. M. Banerjee. And Sri B. C. Purkayastha had been developing techniques of nuclear chemistry.

The necessity of a larger building to house the apparatus, machinery and the research workers was felt as early as 1945. The small two storied building which was constructed in 1942 to house the Cyclotron and its accessories was found quite insufficient. In 1947, the then Vice-Chancellor of the University Dr. P. N. Banerjee arranged for a loan of Rs. 2,00,000/- (Two lakhs) from the Sur Fund for construction of a building, with the consent of the donors. The money is to be repaid in ten years in annual instalments of Rs. 20,000/-. The Central Government was kind enough to provide a sum of Rs. 3,50,000/- (Three and half lakhs). The foundation stone of the new building was laid on April 21, 1948, by the Hon'ble Dr. S. P. Mookerjee, the then Minister of Industry and Supplies in the Central Government, and in course of two years the building was completed. The total area of the building in three stories is over 30,000 sq. ft. and the foundations are strong enough for taking a fourth storey. The Atomic Energy Commission has made a further contribution of Rs. 1,20,000/- in 1950 to enable the Institute to buy furnitures, fittings and complete the services.

The Institute was formally opened on January 11, 1950, by Prof. Madame Joliot Curie, Nobel Laureate and daughter of the discoverers of Radium, in the presence of a solemn gathering in which her husband Prof. Joliot Curie, Lady and Sir Robert Robinson, Prof. J. D. Bernal and many other distinguished scientists were present. His Excellency Dr. K. N. Katju, Governor of West Bengal, presided over the function.

The Constitiution of the Institute, framed and passed by the Calcutta University Senate on the 12th May, 1951, has been given in Appendix I and the standing orders by the Governing Body in Appendix II. By the mutual consent of the Calcutta University and the Central Government, the Institute was constituted into an autonomous body under the joint control of the Government of India and the Calcutta University under the Chairmanship of the Vice-Chancellor of the Calcutta University. Prof. Saha is to remain a life member of the Governing Body and Honorary Director for life.

OBJECTIVE OF THE INSTITUTE OF NUCLEAR PHYSICS—THE PROGRAMME OF WORK AND THE LIMITATIONS.

The Institute of Nuclear Physics was founded with the dual objective of teaching and conducting research in Nuclear Science in its various aspects. As has been mentioned earlier, the teaching of Nuclear Science has been fostered in the early years in the Palit Professor's laboratory since 1939. Nuclear Physics was introduced into the curricula in 1939 as a compulsory subject of study for the M.Sc. examination in Pure Physics. This course has been modified from time to time with the growth of the subject and the present syllabus is given in Appendix V. An advanced course in Nuclear Physics as one of the optional papers for the M.Sc. course in Pure Physics was introduced in 1941. This course included about six experiments in nuclear physics and a more advanced course of theoretical training. However, due to the limitations in laboratory facilities, the number of students that could be admitted to this course was limited. At present about 15 students are permitted to take the nuclear physics optional paper. It was felt in course of teaching the M.Sc. students that further training was necessary if the student is to employ the knowledge usefully in research or in profession. There is no doubt that the training of personnel is important just now and is likely to remain so for sometime to come.

In his letter to the Vice-Chancellor of the Calcutta University, the Prime Minister wrote: "Our resources in scientific talent as well as other matters are strictly limited, although we hope to increase them. We have therefore to make the best use of them. That indeed requires co-ordination on an All-India basis. Because of these various things, certain suggestions were put forward on our behalf to give your Institute of Nuclear Physics more of an All-India character. Of course the running of it and the day-to-day control of it would naturally rest with the Director of the Institute and with the Chairman and Secretary of the Governing Body. But in regard to wider policies it would be beneficial both to the Institute itself as well as to the development of Nuclear Physics and like subjects in India if an All-India character is maintained."

The University accepted the Prime Minister's suggestion and the Institute of Nuclear Physics drew up a scheme of advanced Post M.Sc. training for one year in Nuclear Science open to students from all parts of India. The Post M.Sc. one year course open to 20 students from all over India was started from 1953 and 20 students are admitted each year to this course. In keeping with the All-India character as suggested by the Prime Minister the rules provide that at least forty per cent of the students admitted to the Post M.Sc. course are from outside the State of West Bengal. The course leads to the Associateship diploma. The details can be found in Appendices III & IV.

Our objective and programme are almost identical with those of six British Universities chosen for personnel training in Nuclear Science. Developmental research and production do not fall within our category. Ordinarily we shall not be engaged in any work which falls under secrecy regulations, but shall be prepared to do so whenever called upon by the Central Government, subject to limitations of our capacity in personnel and equipment.

RESEARCH PROGRAMME.

It may not be generally appreciated that in spite of the large amount of practical and theoretical work now being done, we are far from understanding the laws of the nucleus and it may yet take long years before we come to the root of the problem.

It appears that our position with regard to the nucleus is much the same as was the position with respect to the atom about the latter part of the nineteenth century. At present, nuclear reactions and nuclear emissions of Beta and Gamma-rays are being studied still with apparatus which subsequent generations may probably call "crude". But, newer and more powerful technique is being evolved, and more satisfactory data are being collected. But it appears that we have to wait for better and more comprehensive results before we can hope to be put on the right track for understanding the laws of the nucleus.

A research laboratory should therefore be equipped with as good technique as possible, but its organisation and equipment should be capable of adjusting quickly to newer techniques; at the same time one should not neglect theoretical studies, for as Hamilton said long ago, experiments and mathematics are the two eyes of physical science, and to be able to make really good progress, one ought to be able to see with both eyes.

With these objects in view the research programme was drawn up, and was divided in the following sections:

(*a*) Production of high energy fundamental particles, protons, deuterons, α-rays, etc.
(*b*) Study of nuclear reactions effected by these particles.
(*c*) β and γ spectroscopy of radioactive nuclei.
(*d*) Application of these techniques to other fields *e.g.*, biophysics, chemistry, physics, engineering, geology, etc.
(*e*) Study of theoretical physics.

The report of the progress of work of the individual divisions and sections together with the programme of work for the next five years are given in the next chapter.

The major difficulties that we have faced are as follows: The main difficulty has been want of funds as a result of which no long term programme could be drawn up. For lack of funds we could not reappoint our own ex-students who went abroad for advanced training and specialised in specific branches of nuclear physics. As such we could not utilise their experiences. In this respect mention can be made of Dr. D. N. Kundu, who is at present an Associate Professor of

Physics at Ohio State University, U.S.A., Dr. A. K. Ghosh, Dr. S. Biswas, Dr. A. K. Mukherjee, etc.

The second major difficulty has been want of space. The present building is already overcrowded and has no space for new students. As a matter of fact the Post M.Sc. laboratory could not be arranged to our satisfaction as no space is available at the moment. The activities of the Instrumentation Section, Nuclear Chemistry Division, Neutron Physics Section, etc. are also being hampered for want of space.

REPORT OF WORK OF THE VARIOUS DIVISIONS AND SECTIONS AND EXPANSION SCHEMES FOR THE FIVE YEARS 1955-56 TO 1959-60.

As has been mentioned earlier, when the Institute was formed, it constituted of the Cyclotron Division and small sections carrying out researches on the various branches of nuclear science in addition to the Biophysics Division, the plans and programme of which have been excluded from the brochure. A list of publications for the period 1948-55 is given at the end as Appendix VI.

During this period grants were received from Calcutta University, Govt. of India (Dept. of Atomic Energy, Ministry of N.R. & S.R., Ministry of Education, Ministry of Health, Council of Scientific & Industrial Research, etc.), Government of West Bengal for the recurring and non-recurring expenditures. These grants were received from time to time according to research programme submitted and there was no definite sum sanctioned from the Government of India which was bearing most of the expenses.

Towards the end of 1954, Professor M. N. Saha had a discussion with Dr. H. J. Bhabha, Secretary to the Government of India, Department of Atomic Energy, regarding the yearly grant to the Institute. As a result of this discussion a meeting was held at Delhi on 27th November, 1954 attended by Dr. H. J. Bhabha, and others of the DAE, Prof. M. N. Saha and Dr. J. C. Ghosh, the then Vice-Chancellor of Calcutta University where it was agreed that a five-year plan for expansion of the activities of the Institute of Nuclear Physics excluding the Biophysics Division should be prepared and submitted to the Government of India for discussion and approval.

Accordingly the plan was submitted and discussed in meetings on March 21 and 22, 1955 at Delhi, attended by representatives of Calcutta University, Government of India, and the Institute of Nuclear Physics. These meetings laid down the general policy for the five-year development plan of the Institute (Extracts of these meetings are given in Appendix VII), and accordingly the already submitted plan was revised and sent to the Department of Atomic Energy. The final recommendations of the Department of Atomic Energy have since been forwarded to the Ministry of Finance, Government of India for their final sanction.

In view of the 5-year development programme the activities of the Institute have been divided into the following Divisions and Sections:—

1. Accelerator Division ...	... Cyclotron Section
	Mass Spectroscopy Section
	Electron Synchroton Section
2. Nuclear Physics Division	... Beta and Gamma-ray Spectroscopy and Nuclear Induction Section
	Theoretical Physics Section
	Teaching Section
	Neutron Physics Section
	Instrumentation Section

3. Nuclear Chemistry Division ...
4. Administrative Division ... General Administration Section
   Library Section
   Workshop Section

The history of each section, its past and present record, and schemes of expansion are shown separately in the following pages.

THE ACCELERATOR DIVISION

A. *Cyclotron Section :*

Particle accelerators have been found indispensable for nuclear science research. The various types of 'Particle accelerators' are:

(*a*) Cockroft Walton Generators:—200 Kev.—1·5 Mev. heavy ions and electrons.

(*b*) Van de Graaf:—500 Kev.—6 Mev. heavy ions and electrons.

(*c*) The Cyclotron:—Useful energy from 1 Mev.—20 Mev. protons, deuterons and other heavy ions.

(*d*) The Betaron:—1 Mev.—100 Mev.-electrons only.

(*e*) The Synchrocyclotron:—16 Mev.—1,000 Mev. heavy ions (*e.g.* protons).

(*f*) Synchrotron:—
   for electrons—100 Mev.—1 Bev.
   for protrons—1 Bev.—30 Bev. heavy ions (Variously called Cosmotrons, Bevatrons, etc.).

(*g*) Linear accelerators:—
   32 Mev. heavy ions.
   200 Mev. electrons.

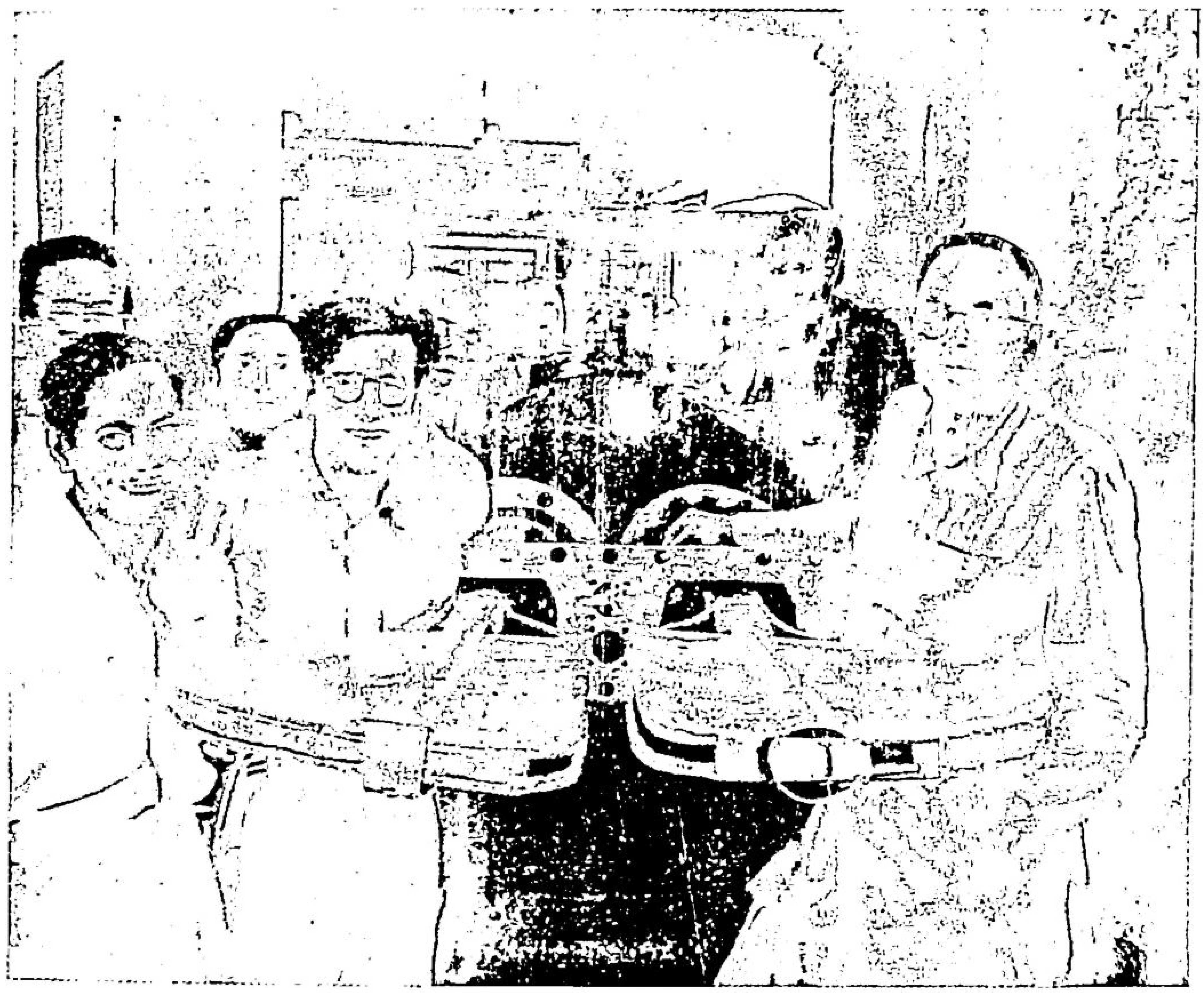
The heavy ions are more useful as projectiles for nuclear work than electrons, but electrons can easily be accelerated to high energies.

In the range of smaller energies, Cockroft Walton Generators being the most simple and inexpensive machine has found general acceptance. However, there are many difficulties in increasing the energy beyond 1 Mev. and the accepted convenient limit is about 1·5 Mev. for these machines.

The range of energies, where nuclear reactions occur with comparative ease is beyond 3 or 4 Mev. for charged particle. Hence an accelerator for conventional use should have energies above 3 or 4 Mev. and preferably upto 10 Mev. or 12 Mev. maximum energy. The cyclotron, being the most convenient and inexpensive instrument in this range, was chosen. The cyclotron was designed by B. D. Nag Chaudhuri and is operated at small beam currents at present.

The cyclotron was designed with a magnet of 38″ pole face diameter tapered from a 42″ pole diameter according to a shape given by Rose. The magnet is carbon free silicon iron and requires 300,000 ampere-turns for saturation. The designed operation ampere-turns is a maximum of 250,000 and the power requirement for this is 35 killowatts. The radiofrequency system was planned to give

80 KV. between the Dees at a frequency of 11 mc/s. The R. F. generator for this purpose was designed by Sri B. M. Banerjee of the Instrumentation division. At first a self-excited pushpull oscillator was designed which was later modified to an excited power amplifier unit. Frequency stability was achieved by designing high Q grid lines for the exciter unit. The dees were tuned by adding lump capacity adjusted within the vacuum by selsyn motors. The whole radio frequency unit requires a power of 85 kilowatts. The vacuum system has a volume of about 2,000 litres which have to be evacuated to better than 10^{-5} mms. of mercury. This requires a carefully designed vacuum system and suitable pumping arrangements.



Prof. Saha and Prof. Nag at the Cyclotron.

A CVD-8610 Kinney pump backs two three-stage ail diffusion pumps (10" each). They are suitably inter-locked to vacuum gauges for protection against sudden leaks or failures in the system. The conventional liquid air trap is not convenient in such large dynamical systems and is replaced by a refrigeration system using freon in which the cooling coils are incorporated in the baffle inside the vacuum system. The vacuum system requires a power of 17 kilowatts. Further, for the arc type ion source with a radio-frequency heated filament, the cooling and the heat exchanger system and auxiliary units require another 12 kilowatts of power. The total power on operation is about 160 kilowatts. To supply the power requirements, a separate power substation of 250 kilowatts was constructed. All these units have to function properly and have to be maintained carefully to enable the cyclotron to be operated satisfactorily.

A deflector system has been designed for operation with an external ion beam and some parts of it have been constructed. It will be installed after the high voltage unit already ordered for, is received and tested.

The maintenance and operation of the Cyclotron requires the full time of 2 operators in four hour shifts for operation in two shifts a day and other research workers and mechanics for work on maintenance and replacements. The team of workers divide this work amongst themselves and use the spare time for development and research activities.

In connection with the construction and use of the cyclotron, the division has to undertake a wide variety of experiments which are summarized below:

(*a*) *Magnetic field and field gradient measurements:* An instrument using two balanced coils are rotated by a synchronous motor. Silver sliprings and brushes were used to reduce contact potential effects. A frequency compensated amplifier was used to amplify the a.c. potential which was then read from a suitable valve-voltmeter.

(*b*) *Radio-frequency power systems and their delivery:* The problem of delivering radio-frequency power into a given circuit brings in special problems. An example of the type of problem solved is the delivery of about 150 watts r.f. power to ionsource filament which has an impedance of 0·1 ohm. Matching devices and impedance transformers have to be used in this case. The cyclotron Dees for example are comparatively at high impedance and power is delivered by nonresonant transmission lines.

(*c*) Magnetic field stabilisation and control is achieved by shuntfield control of the generator by electronic circuitry. The magnetic field has to be kept steady at any set value. It also must be easily adjustible to any other desired value. A double photocell sensing unit with a r.f. carrier frequency to carry the signal to the control unit is used in the present device and has given satisfactory operation.

(*d*) Scintillation counter techniques were first developed in India at the Institute of Nuclear Physics and are now in general use in the laboratory. However, there are many aspects of the technique such as shorted delay lines for pulse shaping, pulsed photomultipliers for large output pulses on which we have already worked, and aspects such as internal delay and spread of the pulses in the photomultiplier which require further study. These techniques have been developed in connection with the setting up of a neutron velocity selector using the cyclotron as a neutron source.

(*e*) Operation of diffusion pumps, problems of back diffusion and general study of the problems of vacuum technology have been the subject of study in the Palit Laboratory of Physics before the Cyclotron project was undertaken. The techniques of production and measurement of high vacua has reached a degree of engineering perfection which are of great use in the design and construction of large vacuum systems. Together with the technical aspect researches have been carried out on the processes of back diffusion.

(*f*) Pulse height correlation in scintillation counting for electrons in the range 100 Kev. to 1·1 Mev.

A study has been conducted on the light yield correlation of various scintillation phosphors (such as terphenyl, diphenyl, stilbene, anthracene, plastic phosphors, NaI etc.) using selected energies of electrons in the region of 150 Kev. to 1 Mev. A small beta-ray spectrograph was used for energy selection. It is planned to extend this work to the study of the mechanism of energy transfer from an ionising particle to the yield of scintillation light. This problem is of interest both to solid physics and to nuclear physics and may give some information on ways to improve and design scintillation counters.

(*g*) *Design and operation of ion sources:* The cyclotron uses a radio-frequency heated arc type ion source which has to be pulsed for many types of work with the cyclotron.

(1) An Ion beam modulation system has been constructed on the principle of pulsing the ion source of the cyclotron. This modulation system is a somewhat modified system of ion source modulation using thyratrons and phase shifting net works and delay circuits and has been built in this laboratory. A small model has been constructed for testing and a larger unit will be built after modifications incorporated as a result of the tests. Cores have been ordered which will enable us to produce pulse durations of the order of 100 millimicroseconds in the ion source.

(2) The other aspect of our work on ion sources is the development of a radio-frequency ion source. A preliminary experimental model working at 70-80 mc/s show that 1 M.A. of ions can be easily extracted from a conventional size ion source but working at much lower pressures.

(*h*) We have also initiated experiments on neutron spectrometry which is our other line of activity. We are at present studying the problem of neutron time of flight measurements by delayed coincidences in the region of 1 to 30 Kev. A plastic phosphor is used to scatter the neutrons into a detector of Lithium Iodide placed about 18 cm. away and the neutron energies to be examined are selected by a delayed coincidence system.

Plan of work for the next five years:

It is proposed in the next five years to extend the work and complete some of the work we have already started. In this connection we may mention:

(1) The work on development of radio-frequency ion sources will be continued as it is found to be a very promising method of producing ions and ion beams at lower gas pressures than other methods now in use. We also propose to investigate the production of multiply charged ions in radio-frequency ion sources.

The Cyclotron at present uses an arc type ion source. Designs are being made and two different types of ion sources, point cathode ion source and Penning type ion source, will be installed.

(2) The present investigation of scintillation pulse height corelation with electrons of energies upto 1·1 Mev. is proposed to be extended to higher energies. In carrying out the recent work on pulse height corelation of scintillation counters it is found that the extension of the investigation to the mechanism of energy transfer is of value to the understanding of these corelations. It is proposed therefore to carry out an integrated programme of work to include the examination of phosphors and their properties and the mechanism of energy transfer the study of pulse height corelations. It is of interest in this connection to note that in the scintillation phosphor the yield is about one proton for every 1·7 Kev. of energy lost in the phosphor by the electrons in the case of alkalihalides and much larger energies are required per proton in other types of phosphors.

Experiments will be made for studying the response of phosphors to different particles, protons, deuterons and alphas after the deflector and the focussing magnet of the Cyclotron are installed.

(3) Extension of the neutron time of flight measurements to higher energies and greater precision. The total cross sections of different elements for neutrons of energies from ·001 ev to 1 Kev have been studied by the Columbia Cyclotron group, the Argonne reactor group and at Harwell and in lesser detail by others, but very little information is available on neutron capture and scattering levels and level widths at energies greater that 1 Kev. We have already started work in this field and have carried out neutron total cross-section measurements at energies between 1 Kev and 30 Kev. The techniques developed promise to be of great use in investigating this region with high resolution. We also wish to develop neutron spectrometry to go upto 100 Kev energy in the first instance and gradually to energies upto 1 Mev. There are however many technical difficulties to be overcome before 1 Mev energies can be reached by neutron spectrometry methods.

(4) Apart from these lines of work which are already on hand we wish to develop certain lines of work applying the techniques of high vacua and electronic engineering we have developed on an engineering scale in the laboratory on account of the cyclotron. These techniques of high vacuum and electronic engineering are common to all accelerators.

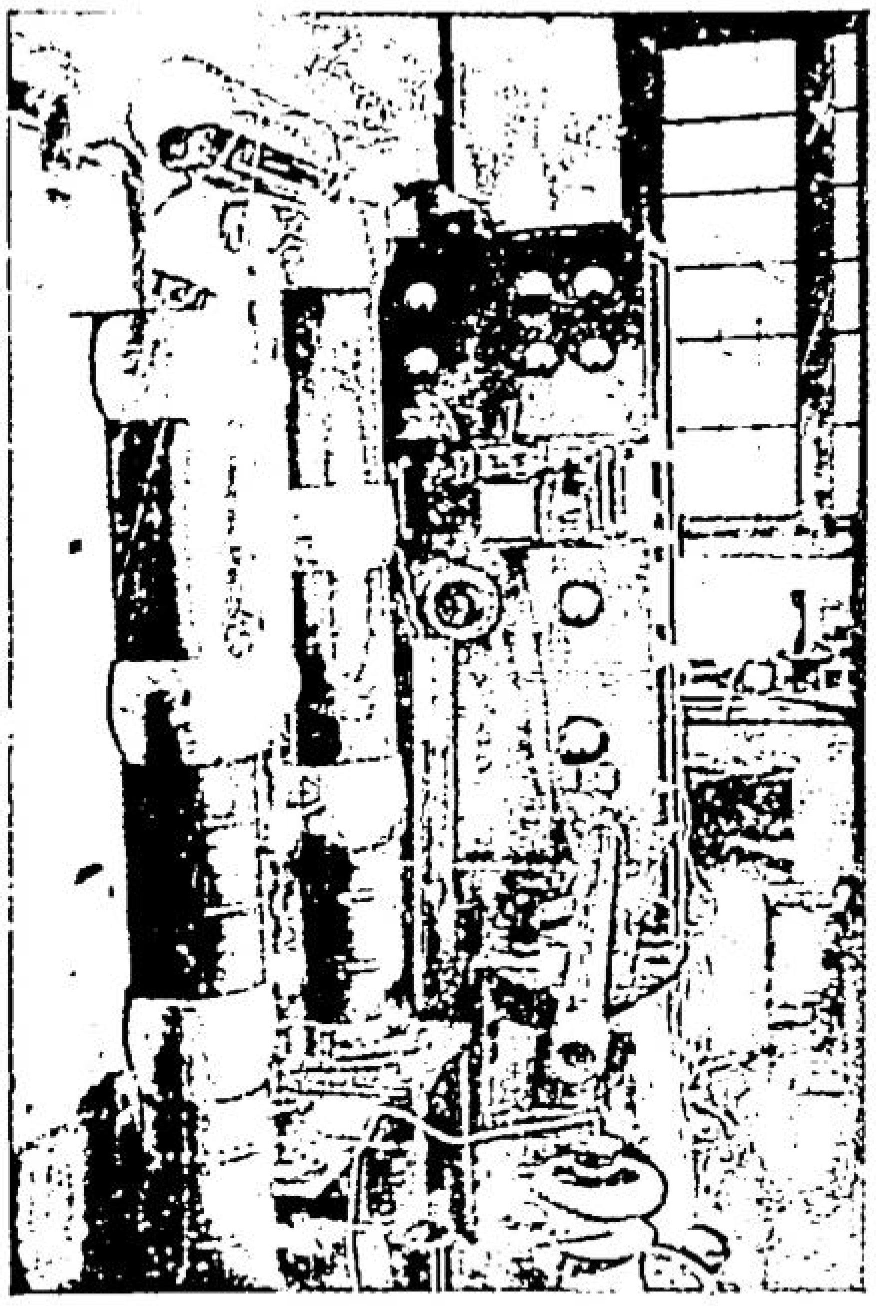
(5) In the first year it is proposed to build a 400 KV radio-frequency Cockroft Walton Generator. The design study of a 400 KV R. F. Cockroft Walton generator has been completed and experiments performed on the various components and possible multiplication of voltages that may be achieved. Experiments carried out on a small system show that it is entirely feasible to construct a 800 KV R. F. generator using conventional transmitting equipment. It is planned to complete the 400 KV generator in 1955. It will be possible in the present design to increase

the voltage by 50% without any radical changes with a few additional equipments. An R. F. ion source for use with this generator has also been constructed and studied as a model. The space for this machine is available.

This will extend the energies available for experiments from the lowest energies to about 8 Mev in the laboratory.

It will also enable us to obtain pulses, as well as continuous streams of monoergic neutrons, in the laboratory from low energies upto about 10 Mev.

A great deal of work has been carried out in the energy region upto 10 Mev. However, there is scope for precision work in this region for example in the field of relative competition between various nuclear processes and in the determination of levels and measurement of level widths. The requirements of precision make this field of work correspondingly difficult. In the high energy region, however, a great amount of information of a qualitative nature can be collected as the present information obtained in recent experiments is mostly qualitative and incomplete. However, the high energy accelerators are expensive and big undertakings. The requirements of power, space, expense and engineering skill in synchrocyclotrons and proton synchrotrons are such that they are not considered feasible within the present limitations of the Institute.



The Cockroft-Walton Generator under construction.

(6) Another field comparatively not so well investigated is that of photonuclear and electronuclear reactions. The high energy electron can give information on the charge distributions of the nucleus. High energy photons give rise to Compton collisions with nucleons of the nucleus at high energies while at lower energies the entire nucleus may share in the various modes of excitation. The detailed experimental investigation of photonuclear and electronuclear effects can yield on the behaviour of single protons or neutrons in the nucleus.

Waffler et al of Zurich have carried out some work on photonuclear reactions and Guth in the USA had done some work on electronuclear reactions. A strong source of high energy photons and electrons is necessary to carry out work of this type. The most convenient source of both is either the electron synchrotron or the linear accelerator. The proportionally higher costs of the linear accelerator for the same energy is the deciding factor in our choice of the electron synchrotron as the source of high energy photons.

B. *Plans for an Electron Synchrotron:*

Various types of accelerators for high energies have been developed in recent years to satisfy specific needs or to examine various principles of acceleration.

The choice of a suitable accelerator in the high energy region is determined by costs and the purpose. A synchrocyclotron or synchrotron for protons is a huge undertaking and requires engineering skill of a high order. However high energy electrons and photons are also of use and can be employed for various experiments at the high energy region for studying photonuclear reactions and excitation functions. The electron synchrotron for this purpose is a reasonably priced instrument. The high vacuum and high frequency techniques are already well developed in the laboratory in connection with the cyclotron and these are exactly the same techniques that are necessary for design and construction of an electron synchrotron. The size and cost of the electromagnet is about the same as that of a medium sized cyclotron. The costs are also comparatively reasonable for the other auxiliary equipment and it will give valuable training for techniques connected with proton synchrotrons which are capable of reaching the highest energies achieved. We have, therefore, taken up the design of an electron synchrotron in the period 1955-57 and propose to start construction from 1957, so as to complete it and bring it into operation by 1960. The electron synchrotron will give a source of high energy photons and electrons which will be used to study photonuclear reactions.

The space required for an Electron Synchrotron will be about 3,000 sq. ft. The Power-Supply for this is available.

The construction of the electron-synchrotron will need the services of one Reader, one Lecturer, one Technical Engineer and a group of Assistants.

We have planned to add various equipments to be constructed as far as possible in the laboratory in the next five years to carry out the programme of work described above.

C. *Mass Spectroscopy Section:*

Mass spectroscopes and spectrometers of various designs have been found indispensable equipments for a nuclear science laboratory for purposes which are listed below. The list, however, is not exhaustive.

(*a*) Precise determination of the mass of isotopes.

(*b*) Separation of isotopes in measurable quantities for experimental purposes.

(*c*) Leak-detection: Mass spectrometric technique for detecting leaks in the vacuum equipments of the laboratory, specially, in the Accelerator Division.

(*d*) Geology: Determination of the ages of rocks and minerals the lead-ratio and potassium-argon method. Studies of fine variations in natural isotopic abundances of elements like C, N, (*e*) Problems of nuclear chemistry and studies of general chemical problems, such as, chemical kinetics, molecular structure etc.

(*f*) Gas analysis as applied to oil industries.

(*g*) Nuclear Problems: Determination of branching ratio and half life of some radio elements.

(*h*) Applications of tracer technique to biochemistry and other branches of science, when enriched isotopes are available.

A study-group on Mass spectroscopy was formed at the Institute of Nuclear Physics and it is proposed to raise it to the status of a Section in course of the next five years.

The study-group has undertaken, besides critical study of different mass spectrographs and spectrometers, the construction of a mass spectrometer of the 180° type of low resolution in 1955-56. After its completion it is planned to construct a second mass spectrometer to measure isotopic abundances in the highest mass-region.

Requirements: At present, the Section, it is proposed, is to be started with a Lecturer, a Research Assistant and a Laboratory Assistant.

Most of the electronic circuits, such as current stabiliser for magnet, stabilised H. V. supply and amplifier etc. will be designed and constructed in this division. An oscilloscope and a pen recorder are to be purchased for a.c. and d.c. detection of ions, respectively. At a later stage, for a precision measurement of low-yield ion beam, we propose to use photomultipliers with phosphors as detectors. The vacuum system needed for the small mass spectrometer has already been designed including the diffusion pump, vacuum gauges, which have been developed in this laboratory. Other equipments, such as the electromagnets, mechanical pumps, and auxiliary units will be purchased according to our requirements for setting up the first mass spectrometer. A small cooling unit for the baffle of the diffusion pump will also be required.

The first mass spectrometer will be installed in 1955-56. The first mass spectrometer will be useful for objective (*c*) and (*f*), that of leak detection and gas analysis enumerated earlier. Immediately on its completion, work will be started on the design study of a second mass spectrometer. The second mass spectrometer will have a resolving power of at least 300 so that the heaviest isotopes can be resolved.

The second mass spectrometer with a resolving power between 250 and 500 can be used for isotope ratio determination as applied to geological age problems, problems of nuclear chemistry as well as mass assignation of radioisotope and tracer techniques with enriched isotopes mentioned as items (d), (e), (g) and (h). This mass spectrometer will also be constructed in the laboratory. The electromagnet will be completed in the succeeding year.

NUCLEAR PHYSICS DIVISION

Research work in the various branches of nuclear physics was started in the Palit Laboratory of Physics as early as 1942 under the guidance of Prof. M. N. Saha. The first few years were spent in developing the detection techniques for the nuclear radiations and in training personnel in the various branches of nuclear Physics. In those days research work developed around individuals and for want of personnel strong groups could not be formed. However, the Palit Laboratory of Physics have trained a good number of efficient nuclear physicists like, Dr. D. N. Kundu, Dr. P. C. Bhattacharyya, Dr. A. K. Saha, Dr. A. K. Mukherjee, Dr. S. N. Ghoshal, etc. who have made substantial contributions to the nuclear science.

The present Nuclear Physics Division, under Dr. A. K. Saha started in 1951 with the BRAE scheme, "Beta-ray activity of nuclei" and in the course of four years it has developed considerable activity. The work of the division can be broadly divided into two parts.

(A) Studies in beta and gamma ray spectroscopy.

(B) Studies of nuclear magnetism.

A. *Beta gamma Spectroscopy Section.*

(1) Recent problems in beta-decay: A formidable handicap that a nuclear theorist faces is the lack of sufficient data on the excited states of nuclei. There is a feeling that 99% of older results which were obtained with apparatus possessing insufficient resolution are unreliable as far as their use in any theory is concerned. The situation is similar to spectroscopic data obtained with the use of prism spectroscopes before Rowland introduced the high resolution concave gratings for measurement. All data obtained with prism spectroscopes had to be discarded in favour of data obtained with the aid of high precision concave gratings. For Zeeman effect studies, which contributed very substantially to elucidation of structure of electronic shells, still more accurate data were needed, and apparatus of still higher resolving power had to be devised. There is an urgent need for unequivocal assignment of energy, spin and parity of as many excited nuclear states as possible. These would provide not only critical tests of many existing theories but there is also the possibility that the systematic study of these data may throw light on the structure of the nucleus. This has been the principal objective behind all the experiments the division had tried to investigate. The main feature of the beta-decay theory consists in the choice of interaction Hamiltonian satisfying the requirement of relativistic invariance. At present the main problem is to decide whether beta-decay problems can be explained by the pure forms of the five possible interactions or whether a mixed form will be necessary. The problem has been approached in two ways, viz.,

(*a*) Theoretical investigations and

(*b*) Fitting the experimental evidences with the theoretical views.

The experimental evidences, that exist, do not provide an unique selection between the pure forms and the mixed forms. But considerably reliable discrimination between the possible forms of interaction is possible by a careful and precise determination of the shape of the beta-spectrum and of the beta-gamma angular correlation of those nuclei which have non-allowed spectrum shape and where the changes in spin and parity of the energy levels are known by other methods. Of these methods, the important ones are gamma-gamma angular correlation, internal conversion co-efficient, measurement of half life of metastable isomeric state and calculations based on the shell model theory of nuclear structure.

An investigation on the shape factor of the energy spectra of β-rays for a general combination of interactions, has been carried out. Expressions for the shape factors of the L-th degree of forbidden beta-transition were given by Greuling for the pure interactions and by Pursey for different mixtures of the pure forms. The same results have been derived here by a method due to Spiers and Blinstoyle and formulated in a manner which readily points out that the correct form of beta interaction is either a STP combination or a VA combination. It has been concluded that the proper way of setting up the beta interaction is to require that all the Dirac covariants, whose scalar products appear in the Hamiltonian, must behave in the same way under space-time reflection.

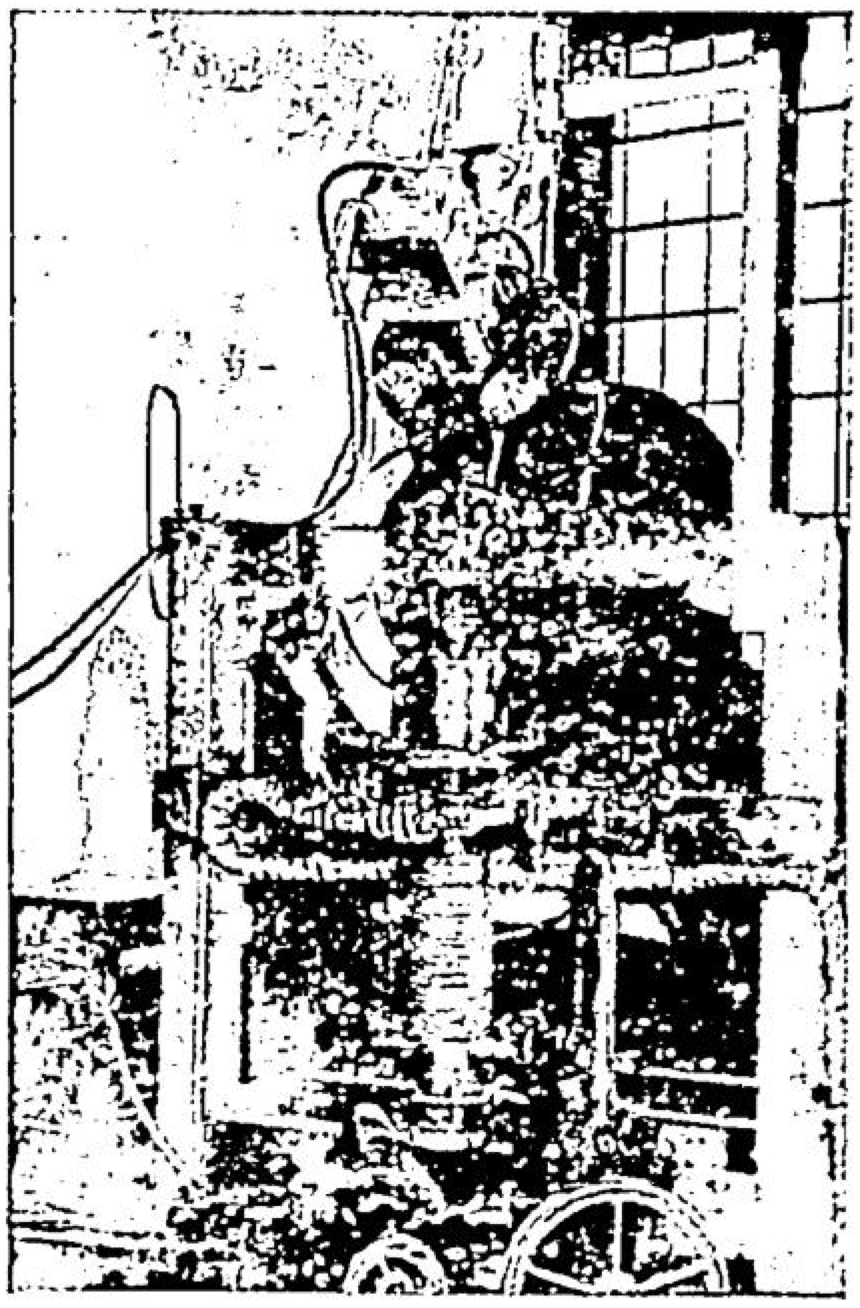
(2) Problems in nuclear structure: In the theory of nuclear shell structure there are two current views, viz., the L-S coupling model and the j-j coupling model. The latter has achieved a greater measure of success, though among the lighter nuclei the former is more successful. Even among the light nuclei, particularly in the case of B^{10}, the j-j coupling model and not the L-S coupling model predicts the ground state spin correctly. But this preference is neither so regular nor so marked, for the excited states of the isobars of mass 12 are better explained with the L-S coupling model. The nuclear forces may contain central as well as non-central terms. The j-j or the L-S coupling model will hold according as the non-central or the central terms are predominant. Reviewing the situation among the light nuclei, Inglis concluded that one should abandon the extreme views and consider the case of intermediate coupling where the two types of terms are present in comparable proportions. Many physicists have worked out the suggestion of Inglis and obtained interesting results. In a paper communicated to Physical Review, we have presented the results of our investigations on the intermediate coupling in nuclei of mass numbers 5, 6, 7, 14 and 15. In the polyads 6 and 7, the idea of intermediate coupling is fairly successful. The case Li^5 provides an independent measure of the strength of the spin-orbit interaction. For the heavier polyads the intermediate coupling scheme does not seem to be very helpful.

There is a hope that the apparent failure of the intermediate coupling among the heavier polyads can be explained by invoking configuration mixing. For example, the structure of N^{14} is supposed to be $(1s)^4$ $(2p)^{10}$ This implies that all the states of N^{14} should be of even parity. But many states of N^{14} are known to have odd parities. This can only be explained as an excitation of the $(1s)^4$

$(2p)^9$ $(3d)$ or $(1s)^4$ $(2p)^9$ $(2s)$ configurations. So it is possible that the even parity states also contain some admixture of $(1s)^4$ $(2p)^8$ $(3d)^2$ and $(1s)^4$ $(2p)^8$ $(2s)^2$ configurations. It is possible that a consideration like this may explain the apparent failure of the intermediate coupling in the heavier polyads. The hope is strengthened by the prevalence of even parity states at not too high excitation energies in the polyad 15 and most strongly by the occurrence of N^{16}. N^{16} state cannot be explained without calling in configuration mixing.

We have already done some elementary calculations on configurational excitation in the polyads 5 and 6. We plan to extend this type of work to heavier polyads, in future.

(3) Beta-ray spectroscopy: In course of an attempt to find reversible relations between the paiameters describing the trajectory of an electron in a short magnetic lens spectrometer, it is found that the magnetic lens closely resembles a thick optical lens of converging type. With the help of the parametric relations in Newtonian form, various properties of the lens spectrometer have been investigated. In particular, the use of a continuous baffle system to improve resolution and line-shape for extended source could be easily and accurately studied with the help of the formulae.



The short lens Magnetic Beta-ray Spectograph.

This investigation has enabled us to design and construct a short lens spectrometer, which is now ready and is in routine operation. Though the spectrometer is quite satisfactory for ordinary purposes, our investigations show that there are serious limitations in its performance. Thus one cannot expect for resolutions of the order of 1% a solid angle much greater that 0·8%, which puts a serious handicap to the use of this instrument for the study of weak radioactivities. At the present moment, the beta-ray spectrometers, available in the market, possessing the highest solid angle possible, viz., 8% for a resolution of 2%, which is not too bad, is the Siegbahn-Slatis type. We propose to set up an instrument of this type in the five-year plan. But for other types of experiment, viz., study of fine-structure of nuclear levels, we require an instrument of extremely high resolution (0·01%). The instrument which has been designed to achieve the highest resolution is the Siegbahn-Svärtholm type. This has the added advantage that a source of larger length can be used on account of its two dimensional focussing. We also propose either to fabricate or to purchase this instrument in the 5 year plan.

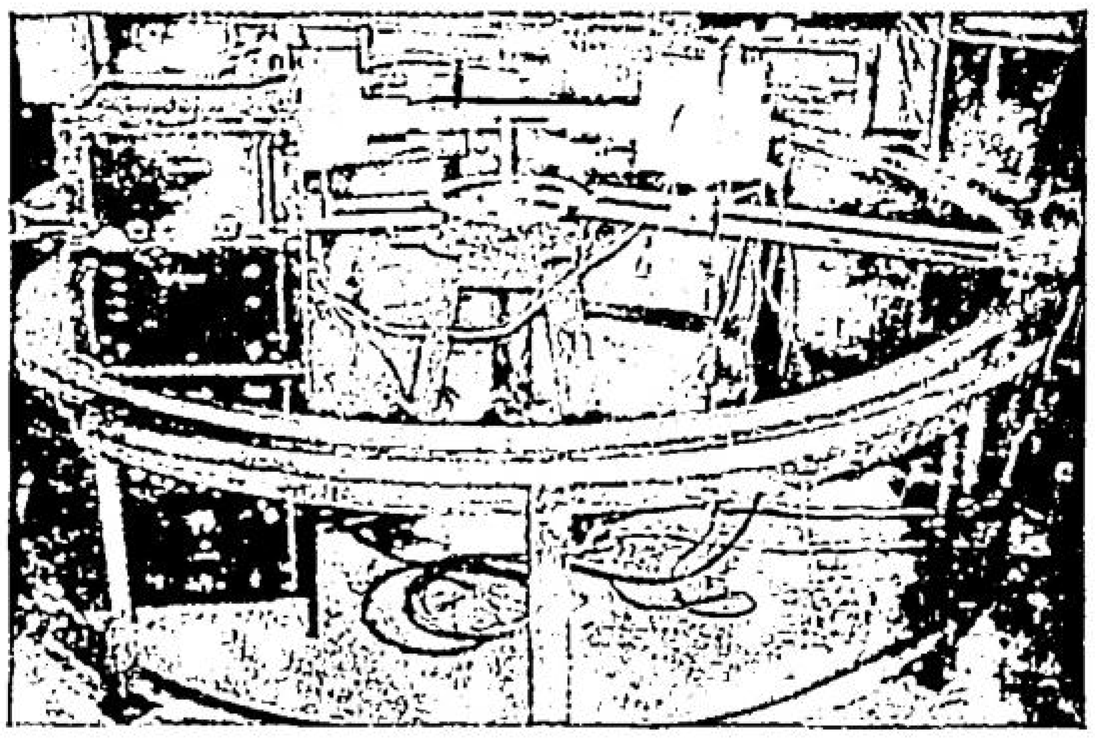
(4) Gamma-ray spectroscopy: We have perfected in our laboratory, the

scintillation type gamma-ray detectors and have developed methods for growing organic and inorganic phosphors.

For growing organic crystals an arrangement for the dropping of the melt of the material through a temperature gradient has been devised which runs automatically, being controlled by a clock work. The apparatus has been in operation for considerable time and is suitable to grow crystals of diphenyl, stilbene, anthracene etc. Diphenyl and stilbene crystals upto 1″ diameter and 4″ long have been grown.

A Verneuil furnace suited for growing calcium tungstate and cadmium tungstate crystals has been constructed. An automatic arrangement for lowering the pedestal according to the rate of growth of the crystal has been made. The mechanical parts and the electric control circuits have been fabricated here.

An overall gamma detection efficiency of 20% has been obtained with these phosphors. Apart from the high efficiency of detection, we have used the scintillation detector as a gamma-ray spectrometer employing a single channel pulse height analyser, which is, however, an inconvenient tool for quick determination of the energy of the gamma-rays as it requires considerably long time, for completing the observations, and is unsuitable for radio-active samples of small life. We therefore propose to fabricate a 20-channel pulse height analyser in our plan.



Angular Correlation Experiment.

(5) Angular correlation studies: In the last few years, directional correlation experiments between cascaded nuclear radiation have proved invaluable to the study of the properties of nuclear levels. A complete analysis of the requirements for the measurement of angular correlation ratio between the different cascaded radiations emitted by an active nucleus has been made. A general expression for the total number of coincidences at any point keeping the error in the correlation ratio within a definite limit has been derived. A theoretical expression for the effect of Compton scattering on the correlation ratio has been worked out and this agrees well with experimental results. The effect of the angular spread, due to the finite geometry of the counters, on the angular correlation ratio has also been calculated. Measurement on Ni^{66} has been reported. The results are in agreement with those of Brady and Deutsch. Methods for obtaining results with better accuracy have been found.

We have designed and set up a goniometer for measurement of directional correlation and we propose to investigate systematically in the course of next five years, a series of nuclei. In the very recent years the emphasis has shifted to the study of angular correlation and distribution of radiation from nuclei suitably oriented by the application of an intense magnetic field at very low temperature. These studies are important because they give a method of determining directly the magnetic moment of metastable states of nuclei. The division proposes to start this work and will therefore need a cryostat for low temperature studies.

(6) Short-lived metastable states in isomeric nuclei: A knowledge of the short-lived metastable states in isomeric nuclei is very important in determining the angular moment, spin and parity of the excited levels. Delayed coincidence methods for the measurement of short half lives have been set up for the range 10^{-9} sec. to 10^{-5} sec. We propose to undertake a systematic study of a number of nuclei by this method.

(7) Instrumentation for beta-gamma ray spectroscopy: All the accessory circuits required for the experiments have been fabricated in the laboratory. These include stabilised power supply units, stabilised extra high tension units, amplifiers of different types, fast coincidence circuits, control circuits for the lens spectrometer, delayed coincidence circuits, scaling circuits of scale of 10000, magnetic current stabiliser for the beta-ray spectrometer.

B. *Nuclear Induction Section.*

As is well-known, the nuclear magnetic resonance technique was first developed independently by Bloch and Purcell and their schools with the intention of measuring nuclear magnetic moments. The measurement is based on an observation of Larmor frequencies of nuclei in known fields H, and using the relation, $2\pi\nu=\gamma H$, where γ is gyromagnetic ratio. The magnetic moment is then given by $\mu=\gamma I$, where I is nuclear spin. A previous knowledge of I, the nuclear spin, is not necessary, because this experiment itself may be used to determine I, from the intensity of the resonance line. But, besides its use in determination of magnetic moments, the nuclear magnetic resonance absorption technique has become a powerful tool in other lines as mentioned below:

Two special techniques have been developed in this line viz.,

(*a*) The Steady Technique.

(*b*) The Transient Technique.

The Steady Technique is again subdivided into two parts, viz., the Stanford Technique of separate coils and the Harvard single-coil technique. We have used the latter technique and have set up a nuclear induction apparatus.

(*a*) Steady Technique developed in the Institute of Nuclear Physics:—

The apparatus for the steady technique involving rf-double bridge has been discussed in detail in a paper by Bloombergen, Purcell and Pound, P.R. 73, p. 679 (1948) and in a thesis by Blomberger for the doctorate degree of Leiden University. The apparatus that we have built up is broadly based on their design, although we have introduced several new features; viz., (*a*) we have used a tuned transformer at the bridge input for large amplitudes, (*b*) we have chosen the Q and inductance in our bridge so as to get fairly large signals even in the large field inhomogeneity (about 0·5 Gauss with our present magnet), and (*c*) we have taken special precautions to minimise noise, both electrical and mechnical. Mechanical noise pick-ups have been reduced by mounting our apparatus on springs and sand. Electrical noise pick-ups as well as Johnson noise of the receiver have been reduced by introducing a line-filter at the input of all the electronic circuits employed, and by incorporating a pre-amplifier within the box containing the bridge to sufficiently enhance the signal before sending it to the receiver. We have used the apparatus to calibrate D.C. and A.C. magnetic fields in our laboratory, a note regarding which appeared in "Science and Culture" Vol. 19, p. 464-466, March '54. We have also set up a 25 cycle generator circuit and a 25 cycle detector and phase mixer, with which to study weak signals. But, we have not yet been able to carry out systematic observations of line-width and relaxation times of solids (which is possible with our present magnetic homogeneity) with it as planned because we are handicapped firstly for recording equipments involving a pen-recorder for recording the phase-mixer output and an electronic arrangement, employing a helipot resistance driven by a synchronous motor, to vary the magnetic field slowly. Besides, we have not also been able to carry out measurements on line-widths and chemical-shifts in liquids, although signals due to them are strong enough to be observed on our oscilloscope because these effects are of the order of milligauss and tens of milligauss while the field inhomogeneity with our present magnet is of the order of 0·5 Gauss, and so precludes all measurements finer than this. So, we need a magnet with large pole faces, to yield very good homogeneity over the area of the rf-coil in which the sample is placed. Recently we have set up an electromagnet of diameter 12″ having magnetic field up to 10,000 Gauss and a good homogenity over the sample area. We propose to work on chemical shift experiments with its help. For work in the range of one milli-Gauss resolution, Nuclear Induction apparatus is available in the market now and we have asked for the apparatus designed by Messrs. Varian & Co. This instrument will enable us to study the effect of cheminal shift and J-coupling on the resonance line and to investigate problems of molecular structure. Some theoretical investigations in this subject have been made and published.

(*b*) Transient technique:

The transient technique consists of Torrey and Hahn's methods. The first, deals with forced motion of the nuclei in the presence of the rf-field when the rf-field is suddenly applied, while the latter deals with free motion (leading to "Spin-echoes") of the nuclei when the rf-field is applied at intervals in the form of pulses. The transient methods have the advantage that they can measure line-widths and chemical shifts in the presence of magnetic field inhomogeneities that are prohibitive in the steady case. Besides, Hahn's spin-echo can give information on the diffusion coefficient of the liquid study from an observation of the damping of the spin-echo signals. Our plan of work in this section is as follows:

(1) Measurement of Magnetic Moments of nuclei, by observation of their resonance frequencies in magnetic fields.

(2) Study of resonance line-shapes and line-widths with a view to analyse chemical structures within a molecule (intra-molar) and without (lattice or intermolar structures), and to detect the presence and extent of motions within solids by repeating these observations at different temperatures.

(3) Study of relaxation times in both solids and liquids with a view to obtain more exact information regarding the extent of motion within them.

(4) Study of Electric Quadrupole Moments by observation of the extent of splitting of the nuclear resonance line.

(5) Study of J-coupling both by steady and Hahn techniques, and

(6) Measurement of diffusion coefficients of liquids by the Hahn method.

We have started plans to begin transient experiments in this laboratory. In the mean time we have investigated a number of theoretical problems connected with these experiments. Our investigations have been reported in three papers.

(*c*) Pure Quadrupole Resonance Study:

For pure quadrupole resonance experiments a similar arrangement as for the steady nuclear magnetic resonance experiments is needed, except that we no longer need a magnet, the resonance lines now occurring due to transitions between the energy levels due to the electric quadrupole interaction of the nucleus under study with the surroundings. But the frequency region is now different, *viz.*, from 50 mc/s to about 150 mc/s and even higher for Iodine Isotopes. For this region, we need to construct a special frequency modulated oscillator preferably super-regenerative oscillator. This experiment will give us an accurate measure of the quadrupole moments of nuclei where the external field gradient is known or conversely, by studying the resonance lines in crystals where the quadrupole moment of the nucleus in question is known, information about the field gradients may be obtained and hence crystal structures may be analysed by this method. For this part of the scheme we need at present only a super-regenerative frequency modulated oscillator. We have not yet started these experiments but we have been able to make some theoretical contributions to this subject. These have been pubuished in two papers.

(*d*) Paramagnetic Resonance Study:

We are also interested in paramagnetic resonance experiments which are concerned with frequencies in the micro-wave region, *i.e.* from 1,000 mc. to about 20,000 mc/sec. The theory is on the same lines as the Nuclear Induction Experiments, viz. it deals with the motion of magnetic dipoles in rotating fields, but as the magnetic dipoles concerned now relate to electronic magnetic moments which are 1,000 to 2,000 times stronger than Nuclear Magnetic Moments, hence the larger frequencies involved. The conventional apparatus for this purpose has been described in a paper by Schneider and England in Physica 17, p. 221 (1950). This method, besides its current wide applications in chemistry, can also yield valuable informations regarding nuclear spins and magnetic moments. This it can do from a study of the hyperfine structures of the paramagnetic absorption spectra, the splitting up of which by interaction with nuclear spin is given by the multiplicity 2I + 1 of the nuclear spin states, I, referring to the nuclear spin, and the extent of the splitting is proportional to the nuclear magnetic moment concerned. The advantage of paramagnetic resonance spectra in determining nuclear magnetic moments and spin over the nuclear induction method is twofold. First, it involves much larger interaction energies so that the level of field-homogeneity necessary is not so stringent as in the case of Nuclear Resonance Spectra. Secondly, due to the much larger frequencies involved, and the wave-guide arrangement employed, noise is not so serious a problem and so very weak samples (*e.g.* short-lived radio-active samples) may be tested by this method. Information regarding electric quadrupole moments (whenever they exist) may also be obtained from a study of the effects of electric quadrupole interaction on the hyperfine pattern of paramagnetic absorption spectra. Our plan of work in this line is:

(1) Determination of the magnetic moments of nuclei of the rare-earth group (which are not accessible to measurement by Nuclear Induction Methods, because their salts are mostly paramagnetic).

(2) Study of electric quadrupole moments and crystal structure from the quadrupole splitting of hyperfine structure.

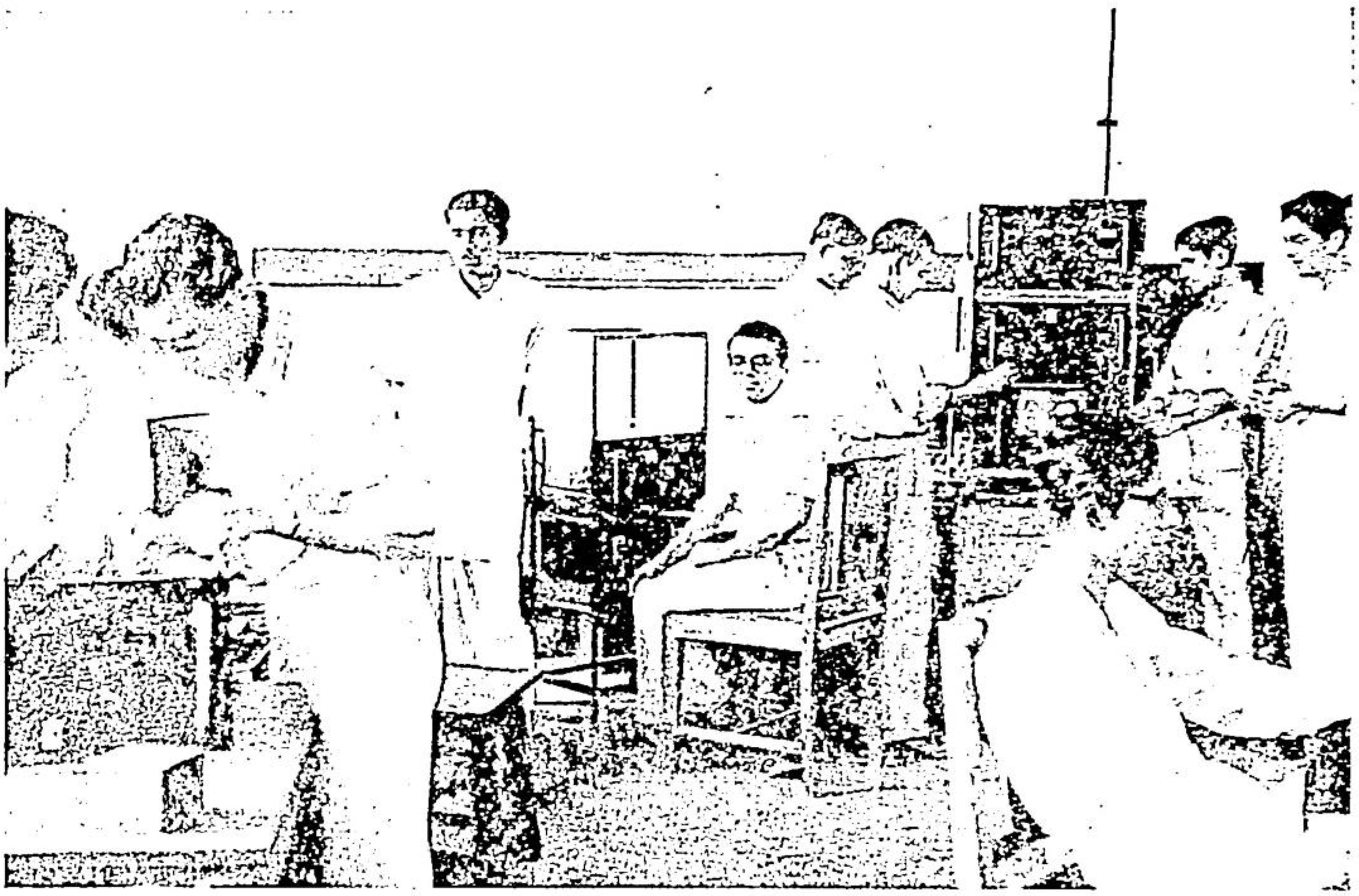
(*c*) Overhauser Effect:

In recent years microwave technique applied for paramagnetic resonance studies have been used in an ingenious manner for nuclear induction studies. Thus the Overhauser effect in metals involves a study of nuclear magnetic resonance signals when the electron magnetic resonance is saturated by applying a strong alternating magnetic field with frequency in the microwave region. It is then found that the nuclear resonance signal is very much enhanced. The theory for this effect has been worked out by Overhauser, but this has not yet provided a complete quantitative explanation. Intensive experimenttation on a wide variety of metals is necessary to provide sufficient data on which the theory will have to be based. The study of the effect, besides providing a method of studying nuclear resonance in metals, which is otherwise very weak, will also go a long way in elucidating the properties and structure of the metals themselves, the role played by the conduction electrons, and the nature of their interactions with the nuclei in the metal.

An extensive monograph has ben written by Dr. A. K. Saha and T. P. Das embodying the theory and experimental methods in Nuclear Induction and the entire theory of its applications in analysis of molecular and crystal structures, as well as the results of investigations on the same. This is now in course of publication.

TEACHING SECTION

An important activity of the Institute of Nuclear Physics is the training of personnel in Nuclear Science. This was started as early as 1953, and it is a pleasure to note that various American and European Universities had the same idea simultaneously. The Institute offers a one year Associateship Course to students who have already received the M.Sc. degree in Physics. The object is to impart advanced



The post M.Sc. Laboratory.

training in theoretical and experimental nuclear physics. This one year course helps the students to qualify for:—

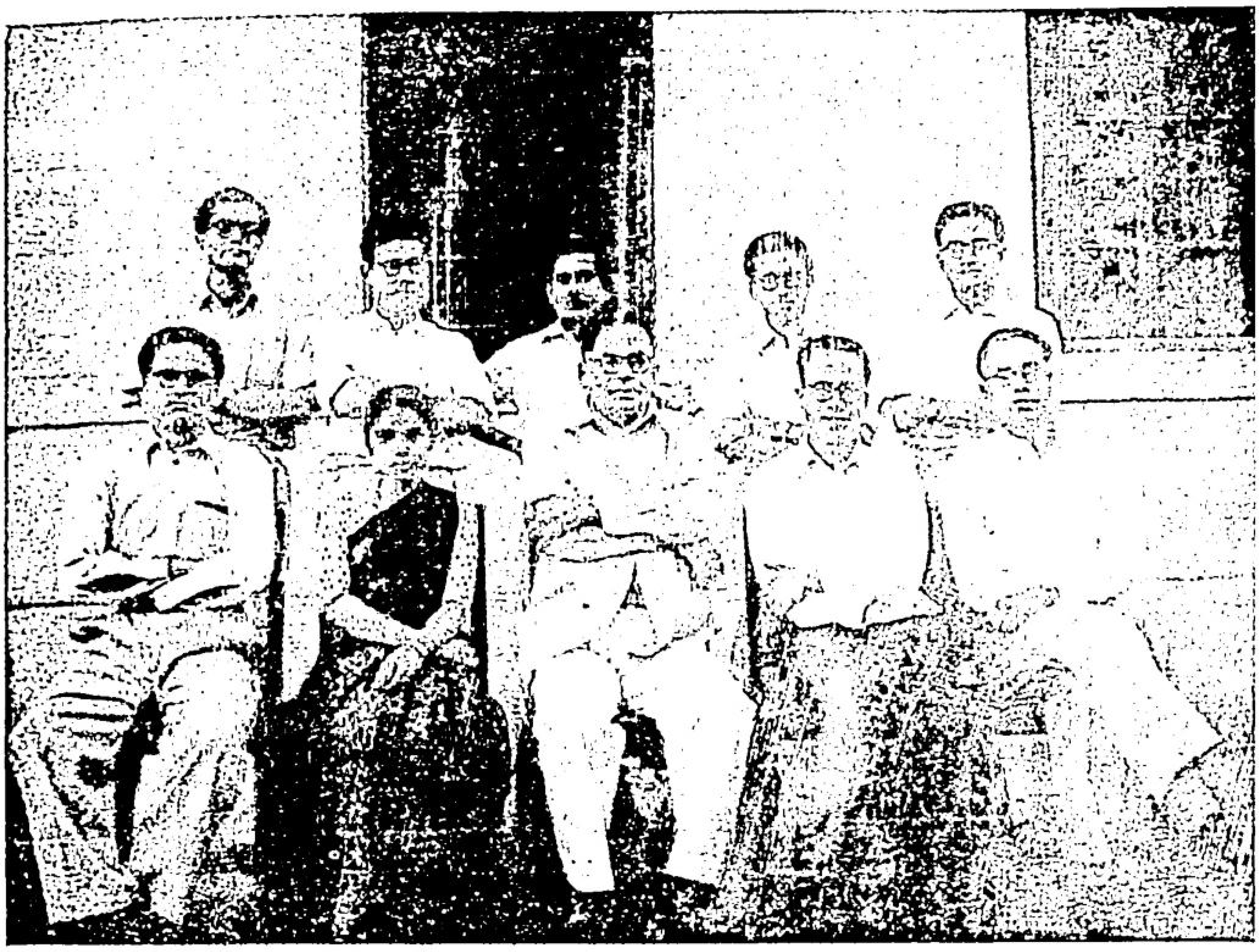
(1) Undertaking research work in some branch of nuclear physics.

(2) Absorption in the different projects of the Atomic Energy Commission of India.

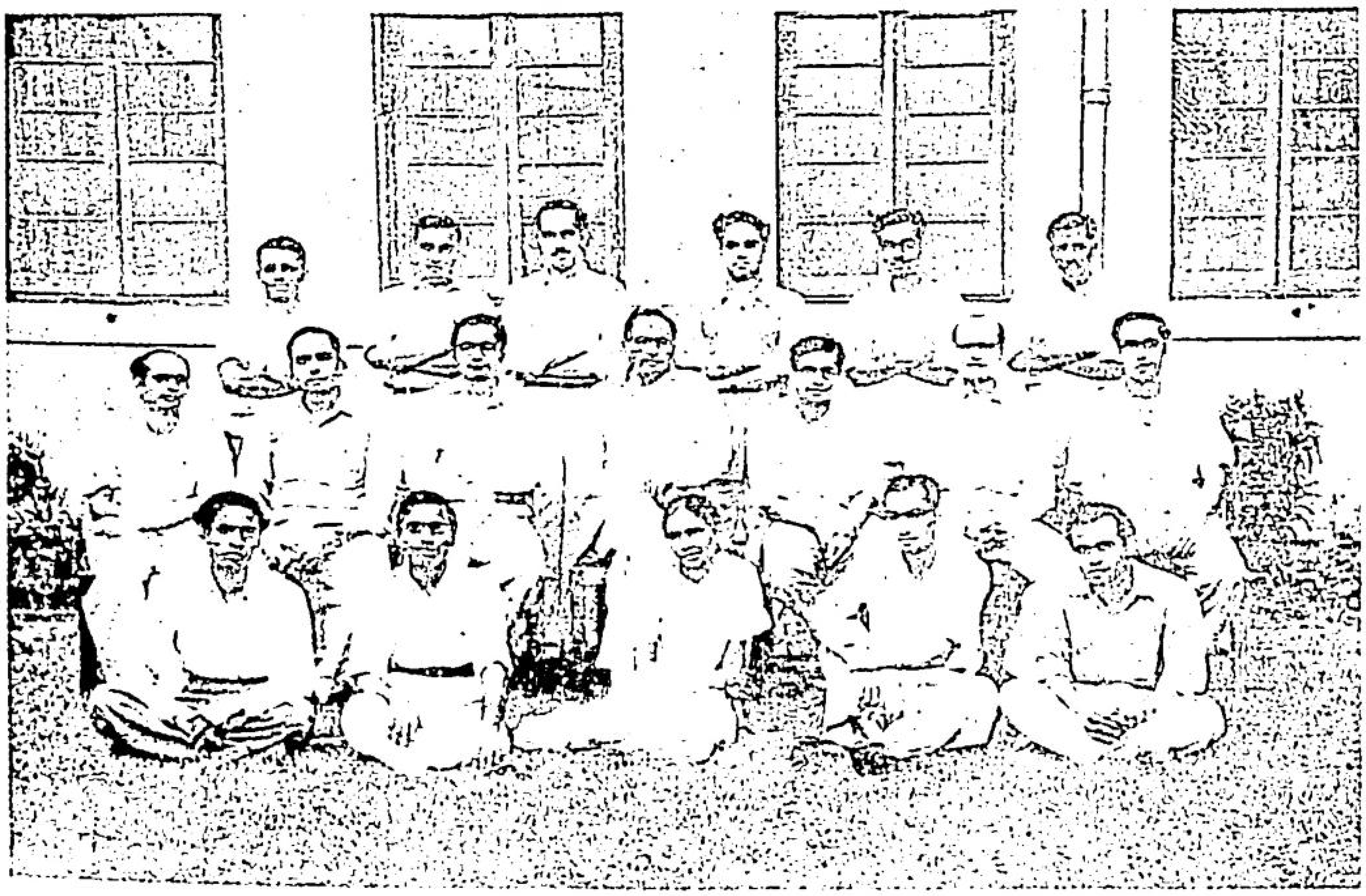
(3) Teaching nuclear science in different universities and technical colleges.

(4) Utilising nuclear science as a tool of research in medicine, biology, chemistry and other sciences.

Some of the students stay and do research work and qualify for the D.Phil. or D.Sc. degrees. Such students are attached to the different divisions in this



Associates of the I. N. P. for the Session 1953-54.



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Institute and work under the guidance of the head of the division concerned. The subjects for specialisation are particle acceleration, nuclear spectroscopy, neutron physics, nuclear reactions, nuclear chemistry, theoretical nuclear physics, instrumentation and applications of nuclear techniques to other fields.

Detail information regarding admission, course of studies, examinations, diploma, scholarships etc. are given in the Appendix III.

The laobratory of the teaching section was placed at first in charge of a lecturer who had for guidance a syllabus framed in 1952. He was, however, assisted by all the divisions in setting up class experiments. The first batch of nine students passed out in May 1954, and the second batch of 12 successful students have completed their course in May, 1955. Due to the increased load of teaching and laboratory work, as indicated by the revised syllabus, the Governing Body has put the teaching section to a Reader in charge, assisted by two lecturers, to supervise the teaching and laboratory work. The Director, the Professors, Readers, lecturers of all Divisions and sections participate in teaching the post M.Sc. students. The syllabus for the course of studies has been revised to be up-to-date (Appendix IV) and courses on Reactor Physics and Applied Atomic Energy have been included.

The expansion scheme of the Teaching Division has been so arranged at present that the Institute will be able to admit 20 students. In course of these five years, the Post M.Sc. Laboratory will be equipped with all the basic equipments to undertake training in all important branches of nuclear physics mentioned in the syllabus. The list of equipment includes educative charts, and models of electrical machines, etc.

The proposal for erecting a hostel has already been approved by the Ministry of N.R. & S.R. and we have received a grant of Rs. 80,000, half of the amount sanctioned. The Govt. of West Bengal has agreed to give us the land. Negotiations for purchase of land is in progress.

NEUTRON PHYSICS SECTION

Researches and teaching of Neutron Physics are fundamental for the development of atomic energy in any country. As is well known it was Prof. Enrico Fermi, the pioneer in the field of neutron physics, who was responsible for the first successful operation of a nuclear chain-reacting system (Pile or Reactor). For the training of physicists who will take part in the development of atomic energy and in the maintenance of future atomic power stations in this country, knowledge of neutron physics is of primary importance.

This section has been started with Dr. S. N. Ghoshal, Sur Reader in Nuclear Physics in charge since the middle of 1954. The chief source of neutrons which is available at present is a 450 mc. Ra+Be source, which yields about 10^6 neuts/sec. Besides, the Institute has 1 gm. of radium which when enclosed in a thick-walled beryllium container will yield monoenergetic photo-neutrons. Fast neutrons will also be available from the cyclotron and the Cockcroft-Walton generator of the Institute.

The work which are being carried out at present in the Neutron Physics Section are as follows:

(*a*) Experiments have been started on the measurement of the cross sections for the absorption of slow neutrons by various nuclei as well as on the identification of nuclear levels by measuring the slow neutron capture gamma-rays. These experiments are being done with the 450 mc Ra+Be neutron source.

(*b*) Experiments on the inelastic scattering of fast neutrons yield valuable informations regarding the mechanism of neclear reactions and throw important light on the general validity of compound nucleus ideas. The chief experimental difficulties have been the availability of monochromatic neutron source, and the detectors for monoenergetic neutrons. The Cockroft-Walton generators can yield neutrons with well-defined energies. The development of modern fast neutron scintillation counters are providing the detectors of mono-energetic fast neutrons. With the development of these new techniques, it has now become possible to attack the hitherto relatively unexplored field of inelastic scattering of fast neutrons.

Experiments on the inelastic scattering of fast neutrons using the Cockroft Walton generator of the Institute are also being designed. Fast neutron scintillation counter is being developed for this purpose.

Folowing is a list of experiments planned:

(*a*) Study of the diffusion of neutrons: The photo-neutron source will be used for doing experiments on the diffusion and slowing down of neutrons in various media. Activity method of detection will be employed.

(*b*) Development of neutron spectrometer using photographic emulsion loaded with Li^6 or B^{10}.

(*c*) Construction of a mechanical neutron velocity selector.

(*d*) Preparation and calibration of standard neutron source. As is well-known, the strength of a laboratory made neutron source *e.g.* a Ra+Be or a Po+Be source depends on the nature of mixing of the constituents. Hence two sources containing same amounts of the constituents will differ from one another in their strength. A method is contemplated and is being tried out which is expected to yield a standard neutron source.

(*e*) Experiments with polarized neutrons. Scattering of polarized neutrons from various nuclei is yielding new information regarding the nuclear forces. These experiments are also contemplated, when the laboratory is more developed.

Since the work of this section has just started, its expansion programme can not yet be completely drawn up. The section starts out with a modest programme at the beginning with only two research assistants.

Since the 400 KV, Cockroft Walton generator will be used as the source of fast neutrons, deuterium and tritium targets are primary requirements. The development of photographic-plate-neutron-spectrometer requires a nuclear emulsion research microscope.

It is planned to build a neutron velocity selector. For doing experiments with polarised neutron beams, magnetic polarizer and analyser systems will be constructed.

The most important requirement for carrying out work in neutron physics is a strong source of neutrons. At present this is available only in Atomic Energy Establishments like Brookhaven, Oakridge or Harwell. But it is felt that in such places, the stimulating academic atmosphere of freedom in research is often lacking, and in the U.S.A. particularly, attempts are being made to evolve university type of reactors. The Institute of Nuclear Physics has made certain enquiries about the possibility of installing this type of reactors, and a report will be found in the Appendix XI.

Lectures to Post M.Sc. students on Neutron and Reactor Physics have been started this year according to the syllabus given in Appendix IV. Reactor Physics deals with the construction and maintenance of Reactors, and a good grasp of the principles of Reactor Physics is indispensable for Atomic Energy developments. The scope of expansion of this division is almost unlimited, but we had to keep ourselves within modest limits in accordance with the funds at our disposal. A University type of reactor, now coming into fashion in the U.S.A. for purposes of instruction is very much desirable, for the proper functioning of this section.

INSTRUMENTATION SECTION

Need for Instrumentation:

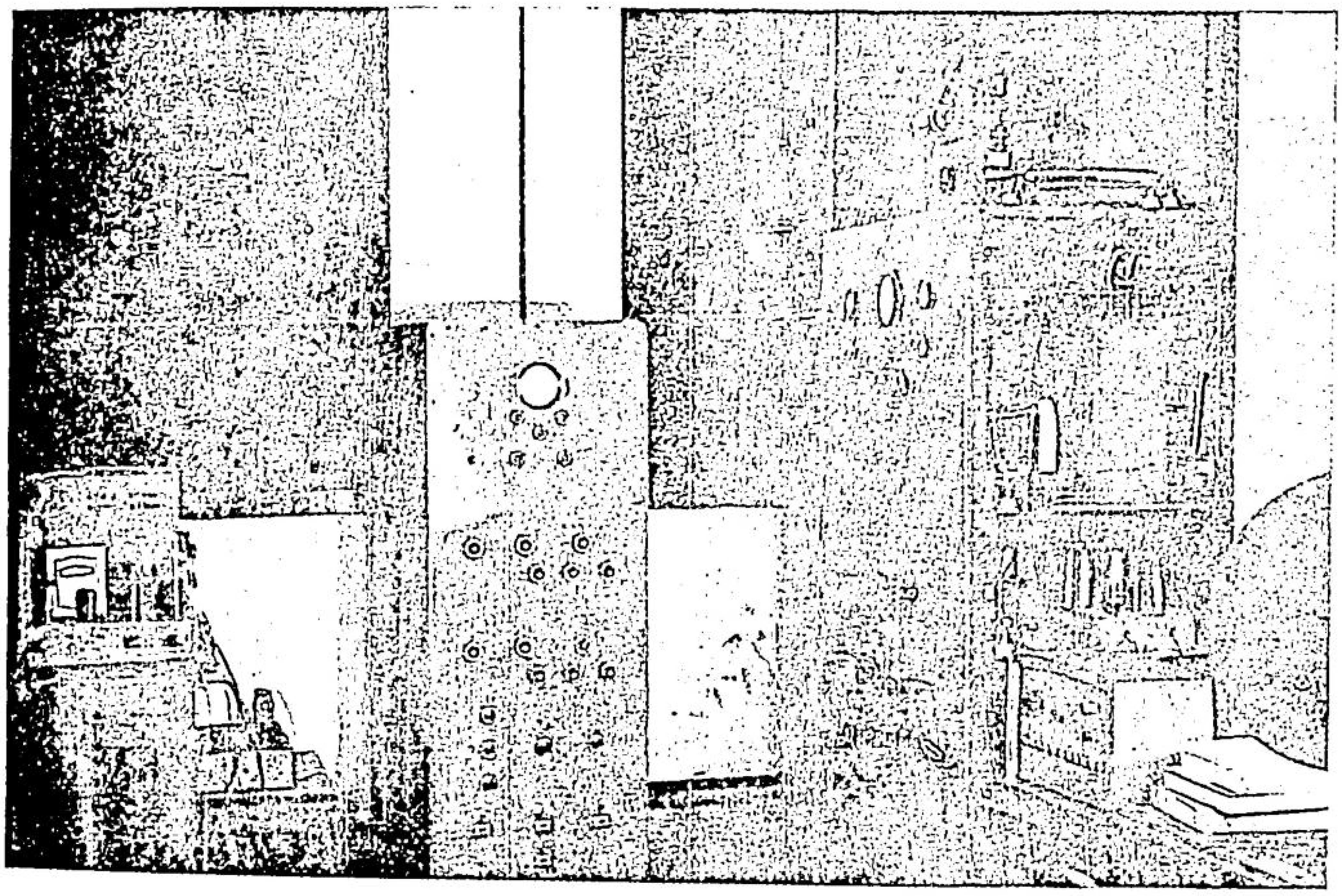
Experimental Research on Nuclear physics requires extensive instrumentation, most of which is electronic and are the latest developments in the field. The prices of these instruments, even when they are commercially available, are often very high. Export of some of these instruments *e.g.* the proton resonance modified magnetometer, were actually banned so that it was not possible for long to import them to India. There are others *e.g.* high power microwave radio frequency generator tubes and receivers about which little is known, and they can be purchased after a good deal of correspondence on government level is carried through. And, to say the least, official formalities in connection with procurement is complex and time-consuming. When some of the instruments go wrong, it cannot be repaired, unless expert knowledge is available.

Repair and maintenance of electronic apparatus is quite beyond the powers of the average Nuclear Physicist. It is, in fact, necessary for any group of workers on an experimental problem in Nuclear Physics, to have amongst them, men who are specially versed in electronics, in order that the set-up of electronic apparatus may be correctly planned, apparatus of proper characteristics selected, and to ensure that correct data have been collected.*

* It is seldom wise to select apparatus of the 'best' characteristics for every work. Electronic apparatus, because they include many small mass produced components, often go wrong. Sometimes defective apparatus just supply wrong data instead of ceasing to function.

It is possible to construct many of the apparatus needed for Nuclear Physics work for which fancy prices are demanded, or whose export was banned or may be banned. This Section has demonstrated this by designing and constructing high resolving power ionospheric recorders. And any such undertaking naturally needs men well versed in the arts and science of electronics besides laboratory facilities (space and many types of measuring instruments). It is but natural that some of these may prove time-consuming and need years of persistent and continuous effort.

Above all, any really first rate experimental research will inevitably need design of new apparatus. Such apparatus have to be fabricated in the laboratory, and will naturally need the services and attention of men well versed in electronics



The Ionosphere Sounding Equipment of the Instrumentation Section.

and instrumentation. It is inconceivable that any plan for really original experimental research could be implemented by those who have never undertaken any development of instruments. Besides, it is wise and in fact it is a generally followed practice, to leave the plan and development of experimental set up to those who like this type of work, rather than to put this additional load on the shoulders of those who have different types of aptitude.

History and activities of the Instrumentation Section:

The Instrumentation Section came into existence in 1949, with Sri B. M. Banerjee who was "Senior Physicist" of the Cyclotron group, in charge of the

Section as Reader from 1953. It was to help other divisions on problems concerning electronic instrumentation and repair and maintenance of electronic instruments. A separate section was considered desirable in view of the demands for attention and assistance of Sri Banerjee by all members of the Institute of Nuclear Physics at that time. Sri R. Roy and J. K. Das Verma joined this section subsequently (1951-52) but were mainly interested on Ionospheric wave propagation studies and construction and operation of related apparatus under the guidance of the Director of the Institute. The instrumentation Section had to plan and design a lot of apparatus like Geiger-Müller counter circuits, power packs, amplifiers of different design for the use of the teaching section. The Instrumentation Section has besides the following major work to its credit.

Actual Construction Work:

(*a*) Design and construction of the 40 K.W.R.F. Generator for the Cyclotron.

(*b*) Design and construction of the High Precision Ionospheric sounding apparatus.

(*c*) Design and construction of the Purcell Bridge apparatus for studies in Nuclear Magnetism for the Nuclear Physics Division.

Researches on operational characteristics of electronic circuits:

(*a*) Tolerance limit of Resistors in Higginbotham type binary scaling units.

Development Research:

Work on a laboratory model fast oscilloscope is virtually complete.

The following work are in progress:

(*a*) A sweep-frequency apparatus for investigation on Lunar and Solar Tides. (Suggested by Sir E. V. Appleton).

(*b*) Spin echo apparatus for studies on Nuclear Magnetism for the Nuclear Physics Division.

Future Programme:

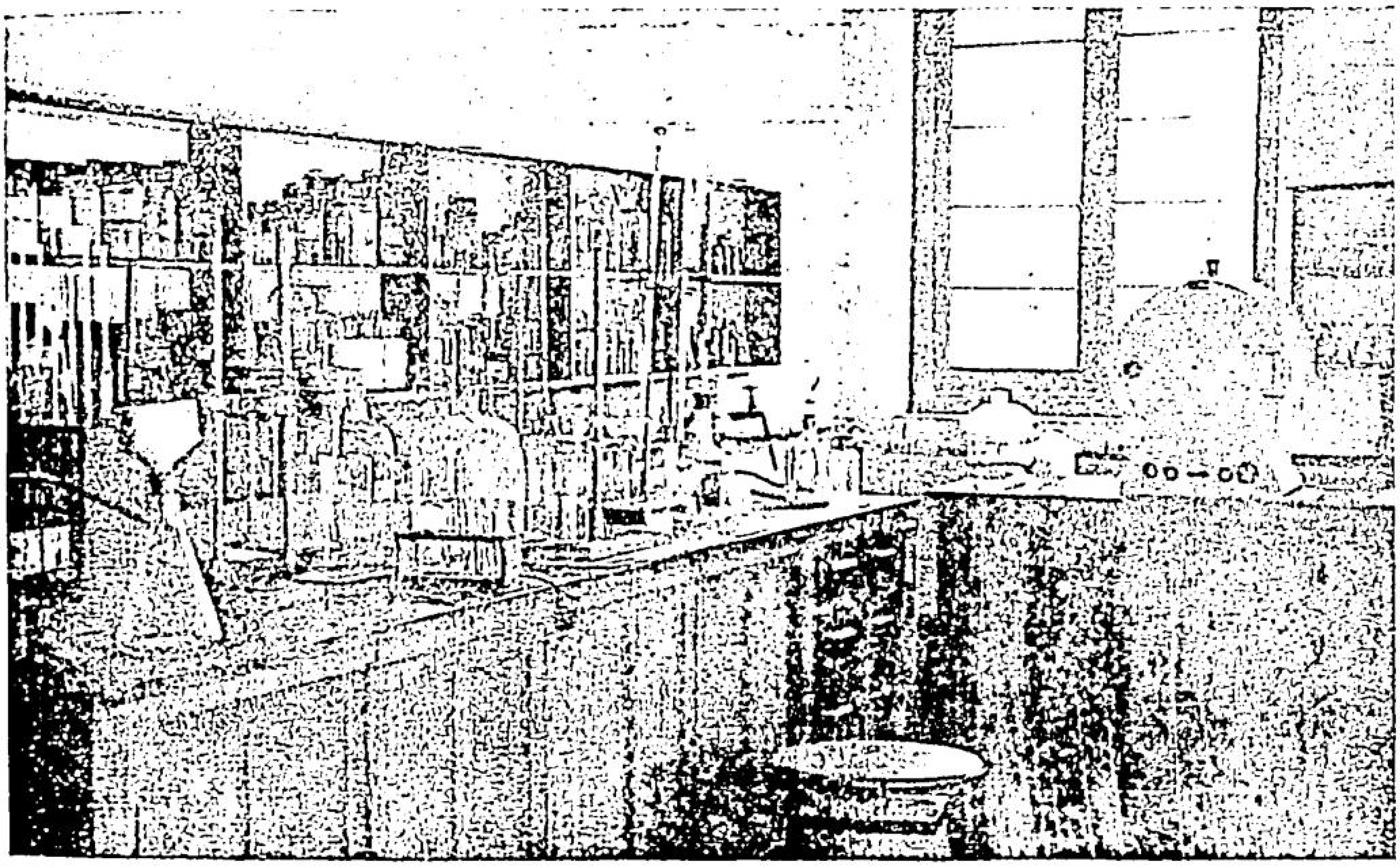
Work on laboratory models of Pulse Height Analysers, both single channel and multi-channel is contemplated.

This Section envisages in the next five years an increased measure of developmental research activity, greater attention to the demands for advice and assistance of other divisions and sections, laboratory construction of a few apparatus such as C.R.O. needed by other divisions, besides repair and maintenance of the increased number of instruments.

NUCLEAR CHEMISTRY DIVISION

Since the discovery of radium by Madame Curie (1898), which event in itself was a great triumph of chemical technique, chemistry has been an indispensable tool in atomic science. Anybody who has studied the discovery of fission knows fully well that it was beyond the capacity of physics to solve the perplexities created by Fermi s neutron bombardment of uranium and it is only the chemical methods persued by Hahn and Strassmann which could lead to the epoch making discovery of fission.

If we recollect the revolutionary changes in nuclear science namely, discovery of radium, establishment of Soddy-Fajans' law, tracer technique and its services in identifying nuclear reactions and its application to chemical, biological, metallurgical and agricultural problems, the discovery of transuranic elements and of fission, the isolation of plutonium and other transuranic elements in weighable amounts and the separation of plutonium from uranium from which it is generated in the reactor, it is evident that in nuclear studies nuclear chemistry is as old and has played as important a role as nuclear physics. It occupies a key position in the solution of nuclear problems and the progress in nuclear



The Chemistry Laboratory.

science has been mainly due to the co-operation and co-ordination between these two sister sciences on the basis of equality. For most work in nuclear physics or atomic energy development, a knowledge of chemical operations is indispensable.

We have therefore initiated a post M.Sc. course for chemistry (both theoretical and practical) in post M.Sc. training for physics students so that our future generations can take up a border land problem without any hesitation.

By rendering service to nuclear science, chemistry itself has gained a lot. Estimation of microgram order of things seems to-day an easy practicable proposition even by direct weighing. By neutron activation even 1.0^{-12} gms. of an element can be estimated under favourable circumstances. Ion exchange, chromatography and solvent extraction procedures have lessened the difficulty of chemical separation to such an extent that even chemically similar elements like Zr, Hf, Nb, Ta or rare earths can be easily separated. Fundamental problems in chemistry (inorganic, organic and physical) can be solved by radioactive tracers. Radiation chemistry promises another aspect of approach.

In our plans of research development we shall not only try to develop chemical techniques that find applications in nuclear science and do work in nuclear chemistry, but we shall also try to solve original problems in chemistry with the help of radioactive tracers.

The following lines of research and development are contemplated in addition to the teaching of post M.Sc. Course for the next five years.

Section A—Inorganic Chemistry:

(1) Original problems of inorganic chemistry with the help of radioactive indicators.

(2) Target reactions and separations of active nuclei from the bulk of inactive material.

(3) Study of fission products.

(4) Study of heavy elements.

Section B—Analytical Chemistry:

(1) Semi-micro, micro and ultra micro-chemistry.

(2) Age of minerals.

(3) Analysis of radioactive minerals and developments of techniques to improve upon the methods of recovery of U and Th and rare earths that find applications in nuclear science.

Section C—Physical Chemistry:

(1) Application of radio-active nuclei to the problems of physical chemistry.

(2) Study of isotope separation with the help of radio-active indicators.

(3) Problems related to radiation chemistry.

Full development of Sections A, B and C requires the construction of two huts covering an area of 3,500 sq. ft.

The work in nuclear chemistry was originally started in 1944 on a very modest scale. The Nuclear Chemistry Division has now taken shape under Śri B. C. Purkayastha. From the brief outlines as has been drawn it is evident that the scope of work is enormous and it requires substantial grants for adequate developments.

As we have a small number of research workers it is not possible for us to start different sections as proposed at the present moment. But our aims and objects will be to work efficiently so that we can give full shape to the scheme as outlined in future.

We do not think that suggestion to rename this division as the radio-chemistry division is a very happy one for the name radio-chemistry implies a limited field. Where chemists have discovered nuclear fission and are synthesising elements after elements, where chemical study of fission products are giving clue to mechanism of nuclear fission, where mass-spectrometric study and work with stable tracers are carried out by chemists, where an isomeric transition brings out valence changes in the daughter element, we cannot say that they are solving chemical problems alone. We must admit that many outstanding problems in nuclear science have been solved by chemists. We closely agree with Friedlander and Kennedy that nuclear chemistry is used to mean all applications of chemistry and nuclear physics to each other (including stable isotope applications). So in our opinion nuclear chemistry (as a twin sister of nuclear physics) is a more appropriate term and it is such wider in scope than radiochemistry. A journal of inorganic and nuclear chemistry has just started publication.

ADMINISTRATIVE DIVISION

This division is under the direct supervision of the Director and he is assisted by the Administrative Officer for the General Administration Section, the Librarian for the Library Section and the Workshop Superintendent for the Workshop Section.

A. *General Administration*:

When the Calcutta University at the meeting of its Senate, held on 12th May, 1951, formed the Institute of Nuclear Physics, this section was manned only by the Office-Staff of the then Palit Professor of Physics of Calcutta University. The Governing Body of the Institute at its meetings held on 22nd June, 1951 and 5th January, 1952 created the posts of an Administrative Officer, an Accountant, and a few assistants to help them. In the course of next 3 years, the administrative staff was a little more expanded.

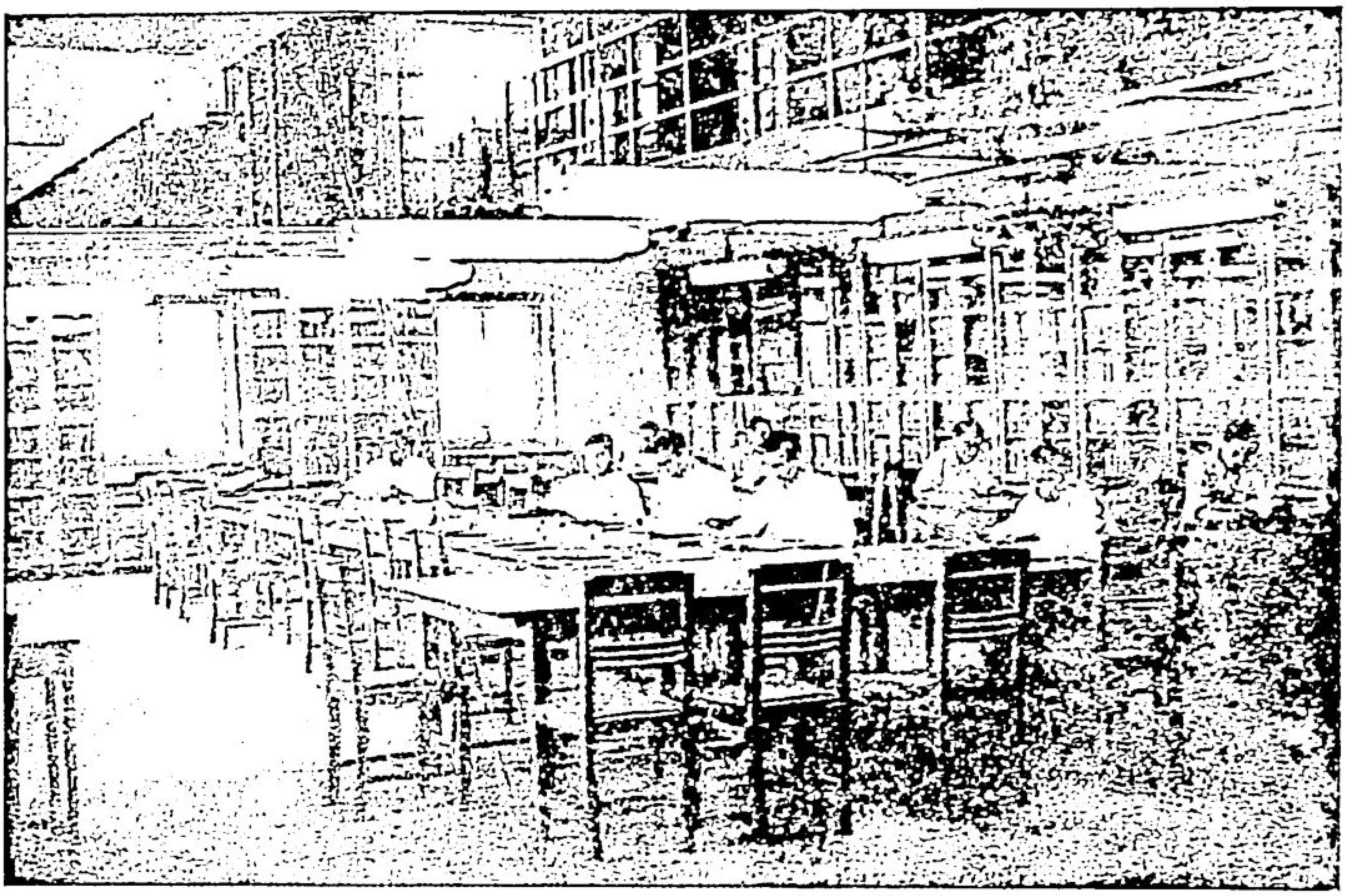
The expansion of the administrative section for the next five years has been planned to cope with the demand for office work by the various research divisions and sections. This Section at present consists of (*a*) Office, (*b*) Accounts and (*c*) Stores. The Governing Body has decided to put this Section in charge of a Registrar, in place of the present Administrative Officer from 1-3-56.

B. *Library Section*:

The library of the Institute shares with its parent body a common origin. It started about a decade ago as a small collection of volumes attached to the Cyclotron laboratory. After the establishment of the Institute in 1949, the need of organising a well-equipped library was keenly felt and the work was finally taken in hand in the last half of 1951.

At present, the library is housed in a spacious hall of 60′×30′ area. It is divided into an upper and a lower tier, of which the latter serves as the reading room and the former as the stack room being divided into small cubicles with reading accommodation for members of the research staff.

The extreme recency of the Institute, combined with the paucity of funds available up till now, explains the library's present inadequate stock which con-

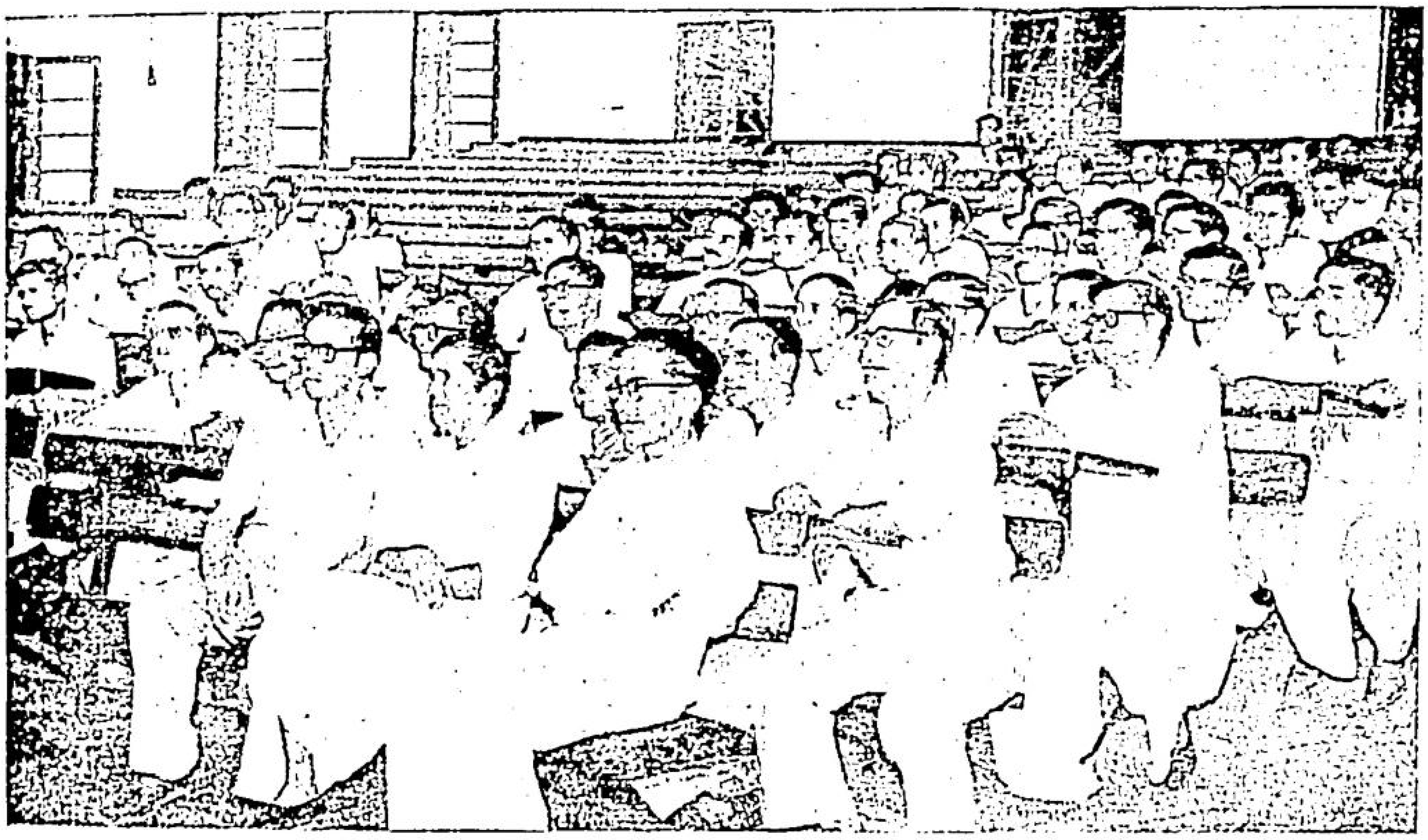


The Library.

sists of 2,024 volumes (up to December, 1954) including books and bound periodical volumes. Even so, the library can claim to have a fairly strong and representative collection of periodicals of physics and some other related subjects (in all, about 125 periodicals are regularly received by the library) and possesses one of the best collections of books and periodicals in Nuclear Science in India: it regularly receives physics journals and research reports from the U.S.A., Canada, Great Britain, France, Italy, Switzerland, Germany, Denmark, Netherlands, Sweden, Yugoslavia, and Japan. The total number of research reports, received from the different national atomic energy authorities as well as research institutions working on nuclear science and electronics, would exceed seven thousands. What the library badly needs to-day is an adequate basic stock of standard and classical works and back volumes of a number of important periodicals. This lacuna can be removed only if a substantial non-recurring grant is available. Only very recently it has been possible to purchase all the post-war volumes of some of the more important journals at a cost of about Rs. 3,500/-.

The library exploits all the traditional sources (*i.e.* gift, exchange or purchase) for the acquisition of its resources.

The library was fortunate enough in receiving, in 1951 and 1952, a generous donation of books and periodicals from Prof. M. N. Saha who presented more than 200 volumes of periodicals—including his entire collection of the Proceedings of the Royal Society of London (115 vols.), Review of Modern Physics (22 vols.), Reports on Progress in Physics (10 vols.), Physical Review (22 vols.), Ergebnisse der Exakten Naturwissenschaften (16 vols.) and a number of other periodicals—and a few hundred valuable books on Physics, astronomy and astrophysics. All current periodical publications of the Royal Society, received by him, are also made over to the library. Dr. P. C. Mahanty has kindly donated 80 volumes of



The Lecture Theatre.

periodicals (consisting of 55 volumes of Nature and 25 volumes of Physical Review) belonging to the Late Dr. P. N. Ghose. We are also thankful to Prof. N. N. Das Gupta for donating 25 volumes of such periodicals as Proceedings of the Physical Society (London), Physics Abstracts, Bulletin of Atomic Scientists and Journal of Scientific Instruments which helped us to complete many of our sets; to Dr. A. K. Saha for presenting about a dozen of books on mathematics and theoretical physics; and to Dr. S. K. Ghosh for making a valuable contribution of 6 volumes of Nucleonics. Our grateful thanks are also due to a number of Institutions, firstly, to the Indian Science News Association, for allowing this library to receive most of the journals, obtained in exchange of its monthly organ 'Science and Culture' and for providing a substantial portion of the basic stock of periodicals of the library; to the Indian Association for the Cultivation of Science for donating

20 volumes of the Indian Journal of Physics: and to the National Institute of Sciences of India for making a gift of a complete set of their "Proceedings" and "Transactions".

The library has regular exchange relation with more than a score of organisations which include, among others, the national bodies in charge of atomic energy research in the U.S.A., France, Great Britain, Canada, Norway and Netherlands. Indirect and temporary exchanges with different institutions are also effected from time to time through UNESCO'S clearing house in Paris.

Only members of the Institute's research staff and post-graduate students of the Pure Physics Department of the Calcutta University may become registered readers of the library. Outsiders, on the written recommendation of a divisional Head, may also be granted similar facilities. However, the reference section of the library is open to all and for the last four years it has been attracting increasing number of research workers from other departments of the Science College. Despite the inadequacy of its resources, the library's registered readers have swelled in number from year to year and increasing use of it is being made by them, as will be borne out by the following figures. The total number of borrowers (for home issue only) in 1951, 1952, 1953 and 1954 was 296, 817, 1,511 and 1,989 respectively while the total number of volumes issued to them during these years increased as follows: 571, 1,144, 1,916 and 2,363 respectively.

Up till now the library has been following successfully a partially open-access system: while it is completely open to the research staff, it is not so for the student readers. Only a few cases of genuine misplacement or loss were noticed during the last four years but not a single case of theft. If this trend continues, the library may be converted into a fully open-access system in the near future. Initially the working hours of the library had been from 11 A.M. to 5 P.M. on weekdays and from 11 A.M. to 3 P.M. on Saturday. For nearly a year they have been extended from 10 A.M. to 7 P.M. on weekdays and it is planned to keep the library open for 12 hours from 9 A.M. to 9 P.M.

All materials received in the library, *e.g.*—books, periodicals, reports, reprints, microfilms and slides—are classified according to the Universal Decimal Classification Scheme.

All the materials available in the library are shown in the catalogue. While reports and author entries of books are available in the card catalogue, the book catalogue shows only a classified subject entry of books. However, steps have already been taken to switch over completely to the card-form and the work is expected to be completed very shortly.

In addition to the routine activities and other services mentioned above, the Library has available a number of specialised services and plans to establish others in the course of the next few years. These are briefly enumerated below:

(a) *Microfilm Service:*

The work of this section consists, at present, of acquisition of microfilm copies of those books or research reports which are not available in print and providing facilities for their reading through a microfilm reader which the Library already possesses.

(b) *Photoreproduction Service*:

Facilities for photostatic reproduction are, at present, available in the Institute; but closer liaison should be maintained between the library and this section. To cope with the increasing volume of work, a new photostat-machine has been recently purchased.

(c) *Language Class*:

At present, instruction is given in *three* languages—French, German and Russian—through the Linguaphone Language Course. In addition to the elementary course, advanced courses of instruction are also available, from the current year, for French and German languages.

(d) *Translation Service*:

Although it would be beyond the resources of the library to undertake translation work on an extensive scale, nevertheless it has been felt that limited—but regular—translation facilities must be made available to the research staff without interfering with the other essential, routine administrative activities of the library. With this end in view, the appointment of one full-time translator, proficient in French and German, has been suggested.

(e) *Information and Reference Service*:

When established, this should include:

(*i*) Answering questions of the research workers and providing them with up to date information on their subject;

(*ii*) Preparation of bibliographies on specific subjects for different departments;

(*iii*) Literature search;

(*iv*) Preparation of abstracts and indexes;

(*v*) Publication of a monthly library bulletin:

At present, this contains only the titles of books and reports received in the library; in future, the scope of this bulletin is to be expanded to include also news about atomic energy work in different parts of the world, list of books on Nuclear Science currently published, current bibliographies of periodical-articles on Nuclear Science and Engineering, news about conferences on various aspects of atomic energy etc.

C. *Workshop Section*

An institution devoted to teaching and research in Nuclear Sciences today cannot function without a mechanical and electrical workshop. Repair and construction of physical apparatus can no longer be carried out by twine and sealing wax methods. They have to be designed and built accurately to suit the specific problem.

The Workshop of the Institute of Nuclear Physics has thus grown out of the necessity of designing and constructing various equipment, connected with the Cyclotron. Before the Institute of Nuclear Physics moved into its present building, most of the mechanical work needed was done in the Physics Department workshop. This was found to be very unsatisfactory and a nucleus for the workshop was formed with a lathe, a drilling machine, a fitters bench and two mechanics and a glass blower. As only a fraction of the work that was necessary could be carried out by this unit, it was decided to carry out an immediate expansion in 1950 to cope with the increased research activities of the Institute. Further equipment was added in 1953 and 1954, so that a major part of the engineering work of design and fabrication could be carried out at the workshop.

We now possess four lathes, one of which is a heavy duty high speed 10¾″ centre Denham machine. This last machine has been installed last year at a cost of about Rs. 40,000/-. We are now in a position to handle heavy and large diameter jobs and can use carbide tipped tools to expedite machining. In addition, we have a small milling machine, two drill presses and one horizontal band saw. We have also installed a 26″ shaping machine at cost of about Rs. 22,000/-. Our present equipments consist of:—

1. One 6″ centre, 6′ bed lathe.
2. One Southbend 5″ centre, 4′ bed lathe.
3. One 5″ centre, 3½′ bed Sheldon lathe.
4. One 10¾″ centre, 3′ bed Denham lathe.
5. One Jeweller's lathe.
6. One 1″ Capacity Drill press.
7. One ½″ Cap. Bench Drill press.
8. One Universal Milling machine.
9. One horizontal band saw.
10. One Air compressor, 10 H.P.
11. Acetylene cutting and welding equipment.
12. One Tool Grinder.
13. One Tool post grinder.
14. One polishing lathe.
15. One 26″ Stroke Shaping machine.
16. One Heat Treating furnace of temperature range upto 1,000°C.

Activities:

During the last great war, mechanical and oil diffusion vacuum pumps could not be imported and research work in which high vacuum was needed were at a standstill. At that time several small capacity mechanical and oil diffusion pumps were constructed. Though one 12″ dia. high speed oil diffusion pump has been fabricated, we are still in need of adequate machinery to make larger pumps. An air driven ultracentrifuge for biophysical researches was developed with a grant from the B.S.I.R.

Apart from the various parts of cyclotron, amongst the the important pieces of apparatus fabricated at the workshop may be named the angular corelation apparatus, the Beta-ray Spectrometer and the magnet of the nuclear induction experiment. The pole pieces of the magnet have been made parallel to ·0005 of an inch and the inhomogeneity in the magnetic field at present is of the order of several milligauss. The complete Beta-ray spectrometer with its 300 lb. coil was fabricated at the worshop. Besides these, we have been making fluon rods with a screw press we have got, but to make rods of larger dimensions we require a hydraulic press. Welding is an important adjunct to a modern workshop. We have acetylene welding and cutting set, but we propose to introduce arc and spot welding.

We have a small glass blowing shop without any glass blowing machinery. Even with this meagre equipment we have developed hauskeeper glass to metal seals.

A list of important apparatus and jobs done in the workshop are given:

(1) Various parts of the Cyclotron vacuum system such as vacuum seals, vacuum stop cocks and gauging systems in it.
(2) The Ionsource of the Cylotron.
(3) Vacuum stopcoks and vacuum connections of the Electron microscope.
(4) An automatic Verneuil apparatus for growing synthetic inorganic crystals.
(5) A beta-ray spectrometer chamber 42″ long × 7″ bore and its associated vacuum system.
(6) A 300 lbs. 28″ diameter coil for the Beta-ray spectrometer.
(7) A machine for winding the above coil.
(8) One 12″ oil diffusion pumps and several smaller oil diffusion pumps.
(9) A furnace for growing organic crystals, with a slow motion device by which the container is lowered at a rate of 1″ in 3 days.
(10) Two pole pieces for the Electron microscope lens.
(11) Four cylindrical lenses of perspex to be used in a cloud chamber.
(12) The pole pieces of the 12″ diameter magnet have been made parallel to ·0005″ of an inch by lapping and hand finishing. The inhomogeneity in the magnetic field is now of the order of 20 milligauss which we hope to bring down to 1 milligauss.
(13) Cavity resonators and waveguides.
(14) Fabrication of Fluon rods from the powder.

Expansion Scheme:

The expansion of the workshop has been planned with an eye to the growing demands for apparatus of the various research divisions of the Institute. It is not possible to purchase a special research apparatus as needed for a particular investigation but it can be fabricated in a well equipped workshop at a comparatively small cost. For example, there is a demand of high speed mechanical and oil diffusion pumps in nuclear researches for various vacuum systems. We have fabricated several such small vapour pumps and two large ones working satisfactorily, but to make larger mechanical pumps we are in need of a boring and a grinding machine which we propose to purchase in the next five years. To produce a flat surface of large dimensions, a shaping machine is not adequate and for this reason we have included a 6 ft. planning machine.

Besides, we have included a number of ordinary lathes for imparting training in workshop practice to the Post M.Sc. students. The precision lathes have been included to produce accurate screws and cavity resonators etc. and for works in which a high degree of accuracy is required.

Lead castles, lead bricks etc. are used profusely in nuclear research but at present we have to purchase them from outside firms, at a high price. We propose to take up casting of non-ferrous materials in the workshop, for which adequate equipments have been listed in our five year plan. We have Accetylene welding and cutting, but we propose to introduce arc and spot welding. We also propose to add a small carpentry shop to enable us to tackle the laboratory jobs as well as to make patterns for small castings. For this we have listed wood working machinery in the five year plan.

A highly developed glass blowing shop is also as essential as a well equipped machine shop. We have included glass blowing machinery and a high frequency heating unit for making glass to metal seals rapidly.

Workshop Training: A laboratory mechanic must have a high sense of accuracy which is not generally demanded of him in an ordinary production shop. He must have a training in all sorts of workshop practices. With this in view, a system of training has been introduced since 1952 and there are 4 apprentices in the Workshop undergoing this training. This scheme would not only meet our own future demands of trained mechanics, but that of other sister institutions.

PROPOSED COSMIC RAY SECTION

The Institute of Nuclear Physics or rather its predecessor, the Palit Laboratory of Physics had maintained a cosmic ray section since 1938, and had carried out a large amount of experimental work. In 1942, it had a temporary station at Darjeeling at the house of Prof. M. N. Saha, where the intensity of mesons was measured in different directions, and the life of the μ-meson was measured. This is still quoted as a standard measurement.

Darjeeling, in some respects, is an ideal station for cosmic ray work. It has well-built pucca houses with electric connection and having open views in all directions. Good boarding comforts are available at heights of 8,000 ft. It can be reached throughout the year from Calcutta within 6 hours. The Institute of Nuclear Physics tried to have a free house from the Bengal Government, but the negotiations did not bear fruit. Recently, however, the West Bengal Government has given assurances of procuring for the Institute a well-built house for housing the Cosmic Ray Station, and encouraged by this prospect, the following programme has been drawn up. It may be mentioned that with a Cosmic Ray Station at Darjeeling, it is possible to have substations for experimental work at sites having height of 16,000 ft., which are available on the Darjeeling Lhasa Road.

1955-56—For the study of the effect of solar flares and day to day magnetic variation due to the Earth's field, on the intensity of cosmic radiation we require a continuously recording high pressure Argon-filled ionization chamber, in conjunction with a proper recording instrument, like an Esterline Angus pen recorder.

1957-58—The study of penetrating air showers in a large Wilson Cloud Chamber will provide us with valuable data regarding the interaction of high energy particles with matter; the properties of V-mesons can be studied in details. As the proposed chamber will be $2' \times 2' \times 10''$ in dimensions, we can perform experiments on the variation of ionization loss with energy of the ionizing particle. According to Fermi's dielectric polarization loss theory the normally accepted Bethe-Bloch curve should not show a logarithmic increament in relativistic region; instead, the curve should become more or less parallel with the energy axis. Very few experiments have been performed to-date to clear this point.

1959-60—A moderately high field magnet for use in cosmic ray studies is more than a mere necessity. For the quantitative study of the energy spectrum of decay electrons from μ-mesons by means of a cloud chamber and for many other quantitative experiments a magnetic field is a prerequisite. As we have already a 12″ diameter cloud chamber and we have some experience in the successful design and construction of 12″ pole face 10,000 Gauss electromagnet, we should construct a 5-6 ton magnet for exclusive use with the cloud chamber.

Note—We are in negotiation with the Government of West Bengal for establishing a High Altitude Research Station. For this purpose there is a suitable building named Point Clear on Jalapahar (7,200 ft.) in Darjeeling. Government of West Bengal is acquiring that house for our Laboratory and they will bear all expenses for reconditioning the Building for Laboratory purpose.

As suggested by the Delhi Meeting (Appendix VII) this scheme of work will be examined by the Cosmic Ray Research Committee.

STAFF OF THE INSTITUTE

Professoor Meghnad Saha, F.R.S., Honorary Director.	Investigations on the ionospheree. Astrophysical problems.

ACCELERATOR DIVISION.

Prof. B. D. Nag Chaudhuri, Palit Professor of Physics, Calcutta University. Head of the Division.	Design of Electron synchroton and Mass-Spectrometers. Neutron studies.
	Cyclotron Section:
S. K. Mukherjee, Lecturer ...	400 KV Radio-frequency Cockroft-Walton Accelerator and neutron production with D-D and D-T reaction. Experiments on fast neutron scattering.
P. K. Dutta	Time of Flight Mass-Spectrometry; Investigations on cold cathode vacuum ionisation gauges; problems on ion-sources for particle accelerators.
A. P. Patro B. Basu Dr. A. Chatterjee S. Mahapatra	Cloud Chamber Studies on Uranium fission. Radiative capture of neutrons. Investigations on neutron cross sections in the intermediate energy range with neutron velocity selectors. Low energy gamma-ray spectroscopy. Construction of a Scintillation Pair Spectrometer. Development of fast electronics. Fast Oscillography, wideband amplifiers and fast coincidence. Distributed coincidence and multichannel delay analysers. Measurement of decay times of scintillating phosphors.
S. B. Kar Mahapatra	Construction of directional focussing mass spectrometers; Design studies of electromagnetic isotope separator.
	Electron Synchroton Section:
Reader in Charge. Lecturer—1. Technical Engineer—1. Research Assistant—2.	(To start on 1-3-56).

Mass Spectroscopy Section:

Lecturer—1. Research Assistants —2.

NUCLEAR PHYSICS DIVISION.

Dr. A. K. Saha, Reader in Nuclear Physics, Head of the Division.

Beta-gamma Ray Spectroscopy Section:

Dr. S. Chatterjee, Reader, Teaching Section).

(M. K. Banerjee, Lecturer, Theoretical Physics).

Theories of nuclear structure: treatment of light nuclei with intermediate coupling shell-model, and of heavy nuclei with the unified nuclear model (individual particle model and collective motion model).

R. L. Bhattacharyya
A. C. Chatterjee
M. K. Pal

Study of energy levels in excited nuclei—γ-γ and β-γ angular directional and polarisation correlational measurements; problems of oriented nuclei.

Design and construction of beta-ray spectrometers; improvement of resolution of short lens spectrometer with continuous baffle system.

Measurement of half-lives of short-lived metastable states in isomeric nuclei by delayed coincidence method.

Scintillation gamma-ray spectrometry; response characteristic of phosphors to beta and gamma rays; growing of organic and inorganic phosphors.

Studies on millimicrosecond pulse technique; distributed amplifiers and fast coincidence circuits.

Nuclear Induction Section:

(T. P. Das, Lecturer, Theoretical Physics).
D. K. Roy
S. K. Ghosh Roy

Study of line widths and line shapes of nuclear resonance signals; study of relaxation times of different chemical compounds; measurement of susceptibility of paramagnetic substances; Spin-echo study of n pulses; spin-echo study of diffusion mechanism in liquids; spin-echo study of quadrupolar effects; structural analysis of metals and alloys. Double resonance studies of different compounds including metals.

(G. N. Sirkar, Workshop Superintendent).	Study of fine and hyper-fine structure of compounds belonging to ion-transition and rare earth groups; study of V centres of crystals after irradiation with neutron source.
	Theoretical Physics Section:
M. K. Banerjee, Lecturer ...	See Beta-gamma ray spectroscopy Section.
T. P. Das, Lecturer	See Nuclear Induction Section.

TEACHING SECTION.

Dr. S. Chatterjee, Reader in Nuclear Physics, In Charge of the Section.	See Beta-gamma ray spectroscopy Section.
Dr. R. K. Das, Lecturer ...	Investigation of the distribution of charged cosmic particles along different zenith angles. Investigation on the N-S assymmetry of the charged cosmic particles.
S. Das	Construction of a Neutron spectrometer using photographic emulsion technique and its use for experiments on Neutron scattering.

NEUTRON PHYSICS SECTION.

Dr. S. N. Ghoshal, Sur Reader in Nuclear Physics, Calcutta University. In Charge of the Section.	Measurement of the cross-section of inelastic scattering of fast neutrons, and identification of nuclear energy levels. Theoretical investigation of neutron inelastic scattering phenomena.
A. N. Saxena	Measurement of absorption and scattering cross-sections of slow neutrons by various nuclei.
B. Bhaskar Baliga	Study of the scattering of polarized neutrons.

INSTRUMENTATION SECTION.

B. M. Banerjee, Reader in Instrumentation, Head of the Section.	Development of spin-echo apparatus for nuclear induction experiments. Development of fast pulse generators for testing applications.
S. Nath	Design and construction of a recording Ionospheric Sounding Apparatus for Study on Lunar and Solar tides.
R. Roy, Lecturer ... ... J. K. D. Verma.	Investigations on the polarisation of the ionospheric echoes; studies on the collision frequency of electrons in the ionospheric layers.

NUCLEAR CHEMISTRY DIVISION.

B. C. Purkayastha, Reader in Nuclear Chemistry. Head of the Division.	Separation of fission products and fissile elements by ion exchange, chromato-graphy, Solvent extraction etc. methods.
V. R. Pai Vernekar S. Bhattacharyya	Some interesting aspects of the Chemistry of rare elements with the help of radioactive tracers. Studies on the products of spontenceous fission.
S. K. Nandy, Lecturer ...	Studies on Indian radioactive minerals: determination of their geological time from lead: uranium ratio. Mass spectrographic analysis of the isotopic abundance of lead. Investigation on Szilard Chalmer's reaction.

ADMINISTRATIVE DIVISION.

	General Administration Section:
H. K. Basu, Administrative Officer. In-charge-of the Section.	
M. K. Bose, Accountant ...	
	Library Section:
K. Bhattacharyya, Librarian. In-charge of the Section.	
	Workshop Section:
G. N. Sarkar, Workshop Superintendent. In-charge-of the Section.	

Honorary lecturers who participate in the activities of the Teaching Section:

Dr. P. C. Bhattacharyya ...	Lecturer in Pure Physics, Calcutta University.
Dr. S. D. Chatterjee	" " "
S. Datta Majumder	" " "

APPENDIX I

CONSTITUTION AND RULES OF THE INSTITUTE OF NUCLEAR PHYSICS

(Passed by the Calcutta University Senate on May 12, 1951)

Name:

1. The name of the Institute shall be "The Institute of Nuclear Physics" hereinafter called the "The Institute."

Object:

2. The Institute shall provide facilities for and offer courses of instruction in both Elementary and Advanced Nuclear Physics to students appearing for the M.Sc. degree in Physics. It will also offer facilities to post-M.Sc. students for research and training, both theoretical and technical, including training in atomic energy, nuclear science and biophysics and carry on scientific and technical investigations and other experiments for the purpose aforesaid.

Relationship with the Calcutta University and the Government of India:

3. The Institute shall function as an All-India Institute and 40 per cent. of seats will be reserved for candidates from States other than West Bengal. Subject to the Institute being administered in accordance with the provisions of this scheme, it will provide for post-graduate teaching and research as an integral part of the University.

Governing Body:

4. There shall be a Governing Body for the Institute composed of the following members:—

(1) The Vice-Chancellor of the Calcutta University, Chairman (*Ex-officio*).
(2) The Director, The Institute of Nuclear Physics, Vice-Chairman (*Ex-officio*).
(3) One Professor of Physics or Applied Physics of the Calcutta University (to be nominated by the Syndicate of the Calcutta University for a period of three years).
(4) One of the Donors to The Institute of Nuclear Physics (to be nominated by the Syndicate of the Calcutta University for a period of three years).
(5) One representative of the Ministry of Natural Resources and Scientific Research of the Government of India (to be nominated for a period of three years).

(6) One representative of the Atomic Energy Commission of the Government of India (to be nominated for a period of three years).

(7) One representative of the Ministry of Education, Government of India (to be nominated for a period of three years).

(8) The Accountant General, Government of West Bengal (*Ex-officio*).

(9) One Science representative of the Inter University Board of India (to be nominated for a period of three years).

The Palit Trust is to be deemed to be one of the donors to the Institute of Nuclear Physics.

Professor Meghnad Saha would be a life member of the Governing Body, and he will also be the Honorary Director hereinafter referred to as "The Director of The Institute of Nuclear Physics."

Note.—The Governing Body of the Palit Trust has permitted Professor Saha to be the Honorary Director of the Institute, and has agreed that

(*a*) All facilities regarding laboratory equipments, staff, etc., now at the disposal of the Palit Professor from the Palit Fund or which may be hereinafter made available to him will be allowed to be utilised for work at The Institute of Nuclear Physics.

(*b*) Work done by Professor Saha at The Institute of Nuclear Physics will be deemed to be done in accordance with the purposes for which the Palit Trust was created and the Palit Professorship was established.

(*c*) The above arrangement will hold good so long as Professor Saha continues as Palit Processor of Physics.

Proceedings of the Governing Body:

5. The Governing Body shall keep an intimate touch with the Calcutta University as also with the Government of India and will report to them all its proceedings and decisions.

Powers of the Governing Body:

6. The Governing Body shall have full powers of administration, finance and appointments, except in the case of the Director, the manner of whose appointment is provided in para. 9, but appointments or re-appointments to posts maintained out of any Trust Fund will be made subject to the approval of such Trust.

Standing Orders:

7. The Governing Body shall have the power to make standing orders regulating its own procedure, the procedure of Committees appointed by it and the duties of the officers, teachers, and other employees of the Institute.

Director:

8. There shall be a Director of the Institute who will be in charge of the internal administration of the Institute and will be responsible for the admission

of the students into the Institute, but the number of students to be admitted in each session should be determined by the Governing Body.

Appointment of the Director:

9. The Director shall be appointed by the Calcutta University from amongst the holders of endowed Chairs in Physics in the Calcutta University or from amongst the employees of the Institute of Nuclear Physics on the recommendation of a Selection Committee of three to be composed as follows:—

(1) The Vice-Chancellor of the Calcutta University—*Chairman.*

(2) One expert to be nominated by the Ministry of Natural Resources and Scientific Research, Government of India.

(3) One expert nominated by the Calcutta University.

In case none of the persons mentioned above is considered of sufficient merit, offers may be made to outsiders.

Note.—This section will come into force only after the retirement, or resignation of Professor Meghnad Saha.

Appointment of Officiating or Temporary Director:

10. In the case of a temporary vacancy in the post of the Director, the Vice-Chancellor shall nominate one of the senior officers of the Institute of Nuclear Physics to be the Officiating Director for a period of 3 months, and shall report the matter to the Governing Body for confirmation or extension of the period. In case of a vacancy likely to extend for over six months, a meeting of the Governing Body should be convened for the appointment of a Temporary Director.

Existing Staff of Institute of Nuclear Physics:

11. The existing employees of the Institute will continue in their services, and all new and subsequent appointments will be made by the Governing Body.

Delegation of Power to the Director:

12. The Governing Body may delegate as much of its powers to the Director as it may think will be in the interests of the Institute.

Reconstitution of the Governing Body:—

13. The Governing Body shall be reconstituted every three years.

Meetings of the Governing Body:

14. (*a*) Meetings of the Governing Body shall be held at least twice a year at such time and at such place as may be fixed by the Chairman at the request of the Director or at the discretion of the Chairman.

(*b*) *Budget:* At the ordinary meeting to be held in the first quarter of the year the annual budget of the Institute shall be dealt with. The financial year will be from the 1st April of a year to March 31st of the next year.

(c) *Notice of meeting:* Fourteen clear days' notice of any ordinary meeting of the Governing Body specifying place, date and hour of the meeting and the general nature of the business to be transacted therein shall be given to every member of the Governing Body by notice sent by post, provided that accidental omission to give such notice to any of the members shall not invalidate any resolution passed at such meeting.

(d) *Quorum:* In such meeting of the Governing Body four members shall form a quorum.

(e) *Vote:* Every member of the Governing Body shall have one vote. In the event of equality of votes at any meeting the Chairman shall have a second or casting vote.

(f) *Requisition Meeting:* Upon a requisition in writing made by any three members of the Governing Body, the Chairman shall call a special meeting.

Retirement of Members of the Governing Body:

15. If any member of the Governing Body fails to attend any four consecutive meetings of the Governing Body he shall cease to be a member of the Governing Body and the constituency will be asked to nominate another person in his place.

APPENDIX II

STANDING ORDERS BY THE GOVERNING BODY

Under Clause 7 and 12 of Rules

(Approved by the Governing Body in its Second Meeting held on January 5th, 1952 and amendments upto the Eighth Meeting of the Governing Body held on February 17, 1955)

1. ADMINISTRATION

1.1 The Director is authorised:—

(*a*) To enter into arrangement with the Government of India as well as any State Government for securing and accepting grants-in-aid to the Institute on terms and conditions, mutually agreed upon by the Governing Body and the Government concerned.

(*b*) To negotiate for, and accept on terms approved by the Governing Body grants from private bodies or corporations, willing to subsidize research in subjects in which the Institute is interested and can offer reasonable facilities of work.

(*c*) To accept endowments, donations and subscriptions on such terms as are likely to further the aims and objects of the Institute subject to the approval of the Governing Body.

(*d*) To do such other things as may be conducive to the interests and objects of the Institute, subject to the approval of the Governing Body.

1.2 It shall be the duty of the Director to carry on the business of the Institute under direction and control of the Governing Body in accordance with the rules and the standing orders.

Any emergency action taken by him with the approval of the Chairman, will be brought to the notice of the members of the Governing Body within fifteen days of such action and placed before the next meeting of the Governing Body.

1.3 There shall be an Administrative Officer for the Institute of Nuclear Physics. He shall be a whole-time employee of the Institute and shall assist the Director in administration. He shall be the Secretary of the Governing Body, and of the Finance Committee and of the other committees which may be appointed by the Governing Body.

1.4 It shall be the duty of the Administrative Officer to perform the following functions under the guidance of the Director:—

(*a*) To prepare the agenda for and issue notices of meetings to members of the Governing Body and of various Committees.

(*b*) To draft the minutes of meetings.

(*c*) To remain in general charge of the office and subordinate staff of the Institute, other than those serving directly under the Director or Heads of Divisions and to exercise such disciplinary control as may be necessary for the purpose.

(*d*) To be responsible for the maintenance and up-keep of the Institute buildings, properties and equipment.

(*e*) To be responsible for submitting draft budget to the Finance Committee and to the Governing Body for approval.

(*f*) To perform such other duties as may be entrusted to him by the Director with the approval of the Governing Body.

Committees appointed by Governing Body

2.1 The Governing Body shall appoint the following Standing Committees:—

(*a*) Finance Committe.

(*b*) Staff Committee.

(*c*) Selection Committees for Class I and Class II appointments.

Other Committees may be appointed, if necessary.

2.2 Finance Committee:—

A. The Finance Committee shall be constituted as follows:—

(*a*) Chairman, to be nominated by the Governing Body.

(*b*) The Director.

(*c*) Accountant General, West Bengal.

(*d*) One member of the Governing Body to be nominated by the Governing Body.

B. The Finance Committee shall meet at least twice a year and two members shall form a quorum.

C. The Finance Committee shall have the following duties:—

(*a*) To scrutinise the accounts.

(*b*) To frame the Budget for the ensuing year.

(*c*) To make recommenations to the Governing Body on all proposals for new demands, which shall be referred to the Finance Committee for opinion before they are considered by the Governing Body.

2.3 Staff Committee:—

There shall be a Staff Committee consisting of the following members:—

(*a*) The Director (*Chairman*).

(*b*) The Heads of Divisions and Sections.

It shall be the duty of the Staff Committee to advise the Governing Body on all academic matters.

2.4 Selection Committees and Appointments:

A. There shall be three classes of posts.

Class I shall include Heads of Divisions, Readers and Lecturers, the Administrative Officer, Workshop Superintendent, Librarian and the Accountant.

Appointments to class I posts shall be made by the Governing Body on the recommendation of a Selection Committee to be constituted as follows:—

(*a*) The Vice-Chancellor (*Chairman*).

(*b*) The Director.

(*c*) Two representatives of the Governing Body.

(*d*) One expert to be co-opted by the Chairman *for each* appointment.

Provided that the Chairman of the Governing Body can make temporary appointments for a period not exceeding six months in Class I service on the advice of the Director.

Three members shall form a quorum.

B. The Selection Committee for Class I service shall recommend at least two names for each of the posts vacant. For reasons recorded in writing the Governing Body may refer the recommendation back to the Selection Committee for further consideration. If the Selection Committee finds itself unable to recommend any suitable name or the Governing Body is unable to accept the recommendation of the Selection Committee, the Governing Body may make temporary arrangements or issue fresh advertisement for the vacant post.

C. Class II shall include all posts carrying a basic salary of over Rs. 100 and appointments thereto shall be made by the Chairman of the Governing Body on the recommendation of a Selection Committee consisting of:—

(*a*) The Director (*Chairman*).

(*b*) Head of the Division concerned.

(*c*) One member to be nominated by the Chairman.

Provided that the Director can make temporary appointment for a period not exceeding six months in Class II post on the advice of the Head of the Division.

D. Class III shall include all posts carrying a basic salary upto Rs. 100. Appointments to these posts shall be made by the Director.

E. No appointment shall be made outside specific provisions in the Budget.

3. Service Rules

3.1 Employees of the Institute shall be whole-time workers and shall not without the special sanction of the Governing Body previously obtained, hold any other office to which any salary or emoluments or honorarium is attached.

3.2 Each employee shall be given a contract embodying the terms of employment. Appointments shall ordinarily be made on a probationary basis for one year, after which the appointment may be made permanent or for a fixed period. The pay and grade if any, of each member of the staff of the Institute of Nuclear Physics shall be determined by the Governing Body and be specified in the agreement.

3.3 No employee will be entitled to leave place of duty without the permission of the *competent authority*, during his duty period, and nobody will be entitled to leave station without permission of the Director.

In the case of the Director, the competent authority shall be the Chairman.

4. Holidays and Vacations

4.1 The Institute shall remain closed on the following holidays subject to any change that may be made by the Governing Body from year to year.

New Years Day ...	... 1	Janmastami ...	... 1
Sri Panchami ...	... 1	Id-uz-Zuha ...	... 1
Doljatra	... 1	Gandhi Birthday ...	... 1
Good Friday ...	... 1	Mahalaya	... 1
Easter Saturday ...	... 1	Durga, Lakshmi Puja	... 11
Chaitra Sankranti ...	... 1	Kali Puja	... 1
First Baisakh ...	... 1	Fateha Duazdaham ...	... 1
Ashutosh Day ...	... 1	University Foundation Day	... 1
Half-yearly closing of Bank	... 1	Christmas	... 1
Id-ul-Fitr	... 1	Convocation Day ...	... 1
Independence Day ...	... 1		

4.2 The Director, Readers, Lecturers, Research Assistants and Fellows shall be entitled to Summer Vacation not exceeding one month.

4.3 An Officer-in-charge of a division or section although not required to be present during the vacation, continues to be in charge of, and responsible for, his division or section wherever he may be, except when another officer has been appointed to act for him.

4.4 The Director may retain any member of the staff for urgent work during a vacation for a part or the whole of it, provided that the person so retained on duty shall be granted compensatory leave as hereinafter provided.

5. Leave Rules

5.1 Leave cannot be claimed as a matter of right.

5.2 Employees of the Institute shall become entitled to the benefits of these rules only on confirmation in permanent posts. Members appointed in temporary or officiating capacity shall be entitled only to such special leave as the Director may decide,—but not exceeding the priviliges enjoyed by the permanent staff.

5.3 Leave due shall be earned leave, less leave with allowances taken under these rules. For each employee there shall be maintained a leave account showing leave earned, leave taken, and leave due.

5.4 The following kinds of leave are recognised:—

(*a*) Earned leave on full-pay.
(*b*) Leave on medical certificate.
(*c*) Compensatory leave.
(*d*) Leave without pay.
(*e*) Study leave.

5.5 Earned leave on full-pay at one eleventh of the period spent on duty shall become due to all employees of the Institute.

N.B.—Duty includes regular vacations availed of, but not vacations falling within the periods of any leave taken.

The maximum amount of leave due on full-pay that may be granted at one time is limited to six months for the Director, Readers, Lecturers, Research Assistants and Research Fellows and four months for other employees. In exceptional cases the maximum limits may be increased by the Governing Body up to twelve and eight months respectively.

5.6 Leave on medical certificate at half-pay may be granted to each employee at the rate of fifteen days for each period of twelve months' completed service but such leave on any particular occasion must not exceed a maximum of three months. Leave on half-pay shall not be given for periods less than a week and may with the permission of the Director be combined with vacation or compensatory leave.

5.7 When a vacation officer is required to remain on duty by the Director during the vacation or a portion thereof, he will be credited with earned leave at full pay for such period of detention on duty. An employee shall be permitted to credit such compensatory leave on full pay to his leave account and he shall be entitled to accumulate it up to a maximum of two months at a time. Such compensatory leave may be taken in combination with approved holidays and vacation.

5.8 Leave without pay up to a maximum of 28 months may be granted by by the Governing Body in special circumstances and may be combined with holidays and other kinds of leave. Such leave will not be debited to the leave account.

5.9 When an employee has exhausted all leave due to him, he may under special circumstances be granted leave not due, up to a maximum period of three months by the Governing Body. Such leave shall be debited to the leave account, and no further leave shall became due to the employee until his leave account shows a credit balance.

5.10 Study leave on full-pay or less amount may be granted to a member of the Research staff for a total period not exceeding two years in his whole service. Absence from headquarters not exceeding a fortnight during a year in connection with academic work elsewhere may be treated as duty.

5.11 In addition to the recognised forms of leave mentioned above, ordinary casual leave for short periods may be granted by the Director to all employees of the Institute. Such leave must not exceed ten days in one academic year. Casual leave shall not be combined with any vacation but may be added to Sundays and holidays.

5.12 Regular leave may be either affixed or prefixed to vacations, Sundays or other holidays. Vacations falling within two successive periods of leave will be considered as leave.

5.13 The sanctioning authority for all kinds of leave shall be the Director in every case. For the Director, the sanctioning authority shall be the Chairman for purposes of casual leave and Governing Body for other kinds of leave.

5.14 The total amount of leave that can be taken by an employee on full-pay (excluding vacations and also excluding leave which is not debited to leave account) shall not exceed two and half years in the whole period of service.

5.15 Nothing in these rules is intended to restrict the discretion of the Governing Body in refusing or revoking the grant of leave, should the interests of the Institute so require.

5.16 Leave allowance shall be calculated on the amount of pay drawn by the employee on the date on which he proceeds on leave.

5.17 Leave with allowance counts as service for the purpose of increment but leave without allowance does not count as service for such purpose. An increment which accrues in the course of a period of leave shall become effective only from the date of return to duty. The next increment will fall due on the normal date.

5.18 Research scholars shall be entitled to the usual holidays and vacations granted to the whole-time research staff. Any applications for leave from such a scholar shall be dealt with on its own merits by the Director in consultation with the Head of the Division concerned and the rules for the ministrial staff shall be applied as far as practicable.

6. Accounts

6.1 The receipts of the Institute shall consist of:—

(*a*) All contributions by the Calcutta University towards the Institute of Nuclear Physics.

(*b*) Contributions by the Central Government and others.

6.2 The Governing Body shall open and maintain in the name of the Institute of Nuclear Physics one or more current accounts at the Imperial Bank of India and shall always forthwith pay or cause to be paid all income and receipts of the Institute, including all capital income and receipts, to the credit of the said account or accounts.

Also, all surplus funds of the Institute, not immediately required for expenditure, may be deposited with the Imperial Bank of India on such terms as the Governing Body may decide.

6.3 The aforesaid Bank accounts (including fixed deposit accounts) shall be operated upon in the following manner subject to any special conditions that may be prescribed by the respective donors of contributions or by the Governing Body, as the case may be.

(*i*) All cash and cheques shall be paid into the Bank over the signature of *any one* of the following persons, namely (*a*) the Director (*b*) the Administrative Officer (*c*) and (*d*) any two members of the Governing Body, other than the Director, to be nominated by that Body from time to time for this specific purpose.

(*ii*) All disbursement and withdrawal cheques and other withdrawal orders on the Bank shall be signed by any two of the persons mentioned in (*i*) above. One of the drawers must be (*a*) or (*b*) above.

6.4 All payments by or on behalf of the Institute exceeding Rs. 100 in the case of any employee's salary and exceeding Rs. 50 in any other case, shall be made by cheques.

For payments of and below Rs. 100 or Rs. 50, as aforesaid, cheques for the total amounts required at any time shall be drawn in favour of the Administrative Officer and the amount shall be distributed by him on obtaining proper receipts. The undisbursed amounts, if any, must be refunded forthwith to the Bank. To meet small contingent expenses, a permanent imprest of Rs. 100 may be kept with the Administrative Officer.

All payments must be supported by relevant bills and receipts.

6.5 The Administrative Officer shall be responsible for maintaining the accounts of the Institute and the Director shall be responsible to the Governing Body for the maintenance and correctness of such accounts.

6.6 Separate capital and revenue accounts and such other accounts as the Governing Body may from to time direct shall be maintained in such form or forms as the Governing Body may decide.

6.7 The Governing Body shall make suitable annual allotments to a Depreciation Fund to be drawn upon for extraordinary repairs and renewals. Provided that so long as the Central Government contributes to the funds of the Institute of Nuclear Physics, the amount of such annual allotments shall be fixed in consultation with the Government of India.

6.8 The accounts of the Institute shall be closed on the 31st of March every year, the first closing taking place on March 31st, 1952.

6.9 The accounts of the Institute for every financial year shall be audited annually by the Deputy Accountant General, Industries and Supplies, Calcutta. The audit report as received from the D.A.G. together with the explanation of the Director thereon, shall be placed before the first meeting of the Governing Body held after the receipt of the audit report. Fees for the audit may be paid as prescribed by the Auditor General.

7. Budget

7.1 The following procedure shall govern the preparation and passing of the budget and the sanction of expenditure contemplated subsequent to the passing of the budget.

7.2 During the month of December of every year, each Head of Division shall forward his budget proposals to the Director who will likewise put forward his proposals concerning the requirements of the divisions and sections under his direct control and his proposals regarding the administrative side of the Institute.

7.3 These will be first discussed in the Staff Committee and the Administrative Officer will then prepare the final budget proposals to be placed before the Finance Committee on or before 15th of January.

7.4 After the Finance Committee has discussed and approved all the budget proposals, the Director will take action for obtaining the necessary grants. As soon as the intimation regarding the grant is received by the Director, the final budget will be prepared accordingly to the accepted budget proposals, and the grants received, and this final budget will be placed before the Governing Body in a meeting to be held before the end of June. If the final budget thus prepared differs materially from the budget proposals, approved by the Finance Committee, the final budget shall be placed for consideration of the Finance Committee again before the meeting of the Governing Body.

7.5 Statements of financial proposals for the ensuing year shall include:—

(*a*) the actual expenditure of the preceeding year,
(*b*) the original budget estimate for the current year,
(*c*) the revised budget estimate for the current year,
(*d*) the proposed budget for the ensuing year.

7.6 There shall be separate budgets for capital and revenue accounts.

8. Provident Fund Rules

8.1 There shall be a Provident Fund, called the Contributory Provident Fund of the Institute of Nuclear Physics. The rules relating thereto are laid down in this Section.

8.2 In these Rules:—

(*a*) 'Salary' means pay as well as 'leave allowance'.

(*b*) 'Family' means (*i*) the wife or wives of a subscriber, (*ii*) the husband in the case of a female subscriber, (*iii*) the children of the subscriber, and (*iv*) the widow or widows and children of a deceased son of the subscriber.

N.B.—An adopted child shall be considered to be a child only in those cases in which the Governing Body is satisfied that under the personal law of the subscriber, adoption is legally recognised as conferring the status of a natural child.

(*c*) 'Leave' means any kind of regular leave recognised under the Leave Rules (Sec. 5 ante).

(*d*) 'The Fund' means the Contributory Provident Fund (Institute of Nuclear Physics).

(*e*) 'Year' means the financial year.

8.3 The Fund shall be administered by the Governing Body.

8.4 The following persons shall be eligible for subscribing to the Fund:

(*a*) All permanent employees of the Institute.

(*b*) Those temporary employees who have completed at least one year's service, and are certified by the Director as likely to continue in service for another 3 years.

(*c*) Those temporary employees who have been specifically permitted to subscribe under the terms of their contract.

Subscription shall be voluntary.

8.5(*a*) The Administrative Officer shall, as soon as may be, require every subscriber to make a nomination in either of the two alternative forms given below according as the subscriber is with or without a family.

Form I

Form of Nomination when subscriber has a family.

I hereby nominate the persons mentioned below, who are members of my family as defined in rule 8.2 of the Rules of the Contributory Provident Fund (Institute of Nuclear Physics) to receive the amount that may stand to my credit in the Fund, in the event of my death before that amount has become payable, or having become payable has not been paid, and direct that the said amount shall be distributed among the said persons in the manner shown below against their names:

Name and address of nominees.	Relationship with subscriber.	Age.	Amount or share of accumulations to be paid to each.

Dated this...................................day of...................................19

at.........................

Signature of subscriber.

Two witnesses to signature.

1.....................................

2.....................................

Note.—This column should be filled in so as to cover the whole amount that may stand to the credit of the subscriber in the Fund at any time.

Form II

Form of Nomination when subscriber has no family.

I, having no family as defined in rule 8.2 of the Rules of the Contributory Provident Fund (Institute of Nuclear Physics) hereby nominate the persons mentioned below to receive the amount that may stand to my credit in the Fund, in the event of my death before that amount has become payable, or having become payable has not been paid, and direct that the said amount shall be distributed among the said persons in the manner shown below against their names:—

Name and address of nominees.	Relationship with subscriber.	Age.	* Amount or share of accumulations to be paid to each.

Dated this.................................day of.................................19

at.........................

Signature of subscriber.

Two witnesses to signature.

1.....................................

2.....................................

* *Note.*—This column should be filled in so as to cover the whole amount that may stand to the credit of the subscriber in the Fund at any time.

(*b*) A nomination made in Form II above shall become null and void as soon as a subscriber acquires a family.

(*c*) As soon as a subscriber acquires a family he shall send to the Administrative Officer a revised nomination in Form I, and formally cancel his previous nomination.

(*d*) A nomination may be cancelled at any time and substituted by another which it would be permissible to make under the provision of this rule.

8.6(*a*) Every subscriber shall subscribe monthly to the Fund when on duty.

(*b*) A subscriber may, at his option, subscribe during leave other than leave without pay. Such option shall be intimated to the Administrative Officer in writing before the subscriber proceeds on leave, and shall be final.

(*c*) The amount of subscriptions shall be fixed by the subscriber himself, subject to the following conditions:—

(*i*) It shall be expressed in whole rupees.

(*ii*) It may be any sum so expressed not less than $6\frac{1}{4}$% and not more than $15\frac{5}{8}$% of the salary.

(*iii*) Salary for the purposes of this rule shall be calculated at the rate payable in respect of the 31st March of the preceeding year, provided that if he was not in service or was on leave or suspension on the aforesaid date, his salary shall be calculated at the rate payable in respect of the 1st day on assumption of or return to duty.

(*iv*) If the amount of subscription payable contains a fraction of a rupee, it shall be rounded to the nearest whole rupee but not below $6\frac{1}{4}$% and not above $15\frac{5}{8}$%.

(*v*) The amount of subscription so fixed shall remain unchanged throughout the year—provided that if a subscriber is on duty for a part of a month and on leave for the remainder of that month, and if he has elected not to subscribe during leave the amount of the subscription payable shall be proportionate to the number of days spent on duty in the month.

(*d*) A subscriber may discontinue subscribing to the Fund at any time but his right of renewing subscription shall lapse if he discontinues subscribing, except when on leave, more than three times.

8.7 Payment of subscription as well as refund of any advance taken from the Fund shall be made by means of deduction from pay or leave salary drawn by or on behalf of the subscriber.

8.8 The Administrative Officer shall keep an account in the name of each subscriber and credit thereto within the 3rd of each month.

(*i*) the subscriber's subscription,

(*ii*) contributions made by the Institute under Rule 8.9.

8.9 Unless an Officer is dismissed for gross misconduct, the Institute shall pay to the credit of each subscriber's account every month a contribution equal to $6\frac{1}{4}\%$ of the salary on which the subscriber's subscription had been calculated and fixed.

The amount of contribution payable shall be rounded to the nearest rupee.

If a subscriber quits the service or dies during a month, contribution shall be credited to his account for the period between the beginning of the month and the date of the casualty.

8.10 At the close of each year the Institute shall credit to the account of each subscriber an appropriate sum representing interest on the total amount lying at his credit from month to month. The interest that will be paid during a year shall be that given in the Post Office Savings Bank account.

8.11 A temporary advance may be granted to a subscriber from the amount standing to his credit in the Fund, subject to the following conditions:

(*a*) No advance shall be granted unless the sanctioning authority is satisfied that the applicant's pecuniary circumstances justify it and that it will be expended on the following object or objects and not otherwise:

(*i*) to pay expenses incurred in connection with the prolonged illness of the applicant or any person actually dependent on him,

(*ii*) to pay obligatory expenses in connection with the marriages, funerals or ceremonies which by his religion it is incumbent on him to perform.

(*b*) An advance shall not

(*i*) exceed three months' pay or half the amount of the subscriber's own subscriptions plus interest thereon at his credit in the account,—whichever is less,

(*ii*) be granted until at least 12 months have elapsed after the final repayment of all previous advances together with interest thereon.

(*c*) An advance shall be repayable in not less than 12 and not more than 24 equal instalments.

(*d*) Interest shall be payable on advances at the rate mentioned in rule 8.10, and such interest shall be credited to the subscriber's own account.

(*e*) The Director shall be competent to sanction temporary advances from the Fund to all members of the staff. For the Director himself, the sanctioning authority shall be the chairman.

8.12 Temporary withdrawals may be permitted to pay premia on policies of insurance on the life of the subscriber or of his wife provided that the policy is assigned to the Governing Body and the receipts granted by the Insurance Company for the premia are from time to time handed over to the Administrative Officer for inspection. Such withdrawals need not be repaid ; but if for any reason the policy lapses or is allowed to be encumbered,—the entire amount diverted from the Fund for financing the policy will have to be repaid with interest.

8.13 For keeping the money belonging to the Fund a separate account shall be opened in the Post Office Savings Bank account in the name of each subscriber, but pledged to the Governing Body of the Institute to which the total deduction from salaries as well as the contributions made by the Institute shall be credited within the first four working days of every month. This account shall be operated on by the same persons and in the same manner as mentioned in Rule 6.3.

8.14 Each depositor shall be furnished with an annual statement of his account showing separately (*i*) the opening balance at the beginning of the year, (*ii*) the subscriptions, refund of withdrawals, contributions, and withdrawals during the year, (*iii*) the interest credited to the account, and (*iv*) the closing balance at the end of the year.

8.15 As soon as a subscriber quits service it shall be the duty of the Director to close the account after paying him the entire balance at his credit. A subscriber who has proceeded on leave preparatory to retirement may also be allowed to withdraw finally the balance at his credit in the fund.

8.16 If a subscriber dies while in service, or before final payment has been made to him—it shall be the duty of the Director to make final payment of the amount at his credit in the Fund, in accordance with the nominations filed by him. Where there are no nominees, payment should be made to family members or legal heirs. The orders of the Governing Body should be taken on each such case.

9. Agenda and Minutes

9.1 The agenda should be drawn up as follows:—

(*a*) Confirmation of the minutes of the last meeting of the Governing Body.

(*b*) Reporting the actions taken on the resolutions passed at the previous meeting of the Governing Body.

(*c*) Reporting the recommendations of the various Committees in the following order:—

(*i*) Of the Finance Committee.

(*ii*) Of the Selection Committees.

(*iii*) Of the Staff Committee.

(*iv*) Of other Committees.

(*d*) To report actions taken by the Chairman.

(*e*) Any other business.

9.2 Minutes of the Governing Body shall be circulated to each member within one month of the meeting, and shall be placed before the next meeting for confirmation, and be signed by the Chairman.

9.3 Additional items, if any, shall be circulated to the members, at least a week before the meeting. The Chairman may permit inclusion of any item not on the agenda for which due notice could not be given, provided the matter concerned in the item is, in his opinion, of sufficient urgency.

10. Suits

10.1 All suits instituted by or on behalf of the Institute shall be in the name of the Governing Body and in all suits brought against the Institute, the Administrative Officer shall represent the Institute.

APPENDIX III

PROSPECTUS OF THE POST M.SC. ASSOCIATESHIP COURSE

Institute of Nuclear Physics

Object :

An important objective of the Institute of Nuclear Physics is the training of personnel in Nuclear Science. The Institute offers a one year Associateship course, which imparts advanced training in theoretical and experimental nuclear physics. This one year course helps the students to qualify for:—

(1) undertaking research work in some branch of nuclear physics ;
(2) absorption in the different projects of the Department of Atomic Energy, Government of India ;
(3) teaching nuclear science in different Universities and technical colleges ;
(4) utilising nuclear science as a tool of research in medicine, biology, chemistry and other sciences.

It is expected that some of the students will stay and do research work and qualify for the D.Phil. or D.Sc. degree. Such students will be attached to the different heads of the divisions in this Institute and will work under their guidance, and specialize in particular subjects, *e.g.* particle acceleration, nuclear spectroscopy, neutron physics, nuclear reactions, nuclear chemistry, theoretical nuclear physics, bio-physics and instrumentation.

Admission :

The session starts in July of every year and closes on June of the next year. Students are admitted to the Associateship course on the basis of their merit. At present there is provision for twenty students, forty per cent of which are reserved for students from outside West Bengal. Applications for admission to the course are invited in April every year through all the important Indian daily newspapers and applications are required to be submitted within a specified date. The application forms "shown at the end of this Appendix" are sent on request. For admission the students must have first class or second class M.Sc. degree in (*a*) Physics or (*b*) Applied Physics, or (*c*) Physical Chemistry with Physics, Chemistry and Mathematics as their principal subjects in the degree course. Preference is given to those who have some knowledge of nuclear physics. Preference is also given to those who are already in service and can utilise the advanced training in building up new centres of teaching and research in nuclear science.

Course :

The session is divided into three terms. The first term (July to September 15) includes 100 hours of lectures and 200 hours of experimental work for preliminary training. The second term (from October to January 14) includes 120 hours of lectures and 240 hours of experimental work and is devoted to advanced training. The syllabus is given in appendix V. The third term (from February to May-about 500 working hours) is to be devoted to study of special problems by the individual students. The special problem will either be a piece of original work or repitition of a standard work, or some review work. This will be usually done under the supervision of a teacher of the Institute.

Specialisation on the following lines are offered: Particle accelerators, nuclear magnetic moments, beta and gamma ray spectroscopy, neutron physics, instrumentation, nuclear chemistry, and theoretical physics.

The students are also expected to attend the seminars and symposia held periodically on subjects of current interests.

Examinations :

At the end of each term there is a written examination as well as a viva voce. There is no practical examination and for experimental work sessional marks are given by the teachers in-charge of the different experiments.

Diploma :

To qualify, the student must attend 60 per cent of the total number of classes, both theoretical and experimental, must secure 50 per cent marks in all examinations, and 55 per cent marks in aggregate. On successful completion of the conditions, the diploma, "Associate of the Institute of Nuclear Physics", Calcutta University, will be awarded to the student by the Chairman of the Governing Body and the Director on the recommendation of the Governing Body of the Institute of Nuclear Physics.

Accommodation :

At present the Institute can not offer any accommodation for the students undertaking Associateship course. However, the hostel of the Institute is expected to be erected by the middle of 1956.

Scholarships :

The Institute offers scholarships of Rs. 150/- per month for one year to 10 students undertaking Associateship course. The scholarships are awarded after the students have joined the course, purely on the basis of merit, and no guarantee can be given earlier.

FORM OF APPLICATION FOR POST M.Sc. ASSOCIATESHIP COURSE

Roll No...............

To
THE DIRECTOR,
Institute of Nuclear Physics,
92, Upper Circular Road,
Calcutta - 9.

SIR,

May I be allowed to apply for enrolment as a student of the Post M.Sc. Association Course for the session 195

The necessary details about my qualifications, etc. are given in the Form.

The......................................195

Yours obediently,

Signature of the Applicant.

INSTITUTE OF NUCLEAR PHYSICS

Admission Form—Post M.Sc. Associateship Course

1. Name of Applicant (BLOCK LETTERS)..
   Present Address..
2. Father's Name and Occupation..
   Address..
3. Age—Married or Single..
4. Race (i.e. Nation, Tribe, etc.).................. ....
5. Home Addres..
6. Calcutta Address..
7. Educational Qualifications:—

Institution	Examination	Year	Class	Subjects

8. Professional Qualifications (attach separate sheet, if necessary)......................
9. List of Published Papers, if any, (attach separate shee, if necessary)...............

10. If the Applicant is already in service:

Present Occupation with basic salary..

Whether study leave with pay will be granted..

11. If the student has decided in which branch he (she) will specialise.................

12. Name and status of two persons who can testify to the character and abilities of the Applicant:

(1) Name
Status
Address

(2) Name
Status
Address

The.................................195

Signature of the Applicant
(in full)

APPENDIX IV

Syllabus of the Post M.Sc. Associateship Course

Syllabus for Theoretical Studies :

(Preliminary, Advanced & Special Courses) :

General Properties of Nuclei

Mass, charge, spin, statistics, magnetic moment; size of protons, neutrons and nuclei.

Composition and parity of nuclei, mass defect, Bethe-Weizäc and other formulae for mass defect, mass defect curves.

Natural radioactivity, decay and genetic relationships in natural radioactive series, and in transuranic elements.

General conditions of stability of nuclei against particle emission and fission, structure of nuclei, the different models of nuclei.

Reference:

Fermi—"Nuclear Physics"
Blatt & Weisskopf—"Theoretical Nuclear Phycics", Chapter I.

Mass Spectroscopy and Separation of Isotopes

(*a*) Mass spectrographs: Positive ray analysis—production of positive rays, velocity spectrum of positive rays.

Aston's first mass spectrograph: comparison of masses by the method of coincidence, the method of "Bracketing".

Modern high resolution mass spectrographs—the principle of Double Focussing—A simplified theory of construction of modern mass spectrographs.

Dempster's double focussing mass spectrograph; Bainbridge and Jordan's double focussing mass spectrograph; Mattauch's double focussing mass spectrograph; Jordan's high dispersion mass spectrograph.

A simplified treatment of Hughes' and Rojansky's method of electrostatically focussing of charged particles. ....

(*b*) Mass spectrometers for studying relative abundance of isotopes: Magnetic 180° and Sector Types—Nier 60° mass spectrometer, Dempster 180° mass spectrometer, Bleakney 180° mass spectrometer, 120° sectorial spectrometer.

Magnetic lens spectrometer of Rumbaugh, Trochoidal mass spectrometer, radio-frequency spectrometers, critical remarks regarding the accuracy of measurements by the different methods.

(*c*) Separation of Isotopes: General introduction, separation by diffusion, thermal diffusion method, "Gravitation" or pressure diffusion, separation by chemical action and by ordinary fractional distillation, chemical exchange method, evaporation at very low pressures, separation by mass spectrometric method, separation by ionic migration, separation by electrolysis.

Reference:

Mass Spectrometry—Progress of Physics, Vol. XV.
Segre, Experimental Nuclear Physics, Vol. I, Chap. V.

Magnetic Moments and Electric Quadrupole Moments of Nuclei

1. Introduction—main features of spin, statistics and magnetic moments of nuclei.
2. Interaction of a nucleus with atomic and molecular fields: (*a*) Electrostatic interaction—expansion in multipole order; (*b*) Magnetic interaction—and expansion in different multiple orders; (*c*) Restriction on multipole orders in the free state.
3. Experimental methods of measuring nuclear spin and magnetic moments: (*a*) Hyperfine structure of optical lines of atoms; (*b*) Bandspectra; (*c*) Molecular and atomic beam non-resonance methods; (*d*) Molecular beam resonance methods; (*e*) Neutron beam resonance methods; (*f*) Nuclear resonance absorption and induction methods (Bloch and Purcell); (*g*) Microwave spectroscopy methods.
4. Absolute measurement of magnetic moments of nuclei—significance of nuclear moment values—Schmidt's charts.
5. Methods of measurements of nuclear electric quadrupole moments: (*a*) From shifts in hf-structure; (*b*) Quadrupole splitting of magnetic resonance lines in crystals; (*c*) Nuclear spin-lattice relaxation times in liquids containing the nuclei in question.
6. Significance of some electric quadrupole moment results.

Reference:

Ramsey—"Nuclear Magnetic Moments".
Saha & Das—"Nuclear Induction".

Radioactivity

1. Alpha-decay:
   (*a*) Experimental studies. Range measurement and measurement of pulse height in proportional counters; magnetic spectrometer studies.
   (*b*) Analysis of experimental results: Geiger-Nuttal relationship, fine-structure of alpha-particles and long-range alpha-particles.
   (*c*) Theoretical explanation of alpha-emission: Transmission through Coulomb barrier, Gamow theory, recent theoretical work of Preston, explanation of the mass of decaying nuclei *vs.* alpha energy curves on

the basis of nuclear-shell-structure, application of the semi-empirical mass formula to alpha-energetics and the explanation of the discrepancies therein in terms of shell-structure.

2. Beta decay:
   (*a*) Experimental studies: The different spectrometers; the effect of line-width on the measurement of continuous beta-spectra.
   (*b*) Initial difficulties in explaining the continuous spectrum and the apparent failure of the laws of conservation of energy, momentum, spin and statistics. Pauli's Neutrino-hypothesis.
   (*c*) Experimental evidence supporting the Neutrino-hypothesis. Experiments in search of neutrino. Methods of estimating the mass of neutrino.
   (*d*) Fermi theory of beta-decay and derivation of the statistical factor.
   (*e*) The beta-decay Hamiltonian.
   (*f*) Sargent's diagrams and forbidden-transitions.
   (*g*) Derivation of the shape-factors for the allowed, first and second forbidden-transitions.
   (*h*) Selection rules in beta-decay.
   (*i*) Experimental confirmation of the allowed and forbidden-transitions.
3. Gamma-decay:

   Methods of measuring gamma energies: small angle reflection; measurement of conversion lines in beta-spectrometer; absorption method; scintillation spectrometry.

   Probability of gamma emission; nuclear isomerism, half-life of meta-stable states; internal conversion.

   Interaction with matter: Photoelectric effect, Compton effect and pair production. Absorption of gamma-rays in matter.
4. Theory of angular correlation: (*i*) Gamma-gamma angular correlation, (*ii*) Beta-gamma angular correlation, (*iii*) Alpha-gamma angular correlation.
5. Indentification of nuclear energy levels from the study of decay processes —example of CO^{60}.

Reference:

Blatt and Weisskopf—"Theoretical Nuclear Physics" chapter XI, XIII.
Fermi—"Nuclear Physics".
Rosenfeld—"Nuclear Forces".
Heitler—"Quantum Theory of Radiation".

Passage of Charged Particles through Matter

General introduction: J. J. Thompson's work on communication of energy to a free electron by a passing charge; Bohr's treatment of ionisation by collision; quantum mechanical treatment of ionisation by collision; energy loss due to ionisation; application of loss formulae and their experimental verification; range energy relations for swiftly moving particles and slow particles; identification of nuclear particles by measurements in cloud chamber and photographic emulsion; single and multiple scattering of particles; capture and loss of electrons by swiftly moving charged particles; ioniation by fission fragments, emission of Cerenkov radiation by charged particles.

REFERENCE:

Fermi—"Nuclear Physics".
Segre—Experimental Nuclear Physics, Vol. I, Ch. I.

TWO PARTICLE PROBLEM

Simple theory of the deuteron: n-p scattering; comparison with experiment—non-central forces; effect of chemical binding.

p-p scattering; quadrupole moment of the deuteron; deuteron theory of Rarita and Schwinger; high energy n-p and p-p scattering.

REFERENCE:

Blatt & Weisskopf—"Theoretical Nuclear Physics", Chapter III & IV.
Bethe—Elementary Nuclear Theory.

NEUTRON PHYSICS

1. Discovery of neutrons. Mass, spin, magnetic moment and half-life of neutrons. Fundamental interaction between neutrons and other nucleons.
2. Interactions with nuclei. Types of neutron reactions. Elastic and inelastic scattering.
3. Sources of neutrons. Detectors of neutrons: foil activation method, neutron proportional counters, ionization chambers and fission chambers, scintillation detectors, photo-graphic emulsion.
4. Neutron spectroscopy: Methods of producing monochromatic neutrons. Neutron monochromators: mechanical velocity selector, time of flight velocity selectors, crystal spectrometer velocity selector. Energy measurement of monoenergetic neutrons. Slow neutron spectroscopy: Thermal neutron cross section and resonance measurements.
5. Coherent scattering with slow neutrons: Determination of coherent scattering cross sections form free atom cross sections. Neutron diffraction and structure of matter—measurement of crystal lattice structures. Determination of nuclear scattering amplitude from neutron diffraction. Spin dependent scattering.
6. Magnetic scattering and neutron polarization. Neutron transmission through magnetized iron. Diffraction from ferromagnetic crystals. Analysis of antiferromagnetic crystals. Paramagnetism. Production and study of polarized neutrons.

REFERENCE:

Huges—Pile Neutron Research.
Segre—Experimental Nuclear Physics, Vol. 2.

Nuclear Forces

A review of the evidences regarding (*i*) short range, (*ii*) exchange character, (*iii*) spin dependence, (*iv*) symmetry of nuclear forces.

Reference:

Blatt and Weisskopf—"Theoretical Nuclear Physics", Chapter III.

Theory of Nuclear Structure

1. A review of the empirical evidences regarding the nuclear properties: Uniform nuclear density, nearly constant binding energy per particle etc.
2. Saturation character of nuclear forces. Possible forms of forces which may produce the saturation character.
3. Bohr-Wheeler liquid-drop-model: proposition and application in the mass formula and explanation of fission.
4. Discovery of magic numbers and periodicity in binding energy of light nuclei.
5. Theories of shell-structure: A sketch of the theoretical problem involved in shell-structure. Enumeration of states of a configuration of identical nucleons. Wigner's super-multiplet theory and its success.
6. A review of the present situation in shell-theory. Comparative study of the L-S, j-j and intermediate coupling model.
7. Brief survey of other models.
   (*i*) Wheeler's theory of alpha-particle model.
   (*ii*) Aage Bohr's theory of coupling of collective nuclear motion with the individual particle motion.

Reference:

Blatt and Weisskopf—"Theoretical Nuclear Physics", Chapter XIV.
Rosenfeld—"Nuclear Forces".

Nuclear Reactions

1. General review of nuclear reactions; experimental background; energy relations; nomenclature.
2. Cross-sections: Geometrical limitations to the scattering and absorption cross-sections. Determination of cross-section from conditions at the nuclear surface; case of neutrons with l=O: general case of charged particles with any angular momentum.
3. The Bohr theory of formation of compound nucleus. Discussion of different excitation energy regions—resonance region and continuum. Energy levels in nuclei—level spacing and level width. Cross-section of a nuclear reaction—general formulation.
4. Continuum theory—determination of cross-section. Neutrons of zero angular momentum.

5. Transmission of nuclear particles through potential barriers.
6. Decay of compound nucleus. Detailed balance. Idea of channels; evaporation competition between different possible modes of decay.
7. Successive emission of particles; resonance theory—quantitative treatment. Derivation of Breit-Wigner equation. Resonance scattering and resonance reactions.
8. Cross-sections taking spins into account.
9. Fission reactions—cross-sections.
10. High energy reactions: Transparency of the nucleus. Nuclear cascade. Correlation among nucleons. The processes of nuclear de-excitation at high energy. Optical model.
11. Comparison with experiments at various energies. Reactions induced by neutrons, protons, alpha particles. Proton induced reactions. Deuteron reactions, Oppenheimer-Phillips reactions, stripping reactions.

REFERENCE:

Blatt and Weisskopf—Theoretical Nuclear Physics, Chapter VIII, IX, X.
Segre—Experimental Nuclear Physics, Vol. 2.

NUCLEAR FISSION

Experimental study of fission, fission cross-sections with low and high energy neutrons; identification of fission products and chemical identification of derived chains of activities; distribution of fission products in mass and charge scale. Neutrons produced in fission and their energies; delayed emission of neutrons. Theory of fission by Bohr and Wheeler; energetics and probability. Fission produced by deuterons and other particles and at high energies; spontaneous fission; fission of other elements besides U. Possibility of using fission as a source of energy; the pile.

REFERENCE:

Clarke Goodman—Nuclear Engineering.

REACTOR PHYSICS

1. Introduction: Resume of nuclear fission process.
2. Basic ideas regarding nuclear chain reaction. Multiplication factor. Four-factor formula. Resonance escape probability. Thermal utilization factor. Fast fission factor. Leakage factor. Critical size.
3. Elementary diffusion theory: Diffusion equation and its application. Diffusion length. Albedo in diffusion theory. Experimental determination of Albedo.
4. Slowing down of neutrons: Slowing down power and moderation ratio. Slowing down in various media without capture. Slowing down in various media with capture. Calculation of resonance escape probability.

Fermi Age Equation. Solution of age equation. Physical significance of age. Experimental determination.

5. Homogeneous thermal reactor without reflector. Critical equation. Approach to criticality, critical condition. Neutron balance in a thermal reactor. Reactor of various shapes: Infinite slab reactor of finite thickness, reactangular parallopiped, spherical, and finite cylindrical. Calculation of critical size and composition. Experimental determination of critical size.
6. Effect of reflector on a homogeneous reactor. Group diffusion method of Friedman, Weinberg and Wheeler. One-group theory. Two-group theory. Multigroup treatment.
7. Heterogeneous natural uranium reactors. Calculation of the various terms in the four-factor formula. Exponential experiment.
8. Time behaviour of a thermal reactor without reflector. Reactor period. Time behaviour with delayed neutrons. Diffusion equation with delayed neutrons. Reactivity.
9. Reactor Control: Temperature effects. Effects of fission products. Control rods theory. One and two group theories of control rods. Eccentric control rods. Poisoning of a reactor. Xenon poisoning. Temperature coefficients of reactivity and density. Control equipments and safety systems.
10. General reactor theory.
11. Intermediate, fast, breeder and power reactors. Theory of breeding.
12. Reactor materials—considerations in their choice.
13. Radiation hazard and reactor shielding.

Reference:

Glasstone and Edlund—The Elements of Nuclear Reactor Theory.
Soodak and Campbell—Elementary Pile Theory.
Stephenson—Introduction to Nuclear Engineering.
Murray—Introduction to Nuclear Engineering.

Applied Atomic Energy

Ordinary Energy Sources: Human and animal power, coal, oil and water power, solar power.

Definition of Energy index: Energy index as a measure of standard of living. Energy position of the world.

Problem of energy development in the world: Possibilities of nuclear energy development and its contribution to energy resources: The position in India regarding energy and the importance of atomic energy development.

The economic and technical problems of atomic energy development, efficiency of nuclear power sources: application of nuclear energy to special purposes e.g. transportation, generation of electricity, thermal and chemical utilization in industry.

By-products of generation of nuclear power: Breeding, production of artificially radioactive bodies. Utilization of breeding.

Utilization of artificial radioactivity in industry, medicine and research.

REFERENCE:

Schurr and Marschak—"Economic Aspects of Atomic Power".
Putnam—"Energy in the Future".

CHEMISTRY

1. Valency and nature of chemical bonds.
2. Periodic classification of elements and similarity of chemical properties amongst elements and radicals.
3. A general survey of the chemistry of rare elements and rare earths with special reference to elements No. 43, 61, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100.
4. Distribution of chemical elements in nature.
5. Occurrence and abundance of radio-active minerals.
6. A general study of physico-chemical principles and practice required in analytical chemistry including electrolytic determinations.
7. A short survey of perfect, imperfect and inner metallic complexes.
8. A short survey of general principles employed in ion exchange and chromatography.
9. Surface chemistry and colloid: Adsorption, general properties and preparation of colloids, radio-colloid.
10. Reversible electrode, single electrode potential, oxidation reduction potential, ionic activities, solubility product, hydrogen ion concentration, buffer solution, hydrolysis of salts.
11. A general survey on the importance of tracer technique and preparation of radio-active nuclei with special reference to some typical elements.
12. Analysis by radio-chemical methods: (*a*) Isotopic dilution method. (*b*) Analysis by activation. (*c*) Radio-metric method of analysis.
13. Chemical study associated with nuclear fission with special reference to:—

    Discovery of fission, identification of fission chains, fission yields and its importance in elucidating the mechanism of nuclear fission, chemical study of spontaneous fission.
14. Radiation Chemistry.
15. Age of minerals.

REFERENCE:

Rankama and Sahama—Geochemistry.
Friendlander and Kennedy—Introduction to Radio Chemistry.

BASIC MATHEMATHICS

1. Elements of Vector and Tensor Analysis.
2. Vectors and curvilinear co-ordinates.
   (*a*) Cartesian co-ordinates.
   (*b*) Curvilinear co-ordinates.
   (*c*) Spherical polar co-ordinates.
   (*d*) Cylindrical co-ordinates.
3. Ordinary differential equations:
   (*a*) Discussion of different types of simple differential equations, Laplace transforms.
   (*b*) Examples of integration in series—(*i*) Legendre's equation, (*ii*) Bessel's equation, (*iii*) Hermite's differential equation, (*iv*) Laguerre's differential equation, (*v*) Mathieu's differential equation.
4. Elements of complex integration—Cauchy's theorem—Taylor and Laurent's theorems.
5. Theory of orthogonal functions.
   (*a*) Gamma function.
   (*b*) Legendre polynomials and associated Legendre polinomials.
   (*c*) Bessel functions and Wankel functions.
   (*d*) Hermite polynomials and functions.
   (*e*) Laguerre polynomials and functions.
6. Partial differential equations—the wave equation and its solution.
7. Eigen-values and eigen-functions. Vibrating string, Fourier analysis and Fourier transforms.
8. Linear algebraic equations—theory of matrices and determinants.
9. Elementary theory of groups: (*a*) The abstract group. (*b*) The cyclic group. (*c*) The rotational group. (*d*) The symmetric group. (*e*) The symmetry group.
10. Elements of statistics and theory of errors. Calculus of observations—the Poisson and Gaussian distributions.
11. Calculus of finite differences.

REFERENCE:

Margenan and Murphy—"Mathematics for Physics and Chemistry".
Pipes—"Mathematics for Physicists and Engineers".

QUANTUM MECHANICS

1. Resume of classical mechanics: (*a*) Calculus of variations. (*b*) Lagrange's Principle. (*c*) Lagrange Equations of Dynamics. (*d*) Hamiltonian and Hamilton's Canonical Equations. (*e*) Contact transformation and Hamilton-Jacobi differential equation; angular momentum, top motion, transformation theory. (*f*) Poisson-bracket. (*g*) Lagrange and Hamiltonian formulation for a continuous system or field.

2. Analysis of fundamental experiments: Principles of complimentarity and uncertainty. Principle of Superposition. Need for quantum mechanics.
3. Description of physical system by vectors in a Hilbert space. Linear operators and physical observables. Eigen-values and eigen-vectors. Commutability.
4. Representations—probability amplitudes and wave-functions.
5. Commutation rules, Poisson Brackets, momentum and displacement operators, Schrodinger's momentum representations—unitary transformations.
6. Schrodinger's form for the equations of motion. Heisenberg's form for the equations of motion—the free particle—the harmonic oscillator.
7. Infinitesimal rotation operator and angular momentum operator.
8. Full treatment of the Hydrogen atom.
9. The perturbation theory (time independent) for non-degenerate and degenerate systems—the variation principle.
10. The Helium atom—the hydrogen molecule, the hyperfine structures of spectral lines, the theory of the Rabi experiment for strong, weak and intermediate fields.
11. The time-dependent perturbation theory—transition probabilities.
12. Statistics of assembly of particles (Bose-Einstein, and Fermi-Dirac).
13. Radiation theory—emission, absorption, and scattering of radiation.
14. Collision problems.
15. Relativistic Wave—Equation.
    (*a*) Necessity of covariant formulation of the wave-equation.
    (*b*) Linear Hamiltonian of Dirac and Dirac operators.
    (*c*) Plane wave solution of Dirac equation.
    (*d*) Spin and magnetic moment of the electron.
    (*e*) Approach to non-relativistic approximation.
    (*f*) Covariants constructed with Dirac operators and their physical interpretations.
    (*g*) Theory of holes: Positron.

REFERENCE:

Goldstein, Corben and Stehle—"Classical Mechanics".
Hill and Landshorf—R.M.P., Vol. 11.
Pauli—Handbuch der Physik, Vol. 24-1A.
Dirac—"Quantum Mechanics".
Condon and Shortley—"Theory of Atomic Spectra", Chapter 3.
Mott and Massey—"Theory of Atomic Collisions".

APPARATUS AND MACHINERY

HIGH ENERGY ACCELERATORS

1. Need for high energy accelerators.
2. Generation of High Voltage: (*a*) Cockroft Walton Generator, (*b*) Cascade transformer, (*c*) The Van-de-Graff Generator.

3. Acceleration of ions by D. C. Voltages: (*a*) Design of acceleration tube, (*b*) Design of ion sources.
4. Cyclic accelerator. Acceleration of ions to high energies without very high voltages: (*a*) Acceleration by electric-field; linear accelerator of Sloan and Lawrance—Cyclotron, design focussing of beams—limitations. (*b*) Frequency modulated Cyclotron. (*c*) Induction accelerator: Betatron-design focussing of beams—limitations. (*d*) Synchrotrons. (*e*) Bevatrons—principle and design.
5. Linear accelerators—electron and proton accelerators.
6. Engineering problems in the design of accelerators.

REFERENCE:

Selected articles from Medical Physics by Otto Glasser.
"Accerteration of Particles to High Energy"—Published by Institute of Physics, London.
Livingston—High Energy Accelerators.

NUCLEAR DETECTORS.

1. Fundamental principles of particle detection. Motion of ions and electrons through gases; detectors based on them. Detectors using motion of ions through liquids and solids.
2. Ionization chambers: Ionization current and ionization pulses. The dependance of ionization pulses on the shape of the ionization chamber. Use of ionization chambers.
3. Geiger Müller counter: General characteristics. Non-self-quenching and self-quenching counters. The propagation of discharge in self-quenching counters. Dead time and recovery time. Efficiency of G. M. counters. Wire counters for alpha detection.
4. Proportional counters: Gas multiplication. Pulse shapes. The use of proportional counters.
5. Scintillation counters: Production of scintillation. Types of Phosphor. Detection of scintillation. Photo-multipliers. Efficiency of scintillation counters. Speed of scintillation counters. Liquid scintillation counters.
6. Cloud chambers: Fundamental principles, design considerations, illumination and photographing of tracks. Magnetic field for cloud chambers. High pressure and low pressure chambers. Diffusion chambers.
7. Photographic plate technique: Response of different photographic emulsions. Grain counting, range and other parameters. Range-energy relation. Use and limitations of the method.
8. Cerenkov detectors.
9. Crystal detectors.
10. Suitability of a detector for the different ionising particles. Criterion for selection.
11. Errors involved in counter data and methods to correct them.
12. The coincidence method.

13. The angular correlation measurements.
14. The delayed coincidence measurements.

REFERENCE:

Segrè—"Experimental Nuclear Physics".
Bleuler and Goldsmith—"Experimental Nucleonics".
Curran and Craggs—Counting tubes.
Curran—Luminescence and the Scintillation counter.
Birks—Scintillation counters.

ELECTRONICS

Preliminary Course:

1. Introduction: Construction of vacuum tubes, Richardson's equation, Child-Langmuir Law; deviations from Child's Law; characteristic curves for triode, tetrode, pentode and other tubes.
2. Introduction to circuit technique: amplifiers, amplifiers in cascade, feed back amplifier, oscillator. Relaxation oscillators, plate coupled multivibrator, cathode coupled multivibrator, trigger multivibrator. Coincidence circuit. Trigger circuits, linear amplifiers, scalers.
3. Power packs, stabilised power supplies.

Advanced Course:

1. Types of circuit elements: Linear elements. (*a*) Resistive, (*b*) R-C, (*c*) L-C, (*d*) R.L.C.
   Differentiating and integrating circuits: Counting rate-meters. Delay lines, lumped and distributed delays.
2. Amplifiers: Band width (rise time), delay, linearity, resolution (low frequency characteristic), considerations of signal to noise ratio.
3. (*a*) Resistance-capacitance coupled amplifiers: High frequency and low frequency considerations, clipping time constant, delay line clipping, feed-back principles.
3. (*b*) Shunt compensated amplifiers: Under, over and critically compensated amplifiers, advantages and disadvantages with R-C coupled amplifiers. Other type of voltage amplifiers and distributed amplifiers.
4. Current amplifiers: Electrometers and other devices, Cathode follower: Impedance matching, power delivery.
5. Use of amplifiers in nuclear particle detection: Design consideration as regards types of detectors, detector rise time, signal to noise ratio, resolution etc., as they affect the choice of the amplifier characteristic.
6. Oscillators: Simple oscillators R-C, L-C. Relaxation oscillators. (*a*) Thyratron relaxation oscillators. (*b*) Multivibrators: (*i*) monostable, (*ii*) bistable, (*iii*) astable. (*c*) Blocking oscillators.
7. Trigger Circuits: (*a*) Thyratron. (*b*) Multivibrators. (*c*) Blocking oscillators.

8. Miscellaneous circuit elements: Gates, clamp, mixer, coincidence, anti-coincidence and various delay devices.
9. Voltage discriminators: Necessity of non-linear elements; Different types of voltage discriminators: (*a*) diode, (*b*) Schmidtt, (*c*) biased amplifiers, (*d*) beam deflection tubes. Differential discriminators: principles and advantages. Scaling circuits. Frequency division (dekatrons).
10. Time Selectors: Rossi circuit, diode bridge, pentode selectors, slow and fast coincidences. Delay discriminators.
11. Pulse Generator: Square wave, triangular, saw tooth and other types. Fast pulse generators, current pulses, application to accelerators. High voltage pulses applied to photomultipliers, radar, linear accelerators etc.
12. Oscillascopes and standard signal generator; V.T.V.M., Q-meter; impedance bridge; frequency meter.

REFERENCE:

Elmore and Sands—"Electronic Experimental Techniques".
Chance and others—"Wave form".
Valley and Wallman—"Vacuum tube amplifiers".
Lewis and Wells—"Millimicrosecond Pulse Technique".

HIGH VACUUM TECHNOLOGY

1. Some salient features in knietic theory of gases. Pressure and temperature; mean free path, viscosity and thermal conductivity; effusion and thermal transpiration.
2. Units used in vacuum engineering and their conversion table.
3. Flow of gases through tubes and orifices: (*a*) Viscous flow resistance; Poisseuille regime; pressure range—upper and lower limit. (*b*) Free molecular flow conductance—Knudsen regime; pressure range. Various aperture and types of tubes. (*c*) Combined viscous and free molecular flow conductance.
4. Production of high vacuum: (*a*) Types and properties of mechanical pump. (*b*) Diffusion pump—Principle of operation choice of working fluid —multistage fractionating and booster pumps. (*c*) Measurement of pumping speed and throughput. (*d*) Ion pumps. (*e*) Electromagnetic flow pumps.
5. Measurement of vacuum:
   (*a*) Theory and properties of McLeod, Pirani, thermocouple, hot and cold cathode ionisation gauge, Knudsen and radioactive gauges.
   (*b*) The pressure ranges and uses of the gauges.
6. Design of high vacuum system:
   (*a*) Overlapping pressure ranges of operation—mechanical or diffusion type.
   (*b*) Permanent gas or vapour—degassing of system.
   (*c*) Refrigerated traps—its pumping speed, dynamic and static equilibrium vapour pressures.

(*d*) Choice of pump speeds—selection of types and capacity of pumps—pumping down time.
(*e*) Size of pump line.
(*f*) Vacuum accessories—components for extremely high vacuum.

7. Theory of leak detection: (*a*) High side detection, (*b*) Backing space detection, (*c*) Response and clean up time. Methods of leak detection: Spark coil, discharge tube, rate of rise measurements, over vacuum, high pressure, partial vacuum and soap solution, sealing substance and change of pressure, probe gas system—change in pressure or in nature of gas; pump outs, vacuum analyser, Helium leak detector.
8. Glass to metal seal: Types and properties of glass. Annealing and strain measurements. Types of glass to metal seal and methods of production.
9. Application of high vacuum technology to Nuclear Physics and industries: (*a*) Cyclotron, synchrocyclotron, electron-microscope, mass spectrometer, gaseous diffusion plants etc. (*b*) Valve production. (*c*) Optical industry. (*d*) Vacuum metallurgy.

REFERENCE:

Dushman—"Fundamental of Vacuum Technique".
Guthrie and Wakerling—Vacuum Equipment and Technique.

HEALTH PHYSICS

1. Elementary characteristics of biological materials. Biological effect of radiation; blood changes due to irradiation.
2. Units of radiation dossage and methods of measuring dosage.
3. Common radiation hazards: Chronic radium poisoning, Leukemia in radiologists, Lung cancer by radon inhalation, etc.
4. Occupational safe dosage-rate, maximum permissible dosage rate, lethal dose.
5. Personnel monitering: Film badge, pocket ionisation chamber dosimeters.

REFERENCE:

The Science and Engineering of Nuclear Power, Vol. II, by C. Goodman.

SYLLABUS FOR PRACTICAL COURSE

(The number of experiments to be performed will be specified later)

PRELIMINARY PRACTICAL COURSE — First Term—July to September 15

1. Workshop practice:

Knowledge of types of machines; operating on lathe, drill, milling and shapping machines; design, drawing and fabrication of an apparatus; bench work—soldering and brazing; acquaintance with different tools and their uses; knowledge of the materials used in fabricating the instruments.

2. Glass blowing:

Testing the quality of glass; glass joints; tungsten seals; fabrication of Geiger counters; glass to metal seal.

3. Vacuum practice:

Knowledge of mechanical pumps, diffusion pumps, baffles, vacuum gauges, vacuum materials, gaskets, wilson seals, and methods of leak testing.

4. Electronic techniques and lay outs :

Valve characteristics; construction and testing of simple electronic circuits; fault finding and repair; use of testing equipments.

5. Counter filling and testing :

Proportional counters and Geiger counters; measurement of deadtime and recovery-time; construction of boron coated counters.

6. Dosage measurements:

Film badge service, moniter dosimeters, blood counts.

7. Preliminary experiments in nuclear physics:

(Students with Nuclear Physics special paper in M.Sc. are exempted).

(*a*) Measuring the range of alpha particles from Ra-C bodies in a Wilson Cloud Chamber, and comparing the same with alpha particles of Po.

(*b*) Measurement of the mass absorption coefficient for gamma ray in aluminium.

(*c*) Measurement of the effective length of a Geiger counter and the efficiency of gamma detection.

(*d*) Measurements of the vertical intensities of cosmic rays and the ratio of hard to soft components.

(*e*) Measurements of the end-point-energy of the beta rays from a given beta-emitter by preparing a Feather analyser.

ADVANCED PRACTICAL COURSE — Second Term—October to Jan. 15

1. Determination of counting losses by extrapolation of known decay curve.
2. Resolution of a complex decay curve.
3. Absolute beta—counting by defined solid angle.
4. Growth and decay phenomena, approach to secular equilibrium.
5. To examine the filial relation of Br^{80} nuclear isomers.
6. Determination of self-absorption correction.
7. Analysis by isotopic Dilution.
8. Szilard chambers effect of aniline on extraction rates (I^{128}).
9. Separations by precipipation:

(*a*) Separation of RaD and RaE from an old radon tube and study the growth of RaE from pure RaD and decay of RaE.

(*b*) To separate La^{140} (40 hours) from a mixture of its parent Ba^{140} (12.8 d) and study the growth and decay phenomena.

10. To determine the solubility of PbI_2 in water. (I^{131}).

11. Measurement of mean range and extrapolated range of alpha particles from Po source using an ionisation chamber.
12. Preparation of a zinc-sulphide phosphor for alpha ray counting with a 931A (RCA) photomultiplier tube. Measurement of alpha activity in minerals.
13. Measurement of pulse height distribution of Co^{60} γ-rays using scintillation counters with thallium-activated sodium-iodide phosphor.
14. Measurement of proton tracks in nuclear emulsion plates.
15. Plotting of coincidence—delay curve with gamma gamma delayed coincidence arrangement using Co^{60} source. Measurement of genuine to random ratio, resolving time of the circuits, source strength, and phosphor efficiency.
16. Measurement of thermal to epithermal neutron ratio from a howitzer using boron-coated counter.
17. Detection of fast neutrons with Hornyk Buttons and scintillation counters..
18. Measurement of slow neutrons spatial distribution with a neutron howitzer using Eu-activated LiI phosphor.
19. Measurement of beta-ray spectrum in a 180° beta-ray spectrometer.

APPENDIX V

CALCUTTA UNIVERSITY

Syllabus for M.Sc. Degree in Pure Physics : Nuclear Physics and Cosmic Radiation (Elementary)

1. Introduction: accurate determination of nuclear mass; mass defect as a measure of the energy of nuclear reaction (Einstein's law of equivalence of mass and energy); constituents of nuclei; discovery of the neutron and its characteristics (mass, spin and statistics).

2. Experimental results on scattering of α-particles by light elements; failure of inverse square law, idea of potential barrier; radioactive disintegration, fine structure of α-rays; energy levels of α-rays within the nucleus; origin of γ-rays; methods of measuring their wavelength; (γ-ray spectra of nuclei).

3. Study of β-rays; internal conversion of γ-rays; nuclear β-rays; Sargent's relations; problem of continuous β-ray spectra and the neutrino hypothesis.

4. Technique of nuclear physics; high voltage generators; the cyclotron; measuring apparatus (Wilson chamber, electrometers and Geiger counters).

5. Elementary ideas about penetration of the nucleus by charged particles and neutrons; different types of nuclear reactions; creation of artificial radioactive nuclei and transmutation of elements; fission of heavy nuclei.

6. Cosmic rays; discovery, variation of cosmic ray intensity with height, proof of cosmic origin, corpuscular nature of cosmic rays; variation of intensity with latitude, shower production.

7. Law of absorption of electromagnetic radiation by matter; Compton absorption; Klein-Nishina formula; pair production.

8. Ionisation by charged particles; Wilson chamber photographs.

9. Discovery of meson; its properties.

CALCUTTA UNIVERSITY

Syllabus for M.Sc. Degree in Physics : Nuclear Physics and Cosmic Radiation (Advanced)

(The course is in addition to the compulsory part included in Paper IV which has to be read more thoroughly.)

1. Mass spectrograph of Aston, Bainbridge and others, and accurate determination of mass; resolving power and focussing properties of mass spectrographs; methods for separation of isotopes; applications of mass spectroscope in other fields, geology and chemistry.

2. Method of determining spin, magnetic moment, statistics of elementary particles, and of nuclei (Rabi, Bloch and Purcell), hyperfine structure of spectral lines ; band spectra ; polarisation of resonance radiation ; quadrupole moment of nuclei.

3. Technique of experimental study of the nucleus ; apparatus for producing high energy particles, particularly the cyclotron, ways of using the Wilson chamber for measuring energy of particles and specific ionisation produced by them ; Geiger counter circuits (coincidence and anticoincidence methods), counter controlled Wilson chamber and stereographic photographs of cosmic particles ; use of electrometers ; ionisation chambers and radiometeorographs ; proportional counters and oscillographs.

4. Fuller study of theories of radioactive disintegration with special application to the origin of α-rays ; penetration of nuclei by charged particles.

5. Introduction to the theories of formation of nuclei out of protons and neutrons ; stability of the nucleus ; the nature of nuclear forces, theory of β-ray disintegration and the inverse process ; proton-proton and proton-neutron exchange forces (experiments on scattering).

6. Theories of nuclear collisions ; Bohr's theory of compound nucleus, theories of dispersion, cross section for capture, particle emission and quantum emission ; dipode and quadruple radiation ; nuclear iosmerism.

7. Theory of fission of heavy nuclei. Nuclear Reactors.

8. Theory of ionisation loss and radiation loss of fast elementary charged particles in passage through matter ; variation of the energy-loss with the mass and energy of the particle ; energy loss due to other causes.

9. Application of the theory of ionisation and radiation loss to experimental results ; apparent failure of the theory in the case of high energy cosmic ray particles ; discovery of the meson ; characteristics of meson ; its charge, mass, spontaneous radioactivity, evidences of its instability ; ionisation showers.

10. Theory of fundamental particles

11. Theory of formation of cascade showers by electrons (Heitler, Bhabha, Oppenheimer) ; work of Millikan, Bowen and Neher and Regener ; method of Gross analysis.

12. Theories of the origin of cosmic rays ; introduction to theories of stormer and Lemaitre and Vallarta, latitude effect and east west asymmetry ; recent hypothesis regarding the nature of primary cosmic radiation.

13. Application of the knowledge of nuclear physics to molecular biology, to astrophysics, and to other subjects.

Syllabus of Practical work in Nuclear Physics for M.Sc.

1. Ionisation chamber and electrometer. Range of β-rays in Aluminium ; Feather's relation.

2. Wilson cloud chamber-range of α-rays in air, corrections.

3. G. M. counter characteristic curve. Plateau, efficiency of a counter for given γ-rays. Statistics of counter observations.

4. Mass absorption coeff. of γ-rays in lead (or Al) using counters, and measuremeant of energy of γ-rays.

5. β-ray counter (thin window).—Energy of β-rays by Feather's method, corrections for window, efficiency of a β-counter.

6. Vertical component of cosmic radiation of Calcutta by coincident counting.

APPENDIX VI

LIST OF PUBLICATIONS FOR THE PERIOD 1948-55

(Excluding Biophysics Division)

1948

1. B. M. BANERJEE: On the Variation of A. C. Permeability of Transformer Sheet Steel with D. C. Magnetisation. India J. Phys. *22,* 265 (1948).
2. B. M. BANERJEE: Linear Time Base Using OA4G Tube. Rev. Sci. Instrum. *19,* 84 (1948).
3. B. M. BANERJEE & S. K. SEN: Concerning the Use of a 920 Double Photocell in Current Amplifier and Stabiliser. Indian J. Phys. *22,* 43 (1948).
4. P. C. BHATTACHARYYA: Experiments on the Separation of Low Energy Mesotrons from Electrons. Phys. Rev. *74,* 38 (1948).
5. S. BISWAS & A. MUKHERJEE: Nuclear Energetics and β-activity (Part III). Indian J. Phys. *22,* 80 (1948).
6. S. BISWAS & A. P. PATRO: Application of Gamow's Theory of α-emission to $(4n+1)$ Radioactive Series. Indian J. Phys. *22,* 539 (1948).
7. S. DAS: Delayed Neutrons. Nature. *162,* 853 (1948).
8. S. DAS & A. MUKHERJEE: Coincidence Experiments on 5.3yCO^{60}. Indian J. Phys. *22,* 311 (1948).
9. N. N. DAS GUPTA & A. K. CHAUDHURY: Study of RaE β-spectrum from Absorption Measurements. Indian J. Phys. *22,* 27 (1948).
10. B. C. PURKAYASTHA: Fission of Atomic Nuclei (Part I). Nucleonics. *3,* Nov. 2 (1948).
11. B. C. PURKAYASTHA: Complementary Series and Conjugate Fragments in U-Fission. Sci. & Cult. *13,* 255 (1948).
12. B. C. PURKAYASTHA: Fission of Atomic Nuclei (Part II). Nucleonics. *3,* Dec. 2, (1948).
13. A. K. SAHA, S. GHOSHAL & S. DAS: Nuclear Energetics and β-activity (Part II). Trans. Nat. Inst. Sci. India. *3,* 1 (1948).

1949

1. S. BISWAS: On the Geiger-Nuttal Relationship. Indian J. Phys. *23,* 51 (1949).
2. S. BISWAS & A. P. PATRO: Fission Cross-Section of U^{235}. Indian J. Phys. 23, 97 (1949).
3. U. C. GUHA: Analysis of Virtual Height-Frequency Records. J. Geophys. Res. *54,* 355 (1949).

4. B. D. Nag, S. K. Sen & S. Chatterjee: A Short-Lived Metastable State in Titanium (46). Nature. *164,* 1001 (1949).

1950

1. B. M. Banerjee: Study of Switching Action of a Multi-Vibrator Circuit (Part I). Indian J. Phys. *24,* 361 (1950).
2. B. M. Banerjee & R. Roy: Time-base Circuit for a High-Precision Ionospheric Sounding Equipment. Indian J. Phys. *24,* 411 (1950).
3. S. Chatterjee & S. Dhar: Scintillation Type α-Counter and its Application in U- and Th-Estimation of Minerals. Indian J. Phys. *24,* 346 (1950).
4. R. K. Das: On the Automatic Pressure-Stabilising Device for a Diaphragm-Type Wilson Chamber. Indian J. Phys. *24,* 465 (1950).
5. R. K. Das: A Triggering Device for Arc Discharge Lamps in Cloud Chamber Photography. Indian J. Phys. *24,* 497 (1950).
6. R. K. Das: On α-disintegration (Part I). Indian J. Phys. *24,* 523 (1950).
7. R. K. Das: On the Erratic Performance of Gas Filled Discharge lamps: a Device to Counteract its Effects in Cloud Chamber Photograph. Sci. & Cult. *16,* 167 (1950).
8. S. Dutta Mazumdar & D. C. Chowdhury: Wave-Function for the Ground State of Lithium. Z. Phys. *128,* 455 (1950).
9. B. D. Nag, S. K. Sen & S. Chatterjee: Effect of Time-Lag in the Measurement of Delayed Coincidences with G. M. Counters. Indian J. Phys. *24,* 261 (1950).
10. B. D. Nag, S. K. Sen & S. Chatterjee: On the Disintegration of Scandium (46) and the Method of Delayed Coincidence for the Study of Short-lived Metastable States in Isomeric Nuclei. Indian J. Phys. *24,* 479 (1950).

1951

1. B. M. Banerjee: Study of Switching Action of a Multivibrator Circuit (Part II). Indian J. Phys. *25,* 329 (1951).
2. R. K. Das: On an Automatic Wilson Cloud Chamber in a Magntic Field and Some Associated Techniques. Indian J. Phys. *25,* 481 (1951).
3. S. Das & S. K. Sen: On the Angular Correlation between Successive γ-rays in Co^{60}—Ni^{60} Transitions. Indian J. Phys. *25,* 451 (1951).
4. U. C. Guha: Reversal of Polarisation of Microwaves from Sun Spots. Indian J. Phys. *25,* 9 (1951).
5. M. N. Saha: Occurrence of Stripped Nuclei of Neon in Primary Cosmic Rays. Nature, *167,* 476 (1951).
6. M. N. Saha, B. K. Banerjee & U. C. Guha: Vertical Propagation of Electromagnetic Waves in the Ionosphere. Proc. Nat. Inst. Sci. India. *17,* 205 (1951).

1952

1. B. M. Banerjee & R. Roy: A High Precision Ionospheric Sounding Equipment. Indian J. Phys. *26*, 473 (1952).
2. B. M. Banerjee & R. Roy: A High Precision Ionospheric Sounding Equipment. Sci. & Cult., *17*, 305 (1952).
3. B. K. Bhattacharyya: Admittance and Transfer Function of a Multi-mesh Resistance Capacitance Filter Network. Indian J. Phys. *26*, 563 (1952).
4. Sunil Kumar Sen & Bimal Krishna Bhattacharyya: A Study on the Triggering of a Plate Coupled Multivibrator by Negative Pulses. Indian J. Phys. *26*, 597 (1952).

1953

1. M. K. Banerjee & A. K. Saha: Investigations on a Short Magnetic Lens Spectrometer. Proc. Phys. Soc. Lond. B *66*, 937 (1953).
2. B. K. Bhattacharyya: Effect of Steepness of Pulse Fronts on the Response of Differentiating and Integrating Circuits. Indian J. Phys. *27*, 269 (1953).
3. B. K. Bhattacharyya: On the Faithful Reproduction of the Flat Top of a Pulse in a High Fidelity Pulse Amplifier (Part I). Indian J. Phys. *27*, 39 (1953).
4. B. K. Bhattacharyya: On the Faithful Reproduction of the Flat Top of a Pulse in a High Fidelity Pulse Amplifier (Part II). Indian J. Phys. *27*, 565 (1953).
5. Santimay Chatterjee & Ajit Kumar Saha: γ-γ Angular Correlation Measurements. Phys. Rev. *91*, 200 (1953).
6. Santimay Chatterjee & Ajit Kumar Saha: Eine Analyse des Winkel Korrelations experimentes mit einem Bericht derartiger Messungen am Ni^{60}. Z. Phys. *135*, 141 (1953).
7. Sobhana Dhar & Sunil Kumar Sen: On the Use of the Scintillation Counter as a Gamma ray Spectrometer, using Stilbene Crystal. Indian J. Phys. *27*, 483 (1953).
8. S. K. Mukherjee & P. K. Dutt: On the Large-Load Characteristics of Vapour Pumps. Indian J. Phys. *27*, 137 (1953).
9. R. Roy & J. K. D. Verma: Irregularities in the Ionosphere. J. Geophys. A, *224*, 472 (1954).

1954

1. B. M. Banerjee: A Reactance Tube Controlled Oscillator of Unusually Wide Frequency Sweep. Indian J. Phys. *28*, 67 (1954).
2. M. K. Banerjee & A. K. Saha: Shape Factor for Beta-decay. Proc. Roy. Soc. A, *224*, 472 (1954).
3. M. K. Banerjee, T. P. Das & A. K. Saha: Effect of Chemical Shift and J-coupling on Nuclear Resonance Line-shape. Proc. Roy. Soc. A, 226 490 (1954).

4. B. K. Bhattacharyya: Effect of Steepness of Rise and Fall of the Input Pulse on the Response of Pulse Amplifiers. (Part I). Indian J. Phys. *28,* 31 (1954).
5. B. K. Bhattacharyya: Effect of Steepness of Rise and Fall of Input Pulse on Response of Pulse Amplifiers (Part II). Indian J. Phys. *28,* 371 (1954).
6. Santimay Chatterjee, A. P. Patro, Binayak Basu, R. L. Bhattacharyya and Fazle Hosain: Presence of Radioactive Dusts over Calcutta. Sci. & Cult. *19,* 570 (1954).
7. T. P. Das & D. K. Roy: Preliminary Results with Purcell's Bridge-technique of Nuclear Resonance. Sci. & Cult. *19,* 464 (1954).
8. T. P. Das & A. K. Saha: Mathematical Analysis of the Hahn Spin-Echo Experiment. Phys. Rev. *93,* 749 (1954).
9. P. K. Dutt: A Demountable All Metal Hot-cathode Vacuum Ionization Gauge. Indian J. Phys. *28,* 1 (1954).
10. R. K. Verma, G. N. Sarkar and S. Chatterjee: An Automatic Verneuil Furnace J. Sci. Industr. Res., *13A,* 516 (1954).

1955 (Upto April, 30)

1. T. P. Das & D. K. Roy: Spin Echo with Four Pulses—an Extension to n Pulses. Phys. Rev. (In Press).
2. T. P. Das & D. K. Roy: Spin Echo in Non-axially Symmatric Crystals. Proc. Roy. Soc., A (In Press).
3. T. P. Das & A. K. Saha: Spin-Echo with Quadrupole Interaction in Crystals. Phys. Rev. (In Press).
4. T. P. Das & A. K. Saha: Monograph on Nuclear Induction (In Press).
5. T. P. Das, A. K. Saha & D. K. Roy: Quantum Mechanical Analysis of Spin Echo Phenomena. Proc. Roy. Soc., A., *227,* 407 (1955).
6. S. Chatterjee: Radioactive Ashes over Calcutta and a Method of Dating a Nuclear Explosion (Atomic Scient. Jour. In Press).
7. Santimay Chatterjee, A. P. Patro, Binayak Basu, R. L. Bhattacharyya and Fazle Hosain: Measurements on Radioactive Dusts over Calcutta. Sci. & Cult. *20,* 399 (1955).
8. Santimay Chatterjee, A. P. Patro, Binayak Basu, R. L. Bhattacharyya and Manoj Kanti Banerjee: Dating a Nuclear Explosion. Sci. & Cult. *20,* 403 (1955).
9. S. N. Ghoshal & A. N. Saxena: Beta Energetics and Nuclear Shell Structure. Indian J. Phys. (In Press).

APPENDIX VII

EXTRACTS FROM DELHI MEETINGS

Department of Atomic Energy

I. Meetings were held on 21st March, 1955 at 12-00 noon in the External Affairs Conference Room and again at 2-30 P.M. in the Council of Scientific and Industrial Research Committee Room. The following were present:

1. Dr. H. J. Bhabha.
2. Prof. M. L. E. Oliphant (in invitation).
3. Dr. K. S. Krishnan (attended in the morning).
4. Dr. M. N. Saha.
5. Dr. J. C. Ghosh.
6. Dr. B. D. Nag Chaudhuri (attended in the morning).
7. Shri C. S. Menon.
8. Shri N. K. Dravid.

The Five Year Plan of the Institute as finally revised and sent by Dr. Saha with his letter to Dr. Bhabha of the 14th March, 1955 was considered. Prof. Oliphant suggested that the Department of Atomic Energy should perhaps concern itself with grants in regard to special projects appropriate to its sphere leaving the general basic education in physics including basic nuclear physics to be looked after by Universities with their normal resources. Dr. Bhabha agreed with this view. Dr. Ghosh pointed out that Universities possessed inadequate funds for promoting significant scientific education and neither the University Grants Commission nor the State Governments were likely to afford appreciable assistance. He, therefore, urged the specialised agency of the Department of Atomic Energy to finance and promote advance in nuclear physics. Dr. Bhabha pointed out that there were numerous other important scientific fields in addition to nuclear physics and a balanced advance in all fields was desirable, so far as basic education in Universities was concerned. Shri C. S. Menon mentioned that funds had to come from the general revenues of Government, whether the Department of Atomic Energy disbursed them or the University Grants Commission. The proper course, according to Shri Menon was, to leave the specialised agencies with the function of administering grants-in-aid for the special work and to take up the question of funds for basic education in Universities separately with the Governments concerned and also with the University Grants Commission. Since the University education was a matter of high policy for the decision of Government, the Department should confine attention to research in nuclear physics in relation to its special sphere.

2. The Five Year Plan of the Institute was then considered and the following conclusions were agreed to:

(a) *Accelerator Division:* The proposal to put in a focussing additional magnet in the existing cyclotron was accepted. As regards the electron synchrotron, Prof. Oliphant pointed out that if an energy of 200 Mev. was to be attained, the cost would be very high (2 or 3 times the amount estimated) and the construction would take much too long for any useful experiments to be carried out in the next five years. It was agreed to design the synchrotron with a capacity upto 50 Mev. and the estimated cost of Rs. 10 lakhs was considered adequate. The estimate was inclusive of salaries of staff—scientific and other. The special staff considered adequate was two physicists, one in the Reader's grade—Rs. 500—750, the other in the grade Rs. 250—500, and one good technical engineer in the grade Rs. 250—500. The synchrotron should be completed and ready at the end of four years or at the most five years.

(b) *Nuclear Physics Division:* The programme was accepted, but as regards additional posts of Professors, etc. asked for, it was agreed that the number should be fixed for the Institute as a whole and the posts should be allocated to whatever section had the need and the qualified personnel.

(c) *Instrumentation:* It was agreed that a division was not needed, since all research workers would partake in the construction of instruments. What was needed was some design staff. There already exist one Reader and one Lecturer for the purpose. . . . .

(d) *Teaching work:* . . . .

No division as such was necessary, but the need was accepted for one Reader, who would be in overall charge of and co-ordinate the teaching work by research workers. In addition, two lecturers for demonstrating the laboratory work were also agreed to but these would also be expected to do research.

(e) *Nuclear Chemistry:* It was pointed out that the correct nomenclature would be "Radio Chemistry". The work of this section would be auxiliary to the other sections. There already exist one Reader and one Lecturer and only one or two Assistants may be given.

(f) *Neutron Physics:* It was agreed that there was no need for a separate division, since the subject matter formed part of the general nuclear programme of the Institute. As regards the scheme under Dr. Ghoshal, who is holding the chair of Reader, it was agreed to give him two Research Assistants. The work of this section would be fitted in with the general plan of the Institute's work. A small cascade generator was under construction as a neutron source and no extra funds were needed.

(g) *Mass Spectroscopy:* The proposal to build one Mass Spectroscope (for higher range) was accepted, but no separate division was needed, since the work fell under general nuclear programme of the Institute. The staff of one Lecturer and two Research Assistants was agreed to.

(h) *Cosmic Ray*: Work was in hard at Darjeeling under Dr. Bhattacharya of the Calcutta University. This may be first examined by the Cosmic Ray Research Committee.

II. The meeting to discuss the Five Year Plan of the Institute of Nuclear Physics continued at 4-00 P.M. on the 22nd March, 1955 in the room of Shri C. S. Menon, Joint Secretary, Ministry of Finance. The following were present:

1. Dr. H. J. Bhabha.
2. Dr. M. N. Saha.
3. Dr. J. C. Ghosh.
4. Shri N. K. Dravid.
5. Shri C. S. Menon.
6. Dr. B. D. Nag Chaudhuri.

It was decided that the details of funds required for the next 5 years should now be worked out in the light of the decisions as to the programme and staff already arrived at. For this purpose, Dr. Nag Chaudhuri was requested to obtain full details showing the present personnel—scientific and other—and their actual emoluments together with the existing pay scales and proposed pay scales. The information would be sent to the Department of Atomic Energy at Bombay as soon as possible. It would be examined by the Department promptly and then Dr. Nag Chaudhuri would be requested to come to Bombay to work out and settle the final details for the purpose of fixing the amount of the grant. The recurring expenditure for equipment, materials, contingencies, etc., and the expenditure on administration, library and workshop would be examined in the light of the programme sanctioned and also having regard to the pattern obtaining in the Tata Institute of Fundamental Research.

2. Dr. Saha and Dr. Ghosh desired that the number of Professors in the Institute should be raised from the existing one to at least three. Dr. Bhabha stated that this would depend on the rest of the structure and that the best consideration would be accorded in the matter of adding a professorship or two.

3. Dr. Bhabha suggested that for purposes of providing elbow room in the general staff structure for expansion in the later part of the 5 year period, a small cushion in the grant might be added. Shri Menon desired to know the need for this when the whole programme and staff had already been gone into. It was explained that some room for adjustment and expansion would be necessary. Shri Menon asked whether the Finance Ministry would be represented on the Governing Body of the Institute, seeing that large sums were now being given as grants-in-aid from the Central Government. It was agreed that since the Natural Resources and Scientific Research Ministry would no longer be making a separate grant-in-aid to the Institute, a representative of that Ministry, who is now on the Governing Body, may be replaced by a representative of the Finance Ministry. Dr. Saha stated that the Institute's Constitution would have to be amended and to achieve this, the consent of the Calcutta University and the Government of India is required. Such consent was, however, easily obtained,

since the proposal was acceptable to Dr. Ghosh, Vice-Chancellor of the Calcutta University and the Government of India representatives present in the meeting. On the assurance that the Finance Ministry would have a representative on the Governing Body of the Institute to ensure that specific expenditure on expansion, when the time came for it, was scrutinised, Shri Menon had no objection to providing a small cushion in the grant as proposed. The exact figure would be settled after the main figure for the grant was worked out in consultation with the Ministry of Finance in due course.

4. Shri Menon advised that the Department of Atomic Energy should keep the Planning Commission informed of the 5 year grant-in-aid proposal to the Institute, when finalised.

APPENDIX VIII

List of Members of the Staff who have been awarded medals of distinction, research degrees, studentships, foreign travelling fellowships etc., during the period 1949-55

Mowat Gold Medal:

(1951)	Dr. A. K. Saha, D.Sc.

Premchand Roychand Studentship:

(1951)	Sri M. L. De.
(1951)	Sm. S. Dhar.
(1953)	Dr. S. Chatterjee, D.Phil.

D.Phil. (Science):

(1949)	Sri S. Biswas.
(1950)	„ S. K. Sen.
(1951)	„ S. Chatterjee.
(1951)	„ R. K. Das.
(1953)	„ S. K. Ghosh.
(1953)	„ A. Guha.

Submitted thesis for D.Phil. (Science):

(1954)	Sri B. K. Bhattacharyya.
(1954)	Sri T. P. Das.
(1955)	Sri A. P. Patro.
(1955)	Sri M. K. Banerjee.
(1955)	Sm. S. Dhar.
(1955) D.Sc.	Sri R. Roy.

Travelling Fellowships:

Commonwealth Fellowship to Australia (1950)	Dr. S. Biswas, D.Phil.
Palit Travelling Fellowship to Durham, U.K. (1950)	Sri B. C. Purkayastha.
Palit Travelling Fellowship to London, U.K. (1953)	Dr. A. Guha, D.Phil.
West Bengal State Scholarship to Liverpool, U.K. (1952)	Dr. S. K. Sen, D.Phil.

West Bengal State Scholarship to Princeton, N.J., U.S.A. (1955)	Sri M. K. Banerjee.
Norwegian Cultural Scholarship to Kjeller, Norway (1955)	Sri A. P. Patro.
Post-Doctorate Fellowship at Cornell University, U.S.A.	Sri T. P. Das.
Ghosh Travelling Fellowship to U.K. (1955)	Dr. B. B. Sen, M.Sc., M.B., B.S.
Research Assistantship at the University of California, Berkeley, Calif. (1954) ...	Sri S. B. Nandi.
Research Associate at the University of Maryland, U.S.A. (1955)	Sri R. Roy.

APPENDIX IX

List of students who have been admitted to the Associateship of the Institute of Nuclear Physics

1953-54 SESSION.

1. Srimati Uma Banerjee (nee Basu Roy), M.Sc.
2. Sri Rangalal Bhattacharyya, M.Sc.
3. Sri Anil Chandra Chatterjee, M.Sc.
4. Sri P. N. Ganju, M.Sc.
5. Sri Sunil Krishna Ghosh Roy, M.Sc.
6. Srimati V. M. Menon, M.Sc.
7. Sri Ramen Poddar, M.Sc.
8. Sri P. K. S. Raja, M.Sc.
9. Sri Dipak Roy, M.Sc.

1954-55 SESSION.

1. Sri Bhaskar Baliga, M.Sc.
2. Sri Udaysankar Ghosh, M.Sc.
3. Md. Fazle Hosain, M.Sc.
4. Sri Pravakar Mahapatra, M.Sc.
5. Sri Manoj Kumar Pal, M.Sc.
6. Srimati Padala Parvati, M.Sc.
7. Sri Venkatesh Raghubir Pai Vernaker, M.Sc.
8. Sri Mylevarapu Rama Rao, M.Sc.
9. Sri Kuouganti Nageswara Rao, M.Sc.
10. Sri Badri Prasad Rastogi, M.Sc.
11. Sri Arjun Nath Saxena, M.Sc.
12. Sri Bhoop Narayana Srivastava, M.Sc.

APPENDIX X

List of Ex-students of Palit Laboratory of Physics (1940-48) & Institute of Nuclear Physics who are employed at other Institutions.

1. Banerjee, B. K., M.Sc., Senior Scientific Officer, Defence Science Services, New Delhi.
2. Basu, A., M.Sc., Army Signal Corps.
3. Basu, D., M.Sc., Ph.D., Reader in Theoretical Physics, Indian Association for the Cultivation of Science, Calcutta.
4. Basu Mallik, J. R., M.Sc., M.S., Principal, Railway Poly Technique Institute, Kanchrapara.
5. Bhattacharyya, D. L., M.Sc., Lecturer in Electron Optics, Indian Institute of Science, Bangalore.
6. Bhattacharyya, P. C., D.Sc., Lecturer, Calcutta University.
7. Bhattacharyya, P. K., M.Sc., M.S., Ph.D., Asst. Prof. of Geophysics, Indian Institute of Technology, Kharagpur.
8. Bhowmik, B. K., M.Sc., Lecturer, Physics Dept., Delhi University, Delhi.
9. Bishui, B. M., M.Sc., Senior Scientific Officer, Glass and Ceramic Research Institute, Calcutta.
10. Biswas, S., M.Sc., D. Phil., Res. Fellow, Tata Institute of Fundamental Research, Bombay.
11. Choudhury, A. K., M.Sc., Lecturer in Mathematics, Indian Institute of Technology, Kharagpur.
12. Chaudhuri, S. K., M.Sc., Central Jute Research Institute, Government of India, Calcutta.
13. Datta Mazumdar, S., M.Sc., Lecturer, Calcutta University.
14. Ghosh, A. K., Ph.D., Lecturer, Carlton College, Ottowa, Canada.
15. Ghosh, S. K., M.Sc., D.Phil., Oakville, Ontario, Canada.
16. Guha, U. C., M.Sc., Ph.D. (Birm.), Lecturer, Birmingham University, Birmingham.
17. Kundu, D. N., M.Sc., Ph.D., Asst. Prof. of Physics, Ohio State, University, Ohio, U.S.A.
18. Kundu, T. K. M.Sc., Asst. Metereologist, Indian Metereological Service.
19. Majumder, N. K., M.Sc., Junior Scientific Officer, Defence Science Services, Delhi.
20. Mitra, S. N., Statistical Institute, Calcutta.
21. Mosouf, A. K., M.Sc., Res. Fellow in Geophysics, Toronto, Canada.

22. Mukherjee, A. K., Ph.D., Res. Fellow, Tata Institute of Fundamental Research, Bombay.
23. Mukherjee, K. C., M.Sc., Asst. Prof. of Physics, Krishnanagar College, West Bengal.
24. Roy, Kamalesh, M.Sc., M.S., Executive Engineer, D.V.C. Maithon, West Bengal.
25. Roy, R. M., M.Sc., Ph.D., Professor Extraordinary, Universite' Libre, Brussells.
26. Saha, B. P., M.Sc., Asst. Metereologist, Dum Dum Air Port, Calcutta.
27. Saha, N. N., M.Sc., Ph.D., Prof. of Physics, Rangoon University.
28. Sen, S. K., M.Sc., D.Phil., Research Fellow, Liverpool University, Liverpool, U.K.
29. Sen Choudhury, P. K., M.Sc., D.Phil., Asst. Prof. of Physics, West Bengal Education Service.

APPENDIX XI

A PROPOSAL FOR THE EXTENSION OF THE SECTION OF NEUTRON PHYSICS TO A DIVISION OF NEUTRON PHYSICS AND REACTOR TECHNOLOGY

The whole world is now placing great stress on the development of Atomic Energy for peaceful purpose, because it is felt that only Atomic Energy can relieve the impending energy famine in many parts of the world, and the existing energy famine in certain parts of the world, *e.g.* in South India. In India, attention to this important problem has been drawn in several articles by Prof. M. N. Saha, and the Govt. of India has shown its alertness to his suggestions. In the Atomic Energy Conference held at Delhi on Nov. 25, 26, 1954, the Prime Minister remarked:—

"..... It is in this connection that Atomic Energy comes into the picture as something which gives us power. Again, I do not know exactly,—I have seen some figures of the possible reserves we have for the production of Atomic Energy —how long it would last. I am told that, on a rough estimate, it will last 800 years on that bigger scale, that is with the whole world as highly developed as America.

Then, again, we calculate power derived from Atomic Energy to-day on the basis of fission. Now, it may well be—and it is highly likely to be—that the next stage will be the production of atom power by fusion, which again produces an enormous, fresh, vast quantity of power.

The hydrogen bomb is, in fact, something which is used by fusion but, is completely uncontrolled. One of the new features that is coming in is the release of uncontrolled—for the present, uncontrollable energy, which the hydrogen bomb possesses. There can be little doubt that the next stage will be to control it, so that you get enormous quantities of energy placed at the disposal of humanity. That is the importance of the development of Atomic Energy for peaceful purposes."

Several countries of the world, notably U.S.A., U.K. and Soviet Russia have announced that they have already started experimental power stations, where energy evolved in Reactors is being converted to electrical energy. Atomic Power is not yet economic, but experiments on an enormous scale are being carried out for evolving an "Economic type" of "Reactor", which can compete successfully with power generated by thermal or hydroelectric stations.

The movement has been growing in the U.S.A., that universities and technical colleges should institute courses in reactor technology, and carry out researches on reactors. The pioneer in this movement in the U.S.A. has been Prof. Clifford Beck of the State College of Engineering and Agriculture of the University of North Carolina in the city of Raleigh. He has built up a Research Reactor of the Water Boiler type at the University Campus which has been operating successfully since September, 1953. It is being used for training of students of engineering and for research. The importance of training students in reactor technology in the Universities has been emphasized by Prof. Beck in the following words:—

"The organised educational institutions of the country can provide basic training more efficiently than any other group. Specialized training and company "know how" must be given almost any new industrial employee, whether he be an electrical or chemical engineer or a bookkeeper. But no company, no matter how large, attempts to provide routine basic training which the employee can readily obtain in established schools. In nuclear engineering, however, participants in the atomic energy program have been forced to provide this basic training, as needed, since no schools were equipped to do the job. Indeed, much of the essential information involved in this training could not at first be divulged to the schools. Such is no longer the case, and, in the interests of over-all economy and efficiency, the established educational institutions should assume their rightful responsibility.

In addition to training of students, participation of colleges and Universities in this program will provide another service which is the "traditional contribution of alert professors; namely, the organisation, assimilation, and presentation of available information in this new field in co-ordinated textbook form most suitable for reference and instructional use."

Following the success of his experimental reactor, a large number of other American Universities and technical colleges are trying to build up University type of reactors. A list of these institutions and the types of reactors they propose to instal are given below*:—

INSTITUTION	REACTOR TYPE	STATUS AND REMARKS
Columbia	Swimming pool	Financing incomplete.
Utah	Water boiler	Reactor designed; power 100 kw.: flux, 3 or 4 $\times 10^{12}$ n/cm^2/sec. Financing incomplete.
Penn State	Swimming pool	Approved by AEC, work under way; scheduled to be in operation by mid-1955; total facility cost $300,000; power 100 kw.
North Carolina	Water boiler	In operation 9/53.
Michigan	Swimming pool	Up for approval before Reactor Safeguard Committee; power, up to 1 megawatt; flux, 10^{13}n/cm^2/sec.
UCLA	Water boiler	For medical school; financing incomplete.

* From Nucleonics, April, 1954.

NOTE: Other Universities reported to have an interest in obtaining a reactor are: Ohio State (approved by board of trustees in Feb.) Alabama Polytech.; Case; Connecticut; and Texas Universities.†

Industrial organisations known to be interested in design, engineering and or construction of research reactors are: American Machine and Foundry, Babcock and Wilcox, Bendix Aviation, Foster Wheeleer, General Electric, Kaiser Engineers, Walter Kidde, Nōrth American Aviation, Nuclear Development Associates, Vitro.

A comparison on the various types of neutron sources may be given here :

Source	Neutron Flux at 1 metre from source	Total number of neutrons emitted
(*a*) 1 gm. of Ra & Be	10^2 neuts/cm^2/sec.	10 to 15×10^6 neuts/sec.
(*b*) 200 kev. deuterons on tritium ...	10^4-10^5-neuts/cm^2/sec.	10^9-10^{10} neuts/sec.
(*c*) Low Power Research Reactor (Raleigh type).	10^8 neuts/cm^2/sec.	—
(*d*) High flux reactors (M.T.R. type)	10^{10} neuts/cm^2/sec.	—

Thus it can be easily seen that the low power research reactors provide a neutron flux which is at least 1,000 to 10,000 times greater than that from other sources. Of course there are more powerful reactors providing higher flux, like the M.T.R. type. But their costs are also much higher—beyond the capacity of research institutions. Besides they are used for studies connected with reactor development work, which is beyond the scope of Universities and similar research institutes. Hence the low power research reactor whose cost is not beyond the capacity of a fairly large sized research laboratory is ideal as a high intensity neutron source with which many modern experiments in Physics, Chemistry and other fields can be carried out.

The Institute of Nuclear Physics got interested in these American enterprises and requested Prof. S. C. Sircar of the Indian Association for Cultivation of Science who was on a visit to U.S.A. during the latter part of 1954, to undertake a journey to Raleigh, spend some time there and get acquainted with the details of the Raleigh Reactor. Prof. Beck very kindly extended his hospitality to Prof. Sircar, who was able to secure all details about working condition and other details during his stay at Raleigh.

His report indicates that it is quite possible to install a University type of reactor at the Institute of Nuclear Physics and it will be very helpful for training

† In U.K. there is a proposal to instal a Reactor at Cambridge University. In Australia. Sydney University is expected to have two low power reactors. The Soviets have announced that they are helping certain friendly countries with research reactors having a thermal power of 2500 KW. A description of this reactor was given by Nikolaev at the Geneva Conference (P/622).

and research in Nuclear Science and Technology because of the high neutron flux (10^{12}) available from it.

It is earnestly hoped:

(*a*) that the Government of India may be pleased to give sanction to our idea of having a Division of Neutron Physics and Reactor Technology in the Institute of Nuclear Physics.

(*b*) that the Government of India may be pleased to sanction the installation of a University type of research reactor for this Division and provide the necessary funds for that purpose.

Range of Research Work Possible with a Low Power Reactor

In most of these reactors the maximum thermal neutron flux inside the reactor is about 10^{12} neuts/cm^2/sec. A well collimated thermal flux of about 10^6 neuts/cm^2/sec. may be obtained outside the thermal column. The flux of 10^{12} neuts/cm^2/sec. is sufficient for many types of scattering and diffraction studies with slow neutrons. Possible topics of study include:

(a) *Physics:*

(1) Diffraction and scattering study with neutrons of various single energy. Single energy is produced by the use of:

(*a*) Mechanical velocity selector. Latest addition in this field is the "fast-chopper" designed by W. Selove at the Argonne National Laboratory.

(*b*) Time of flight velocity selector or by crystal diffraction. There are designs of different types of neutron monochromators to produce these monoenergetic neutron beams.

(2) Studies in the reaction threshold;—accurate determination of reaction thresholds by monoenergetic neutron beams will furnish information on the masses of unstable isotopes.

(3) Yield ratios of reactions in which a number of products are formed. This helps in the study of competitive processes in nuclear reactions, and verification of the theories of nuclear reactions.

(4) Study of neutron polarization, decay of neutrons, scattering of polarized neutrons by polarized nuclei. Scattering experiments are performed to find out the law of interaction between nucleons viz. between proton-proton, proton-neutron, neutron-neutron, proton or neutron—different nuclei.

All neuclei have spins, and formerly all experiments were performed using unpolarized beams. Recently these experiments have been revised using 100% polarised beams of neutrons, and nuclei which are 100% polarized. The results are found to be quite different from those obtained earlier with unpolarized beams.

(5) Resonance absorption of neutrons leading to information regarding nuclear levels.

(6) Energy level studies with isotopes produced in nuclear reactors by Beta and Gamma ray spectroscopy.

(7) Study of reactor characteristics—distribution of neutrons; temperature effects on distribution of neutrons; study of reactor designs.

(b) *Chemistry :*

(1) Relative yields of fission products produced in U, Th etc. fissioned with neutrons of different energies. Also relative yields of fission products in photo-fission.

(2) Activity method of analysis—such as in complex mixtures of rare earths etc. Cross-sections of some of the constituents for neutron capture may differ considerably from those of others and hence estimation of their radioactive products gives their percentages.

(3) Radiation Chemistry—i.e., effects of irradiation by pile radiation (neutrons and gamma rays) on chemical valency, chemical binding etc. Study of the primary effect of irradiation—i.e., nature of the primary products ; as for instance whether H and (OH) are the primary poducts of the irradiation of H_2O or aqueous solution.

(4) Polymerization effect of radiation ; study of the irradiation induced polymerization of gasses, and liquids, e.g., styrene, benzene and cyanide compounds.

(5) In isotope separation problems, radiometric method is a very promising method for the analysis of the percentages of enriched isotopes. The relative radioactivity of the neutron capture product of the required isotope before and after separation will give the enrichment factor.

(6) Use of radioisotopes as tracers in various types of chemical problems, e.g., Thermal and photochemical exchange reactions (C^{14}), Chemistry of detergents (S^{35}), Absorption processes study leading to better dehumidifiers (S^{35}, P^{32} etc.), Ion exchange problems in the recovery of minerals, Concentration of sugar solutions etc. (Ca^{45}, Cs^{137}), Crystal formation and deposition at grain boundaries (C^{14}, Fe^{55}).

(c) *Metallurgy :*

(1) Effect on materials for reactor construction of the intense beam of neutrons in reactor.

(2) Uses of radioactive isotopes as tracers in (*a*) the study of the role of P and S in steel making and their removal (S^{35}, P^{32}), (*b*) the study of ageing mechanism of metals, e.g. diffusion of C in iron (C^{14}), (*c*) absorption of Cl from salt solutions in stainless steel (Cl^{36}), (*d*) rapid determination of Ti content in iron alloys (Ti^{51}), (*e*) study of mechanism of corrosion and surface wetting of iron by organic acids (Fe^{55}, Fe^{59}).

(d) *Biology, Botany and Medicine :*

(1) Use of radioactive isotopes as tracers in the study of:

(*a*) Metabolism of various elements in animal and plant systems,

(*b*) Role of various carbon atoms in photosynthesis etc.

(2) Therapeutic uses of the radiations from radio-isotopes ; viz. I^{131} in toxic goitre, Au^{198} in cancer therapy, P^{32} and Au^{198} in lukemia etc.

(3) Study of the therapeutic value of pile radiations.

(4) Germicidal property of radiations, e.g. destruction of trichinosis cycle in pork by gamma rays.

$p\bar{p} - \frac{1}{2} n\bar{n} + p\bar{p}$

$= \frac{p\bar{p} - n\bar{n}}{2}$